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SPACE SCIENCES LABORATORY

AN INTEGRATED STUDY OF EARTH RESOURCES IN THE STATE OF CALIFORNIA USING REMOTE SENSING TECHNIQUES

A report of work done by scientists of 6 campuses of the University of California (Davis, Berkeley, Santa Barbara, Los Angeles, Irvine, and Riverside) under NASA Grant NGL 05-003-404

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PREFACE

Since May, 1970 scientists on 6 campuses of the University of California have been engaged in a NASA-funded project which seeks to make an integrated study of the entire earth resources "complex" for one of the three areas which have been selected by NASA as primary test sites for earth resource surveys, viz., the State of California. Among the resource components being studied are California's timber, forage, agricultural crops, soils, water and minerals. This is the second annual progress report dealing with our study.

The urgent need to manage earth resources wisely generates, in turn, a need to inventory them accurately. As a prerequisite to intelligent management, the earth resource manager must know, for each type of resource, how much of it is located in each portion of the area which he seeks to manage, i.e., he must have an "integrated" inventory. The development of suitable techniques for the making of such an inventory in representative portions of California with the aid of aerial and space photography has been, from the outset, a major objective of our study.

Many of the earth resource components in California, as in most other parts of the world are dynamic rather than static. Therefore it is necessary for the resources to be inventoried frequently and rapidly -- <u>frequently</u> so that resource trends can be followed -- <u>rapidly</u> so that resource management decisions can be made and implemented while the inventory data are still current. Our present studies, based largely on NASA-flown high altitude aerial photography, are giving major emphasis to such considerations. Our studies are being conducted particularly with a view to the opportunities that will soon be afforded for satisfying these requirements through the acquisition of data by ERTS-1, the first in a series of Earth Resources Technology Satellites. It is anticipated that for a period of approximately one year, ERTS-1 will be able to acquire remote sensing data for vast areas of the globe at 18-day intervals, weather permitting.

The wise management of earth resources in an area such as the State of California depends, however, on far more than the mere making of timely, accurate resource inventories. Even when given such information, the resource manager could easily make wrong decisions if he were to ignore certain important socio-economic factors. Alternately stated, human needs and emotions cannot be overlooked (particularly in these days of the environment "crusaders") as we seek better to manipulate earth resources, whether on a local, regional, national or global basis.

As will be indicated in the present progress report, due consideration is being given to each of the foregoing factors in this "integrated" study.

Robert N. Colwell
Principal Investigator
April 28, 1972

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INTRODUCTION

Robert N. Colwell

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1.1 BASIC CONSIDERATIONS

Since its inception, the study dealt with in this report has been given the rather cumbersome but aptly descriptive title: "An Integrated Study of Earth Resources in the State of California Using Remote Sensing Techniques". Reasons for our undertaking an "integrated" study are set forth in the Preface of this annual report. Reasons for selecting the state of California for the test site included the following:

1. The state of California exhibits a great variety of conditions in terms of each of the major earth resource categories that are of interest to man on a regional, national or global basis (e.g., timber, forage, soils, water, agricultural crops and minerals as well as oceanic and atmospheric resources).

2. The state of California exhibits a great variety of climatic conditions, mainly because of four factors:

a. its great latitudinal range

b. its great altitudinal range

c. the strong coastal influence which is exerted on the western part of the state by the Pacific Ocean

d. the strong "continental-interior" influence which is exerted on the eastern part of the state and which is accentuated by a pronounced "rain shadow" effect and shielding of this area from the coast by the

Sierra Nevada mountains.

3. Large amounts of remote sensing data and associated ground truth data already are available for many parts of California.

4. With respect to earth resource management, various social and environmental stresses already are being felt in this most populous of the fifty states, thereby making California a model of things to come, both nationally and globally. Additional validity is given to this "model" concept by virtue of California's strong economic base, which makes possible the implementation of costly resource development projects, such as the $3 billion California Water Project with which much of our study deals. Also the fact that the state of California is a political entity within which resource management decisions can be made and implemented contributed still further to the validity of this "model" concept.

5. Many competent investigators were known to be residing in California and to be available for assignment to such an integrated study. In fact several of them had been performing research under the NASA-funded Earth Resources Survey Program almost since its inception in the early 1960's.

6. Appropriate NASA-funded facilities which had already been established in California (such as the Space Sciences Laboratory on the Berkeley campus of the University of California, and the NASA-Ames Research Center near Sunnyvale, California) were known to be available to provide administrative and monitoring support, as necessary, for any sizeable integrated study that might be conducted within the state.

From the outset, half of the funds which have been contributed to our project by NASA have come from its Earth Resources Survey Program and half from its Office of University Affairs. In addition, there continues to be a substantial amount of matching support provided by the University of California, mainly in the form of salaries for some of the participating scientists.

1.2 SPECIFIC NATURE OF THE STUDY

Even at the time when this integrated study was being conceived it was recognized that little would be accomplished if we attempted to investigate simultaneously all components of California's entire earth resource complex, statewide. Ideally we would begin our study by investigating some discrete phase of this complex which, although of limited scope, would require a consideration of both the resource interrelationships and the attitudes of the people in a very sizeable part of the state. Given these constraints and ambitions we tentatively selected the previously mentioned "California Water Project" as the focal point for this initial phase of our study.

Initially there were some serious reservations expressed by certain personnel in the Administrative Branch of the State of California as to the advisability of our conducting any study, whatsoever, that might relate specifically to the California Water Project. These individuals quite properly pointed out that most of the decisions that were required both in conceiving and in developing the California Water Project already had been made long before our study was proposed. We were well aware of this fact and had been regarding it as a major strength rather than a weakness in our proposed study, since our objective was not to provide a "critique" of either the concept that resulted in authorization of the

California Water Project or the steps being taken to implement it. Instead, we were hoping to be able to use in our proposed study the valuable experiences gained and "ground truth" data acquired by those who had been working for many years on the California Water Project. We realized that it would be prohibitively costly and time consuming for us to attempt to acquire this same kind of information independently. However it was our belief that this situation enhanced the usefulness of the state of California as a "calibration" site, so that our research findings could be more confidently applied, by extrapolation, to other parts of the world that were less developed than California, yet highly analogous to it in terms of characteristics of the total resource complex. As our study has been developing, a progressively more amicable relationship with the Administrative Branch also has been developing, largely through the maintenance of close liaison with California's statewide coordinator of remote sensing, Mr. A. Earl Davis.

The emphasis that has just been given to matters of "protocol" is a highly purposeful one. For it seems quite possible that the future success for the entire NASA-sponsored Earth Resources Survey Program, especially as it approaches a semi-operational phase, could depend in very large measure upon the extent to which attention is given to such matters by the various NASA-funded investigators. Resource managers are subjected to ever-increasing amounts of criticism by those who seek to command attention by being so bold as to "second-guess" the wisdom of certain resource management decisions. These critics range all the way from a certain group of discourteous antagonists known as "eco-freaks", through a wide variety of public spirited and usually well informed groups, to individual politicians who in some instances seem to be almost desperately in search of environmental issues which can be molded into popular planks for their platforms. In the presence of such potential criticism, many resource managers are becoming increasingly sensitive about the kinds of resource surveys that should be permitted in geographic areas which they consider to be part of their domain. Criticism, or even the prospect of it, can beget counter-criticism, and the age-old maxim that "the best defense is a vigorous offense" can prompt some resource managers to seek to discredit at the outset any individual or group who seemingly is about to delve into their affairs. To ignore this fact in future studies conducted under the NASA Earth Resources Survey Program, whether in California or elsewhere, might be to ensure at the outset the ultimate failure of such studies. Furthermore, the more closely these studies approach operational significance, the greater the likelihood that attempts will be made to discredit them. This is one of the major reasons why an important component of our present integrated study deals with the demands, desires and attitudes of various kinds of people who are likely to be affected by the resource management programs and practices which are imposed upon them.

1.3 TYPES OF INTEGRATION BEING SOUGHT IN THE STUDY

We are making a sizeable effort to achieve "integration" in our study from three standpoints: data acquisition, data analysis and data use as indicated in the three paragraphs which follow.

From the data acquisition standpoint this study seeks to integrate: (1) data acquired from sensors operating in several wavelength bands (the

Multispectral or Multiband concept); (2) data acquired from sensors operating at several different times (the Temporal or Multidate concept); (3) data acquired from two or more stations in the same flight path (the Parallax or Multistation concept; (4) data acquired using both like- and cross-polarization sensors (the Multipolarization concept); (5) data acquired from two or more nearly identical images (the "improved signal-to-noise" or Multi-image Correlation concept); and (6) data acquired from space, air and ground (the Multi-stage concept).

From the data analysis standpoint this study seeks to integrate: (1) analyses contributed by analysts from several disciplines (the Multi-disciplinary concept); (2) analyses made possible through the making of various optical and electronic image enhancements (the Multi-enhancement concept); and (3) analyses made possible through proper interaction between humans and machines (the "Human" vs. "Automatic" or Multiple Data Processing concept).

From the information use standpoint this study seeks to integrate: (1) information about all components of the total resource "complex" and the inter-relations of these components (the Multi-resource concept); (2) information needed in producing several kinds of earth resource products from the same piece of property (the Multi-use concept); (3) information needed by several types of earth resource managers and consumers (the Multi-user concept); (4) information displayed in various formats (thematic maps, 3-D models, annotated photo mosaics, tables, graphs, etc.), to better satisfy the various multi-use and multi-user requirements and preferences (the Multi-display concept); and (5) information about inter-relations among earth resource components and the uses of these components in one geographic area vs. another (the Multi-association concept).

While this "multi" concept could be still further enlarged upon, perhaps it already has been overdone in the preceding paragraphs. Nevertheless, at the very heart of our integrated study is the central theme implied above and expressed as follows: The providing of useful information about earth resources through the use of remote sensing techniques is, at best, a difficult task. In fact it becomes an almost futile task if only one image of the area of interest is given in the completely unenhanced form, to one analyst, and he uses only one approach in attempting to extract information from it that might be of use to only one of the host of potential beneficiaries of such information. In contrast with this limited approach, each of the "multi" concepts just expressed may add a small amount to his ability to improve the usefulness of resource information that he is attempting to provide. Furthermore, the overall usefulness of the final product may be improved far more than might be suggested merely by summing up the improvements made possible through individually employing these various "multi" concepts, as appropriate. It has been our experience that the total improvement often corresponds more closely to the product of the individual improvements than to the sum of them. Hence, at some point in the process a threshold is crossed, to the left of which the information acquired by remote sensing is virtually worthless and to the right of which it becomes progressively more useful, even to the point of becoming one of the most useful combination of tools and techniques available to those interested in achieving the wisest possible management of this globe's critically limited complex of earth resources.

Figure 1.1 shows the locations of study areas for certain of the participants in this 6 campus project. A seventh campus (San Diego) also is shown because of a limited amount of informal participation already being contributed by that campus and the probability that very substantial participation by scientists from that campus may become a reality in the near future. In the chapters which follow the findings of participants from these various campuses during the present reporting period (May, 1971 to May, 1972) are reported upon in detail.

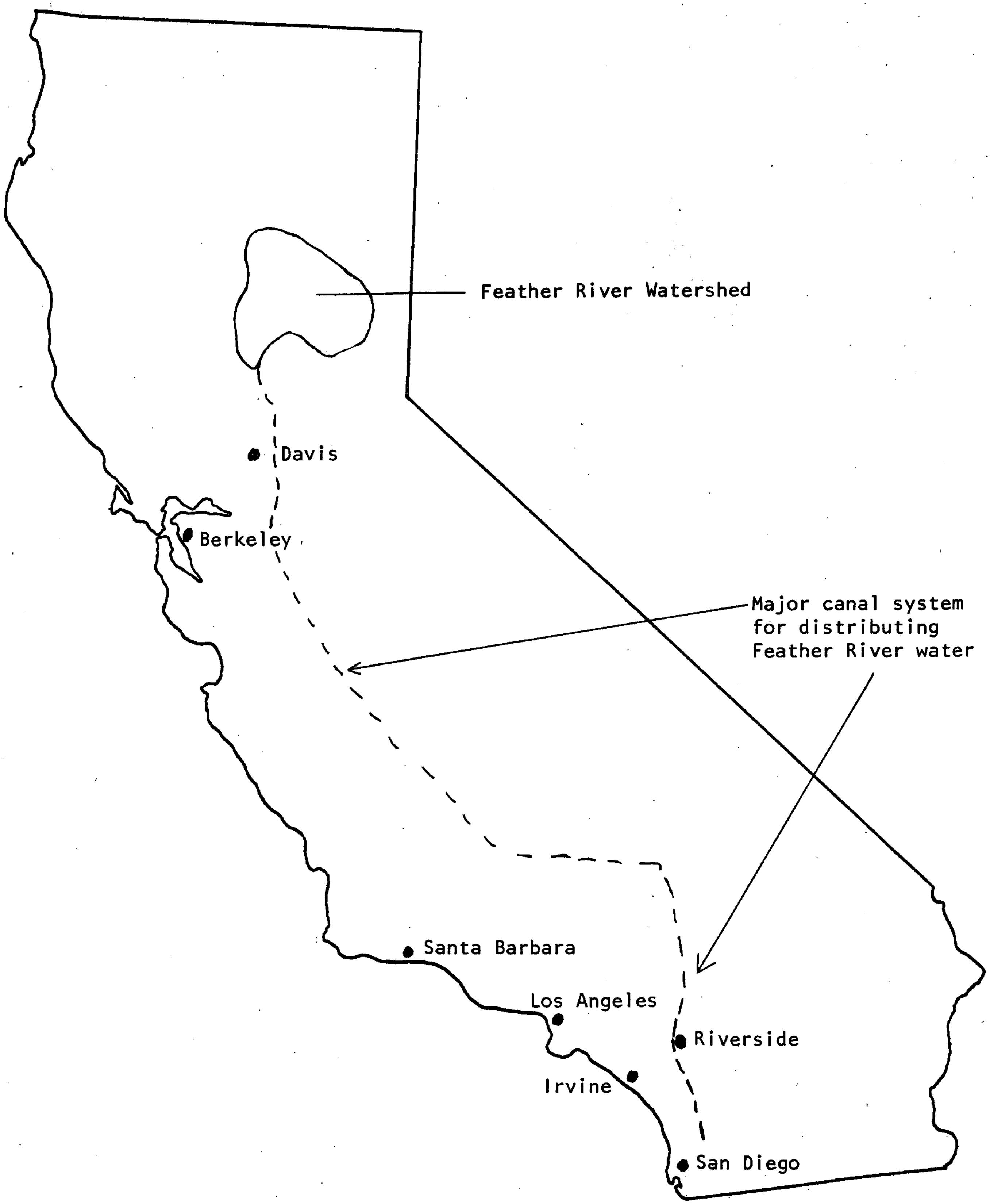

Figure 1.1. Location of participating campuses that are involved in the Integrated Study and their relation to the California Water Project.

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Chapter 2

DEFINITION OF EARTH RESOURCE POLICY AND MANAGEMENT PROBLEMS IN CALIFORNIA

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2.1 REVIEW AND PROSPECTUS

The past year has been a period of consolidation and preparation for social science studies on ERTS data. With the data soon to beome a reality, the Social Science Group, while continuing (with a view to early completion) some of the projects under way and reported in the accompanying Appendixes, has begun preparing for a change in research focus. The prime objective of the Social Science phases of our integrated projects is to combine scholarly research with empirical observation and to translate the results in a form that may be useful to government officials responsible for making the ERTS program viable in socially relevant terms. Summing up the activities of the past six months is, therefore, less a chronicle of substantial contributions and more a statement of groundwork laid. A positive and very promising characteristic of the accomplishment for this period has been the exploration and enlargement of opportunities for greater collaborative effort within the framework of the California Integrated Study of Earth Resources, between the University of California and the State of California.

In its foregoing studies, the Social Sciences Group attempted to identify potential users of ERTS data, ascertain their needs, and assay the organizational impacts of new and technologically advanced sources of information. Last year, consideration was given to developing a large-scale linear programming model which could be useful in decision-making with respect to resources being observed by ERTS and other remote-sensing vehicles. As detailed later, we are now in a position of being able to exploit these findings, particularly as we can enter into a cooperative phase with the California Department of Agriculture. There is a growing realization that the basic concepts of this kind of model could be applicable and useful in the utilization of ERTS and related data by such an agency. The California Department of Agriculture was chosen as one from which such a decision making model would emanate because (1) as a service agency, it was likely to be a ready recipient for and user of such data; and (2) its long-time cordial relationship with the University through its Secretary, Mr. Earl Coke, and the project's principal investigator, Professor Robert N. Colwell, facilitated contact with key personnel. With the cooperation of Mr. Earl Davis, State Coordinator of Remote Sensing, and through the participation of Dr. Gordon Snow, Special Assistant to the Director of Agriculture, arrangements for the study are being formulated through a series of meetings between our group and representatives of the California Department of Agriculture. Mr. Earl Davis and Dr. Robert Colwell also are participating in these meetings.

In preparation for the field work to be done, some investigation into pertinent facets of the State Department of Agriculture's functions have been carried out; we have identified a number of specific areas in which information regularly gathered and disseminated could be highly useful. Some areas which might benefit from ERTS and related data are listed as examples to be explored:

<u>For various agricultural products</u>

- Amount of production and distribution (geographical)
- Quality of production and quality of distribution
- Growing conditions and crop conditions during season
- Effects of weather on specific crops and on animal and pastoral production
- Hail and frost damage
- Percentage of full crop and changes therein during the season
- Progress of harvest
- Existence and amount of plant and crop disease, insect infestation or other malady
- Soil condition (moisture, existence of chemical residues, etc.)
- Condition of farm-to-market roads

<u>Fruit Orchards</u>

- Condition of bloom on trees by area
- Amount of pruning required
- Condition of ground cover
- Progress of fruit picking
- Condition of raisin lays and other sun-dried fruits

The above list is intended to be indicative and not comprehensive. Nonetheless, it points to areas in which the California Department of Agriculture might provide improved service through utilization of remote-sensing technology. Since California is the nation's leading farm state, with its agriculture considered the most diversified in the world, it provides an ideal proving ground and demonstration site for reception, application, and utilization of ERTS and similar data. Great interest in the proposed case study has been expressed by division chiefs within the Department of Agriculture; official permission has been granted by the Director; and the preliminary exploratory conferences which have been held have done much to define problems and to develop plans for an orderly investigation of them.

Development of the model as now planned will include the following considerations: What kinds of policies does the Department make? What kinds of decisions are regularly its responsibility? Classification of the decisions now being made and identification of the decision-makers will constitute an important first step and will be achieved through interviews with key officials. Details as to timing of decisions, alternatives that must be scanned, and constraints which prevail will be explored through contact with the specialized divisions and sections. It is important to note that this step consists of two parts: (a) an understanding of the decisions made by the Department; and (b) an examination of decisions that might be made more expeditiously or implemented more efficiently given the "information power" derived from ERTS and other remote sensing devices and given the systems analysis itself.

In developing the model, the analyst must first ascertain the considerations that govern decisions being made. These may be institutional and formal or merely conventional and historical; they may be open and unequivocal or obscured by controversy and political sensitivity. Determination of goals and objectives, who sets them, for what purposes, and under what circumstances represents a crucial step in the analysis. As useful background, the work completed during the past year (as reported in the January 1, 1972 Progress Report) will be brought to bear. In the earlier studies, research focus had been on the whole problem of resource information as it relates specifically to satellite and similar technologies. The effort was made to understand different perspectives on management information systems in the management of resources and on the effects of new methods and sources of data on organizations, agencies, and individuals. Substantiated was the conclusion that there is considerable divergence as to perspectives about resource management and that these must be taken into account in constructing viable decision-making models. Accordingly, the determination of an agency's goals is a two-fold process: (1) ascertaining the way in which the agency now perceives its objectives; and (2) learning how the goals are perceived outside the agency, by conservation groups, development entrepreneurs, local political entities (cities, counties, and regional associations), grower-producer organizations, and individuals.

The second consideration facing the analyst is the determination of how the decision relates to the goals as perceived by the decision-maker. Herein lies the basic logic of the model. One might explain it by pointing out that in the conventional linear programming model one tries to describe the goals in terms of a measure of performance which is then related to various activities. In the case of the California Department of Agriculture, the problem might be the acquisition and allocation of water for irrigation purposes. It might be spraying of range and farmlands with insecticides or blight-preventing chemicals. The information that is generated would fit into the model by showing specifically how measures of performance would be affected by actions taken.

The third consideration follows in natural sequence, namely, how the data <u>should</u> be used to improve decisions, that is, to improve the effectiveness of decisions relative to the perceived goals of the decision-maker. This is an area in which ERTS and other remote sensing data could have direct relevance to the ongoing functions of the California Department of Agriculture. In those of its activities which depend on field information, the Department of Agriculture would now have available up-to-the-minute data that could have marked effect on its service and regulatory functioning. If, for example, the issue were crop control, now achieved mainly through marketing orders, the setting up of the order and its implementation could be made more responsive to the needs of growers, processors, and consumers. Moreover, improved channels of information would ease the tasks of legislative committees responsible for the issuance of such orders.

A fourth consideration of the decision-maker model encompasses its interregional aspects. Suppose, for example, that floodgates were to be opened upriver to protect levees. The major impact would be felt downstream in fields and orchards. Similarly, allocation of Feather River waters in the San Joaquin Valley has consequences in the Los Angeles region. Another illustration may be found in changing patterns of land use, with spreading urbanization affecting farm operation and making irreversible inroads into once remote desert and forest areas.

Fifth, the analyst must include in his model the constraints on the decision-maker, that is, those matters over which he has no jurisdiction but which nevertheless affect the quality of his decisions. For example, with respect to water allocation, the total amount flowing through the system is governed by weather conditions and also by laws, policies, and political pressures outside the decision-maker's control. Yet, all of them represent constraints imposed upon him.

Finally, the decision-making modes must also reflect conflicting viewpoints as regards objectives; that is to say, the decision-maker in a given agency must go beyond his personal perception of what the goals are. He must appreciate and understand other legitimate and reasonable perspectives as to goals. This is necessary because the agency must serve the divergent and sometimes conflicting needs of various sectors of the public--growers, processors, conservation groups, recreation entrepreneurs, land developers, and industrialists too numerous to detail. In the course of our work during the past year (see appended reports), we have made the point that the perspective with respect to resource goals, as, for example, the utilization of land for agricultural purposes, must even include responsiveness to the idea that land use and the use of earth resources are not exclusively the prerogative of man himself. It appears that there is a plausible position that argues that man can no longer limit himself to the notion of human-oriented world development. Recognizing himself as one of the species, he can then assign due value to <u>total</u> natural development in which anthropocentric ego-librium would give way to genuine eco-librium.

Plural objectives and multiple perspectives, although constituting major practical preoccupations in the lives of government administrators, have not been adequately reflected in decision-making models in the public domain. Typically, model-builders have tried to relate decisions to goals without acknowledging that the decision-maker himself is required to play a number of different roles with respect to the public whom he serves. Consequently, it would be an oversimplification and, in fact, inaccurate to assume that data from the Earth Resources Satellite and related technology will flow into a clearly demarcated decision-making system amenable to abstract representation by a large scale linear program. The real-life dimensions of public decision-making are numerous, complex, and contradictory. Officials must be responsive to varying and frequently antagonistic social values which they do not personally share but which may be held by the array of publics whom they are obliged to serve. To ignore the multiplicity and conflict of objectives would be to impair the usefulness of the proposed decision-making model, for considerations of this kind are an intrinsic facet of the government officials' job, especially those in the Department of Agriculture. Several typical problem areas will serve to illustrate this point: agricultural burning that gets rid of wastes and certain insects but contributes to air pollution, chemical fertilizers and pesticides that improve crop production but poison the creeks and rivers; farm labor measures that seem to favor one side against the other in a struggle that has characterized the agriculture industry since long before John Steinbeck dramatized the plight of the migrant farm worker.

To recapitulate, the Social Sciences Group is in the process of developing, with the cooperation of Mr. Earl Davis, the State Coordinator of Remote Sensing, and Dr. Gordon Snow, Special Assistant to the Director of Agriculture, a case study of the California Department of Agriculture for the purpose of ascertaining its data needs with specific reference to ERTS and related technologies. The background work, as reported earlier, has led to some of the broad aspects of decision-making with respect to resources. The seminars which previously were conducted by our group both at Lake Arrowhead and at NASA-Ames Research Center have yielded important insights into the kinds of decisions now being made in agriculture and some preliminary hypotheses about possible utilization of ERTS and related data. Research into the functions and structure of the State Department of Agriculture and exploratory interviews with experts in the field have constituted the necessary preliminary activity in preparation for the work ahead.

The case study which we will be making with the California Department of Agriculture will provide the basis for a decision-making model useful not only for that agency but for others at the State level. It is expected that this dimension of the California experience with ERTS will not only be helpful to the State planners immediately involved but will also prove valuable to policy-makers in NASA as a guideline for the meaningful utilization of its advanced technological capability. It is noteworthy that even at this stage of the research, all of the State executives interviewed have expressed interest in and satisfaction with the fact that NASA, through the Social Sciences Group and the Integrated ERTS project, is concerning itself with and encouraging study into the social aspects and effects of ERTS and related data.

Preliminary, but necessary and important, steps were taken in late April, 1972 in an organizational meeting in Sacramento. Participating were Mr. Earl Davis, Coordinator of Remote Sensing for the State of California, Dr. Gordon F. Snow, Special Assistant to the Director of Agriculture, Mr. W. Ward Henderson, Chief of Agricultural Statistics, Dr. C. W. Nichols, Chief of the Bureau of Plant Pathology, and several staff members who would serve as liaison as the study progressed. The California Integrated Remote Sensing Project was represented by Professors Robert N. Colwell, C. West Churchman and Dr. Ida R. Hoos. The session achieved clarification on a number of essential points: (1) the intent of the University in conducting the proposed study; (2) the methods to be used; (3) the extent of State involvement; (4) the benefits to be realized from such a study. Each of these items was discussed with great candor and many doubts dispelled. State executives who previously had been "researched to death" and who were inclined to suspect "hidden agenda," came away assured that their organization and operations were not going to be subjected to critical scrutiny but were merely going to be reviewed as vehicles for the possible receipt and use of ERTS data. With the study serving as a means of feedback to NASA, it was deemed likely that what could be learned on this very practical level could become useful to NASA vis-a-vis Skylab and other projects still to come. What was stressed in this context was that the case study was intended as a learning experience and that what could be learned would ultimately be useful not only in California but nationally and world-wide, and not only with respect to ERTS but to remote sensing technology still forthcoming. The State officials were further assured that, while their cooperation was vital, it was requested in the form of referral to necessary (and not confidential) documents, guidance as to persons to be interviewed as authoritative on various matters, and not in the form of extensive staff time, etc. As is customary in such research, the University people offered to send their reports to the State officials so that the relationship of mutual confidence would be preserved.

The frequently-encountered question arose as to whether this effort would result in a cost/benefit study of, for example, the advantages of ERTS data collection over some other forms. In the discussion of the limitations of this approach to planning, the University group had the opportunity to explain the broader social aspects and impacts likely to be more important in public decision-making than the rather limited cost/benefit calculations now in popular practice. As for ultimate benefits to be derived from the study, the research group explained that, in their view, no "recommendations" for organizational and policy change would be forthcoming. A study as limited in scope and depth as this one must be, because of the paucity of staff, would end on a presumptuous note, indeed, if it were to come up with "recommendations." Instead, the Social Science Group stressed that it hoped to achieve professional analysis of a demonstration project--ERTS at work in the service of a government agency--and that the findings would be useful in public policy making at the state and federal levels.

It was recognized in our preliminary meetings with officials of the California Department of Agriculture that there was a need from the outset, for developing adequate perspectives relative to the use of ERTS and related data as aids to the management of California's agricultural resources. The fact that agricultural resources constitute only one element in California's over-all resource complex was readily acknowledged, but it was also agreed that the exact nature of certain of these resource interrelationships needed to be more clearly perceived. Consequently our Social Science Group is in the process of attempting to sharpen such perspectives by compiling and analyzing information under the broad heading "ERTS and Environmental Management," but with special emphasis on the aspects of greater relevance in California. The status of our efforts to date in this regard will be indicated in the following section.

2.2 ERTS AND ENVIRONMENTAL MANAGEMENT

2.2.1 Quality of the Environment--A Social and Controversial Issue

Concern with the quality of the environment is not only popular at present, it is actually, in some quarters, mandatory. The responsibility of public agencies, the raison d' être of conservationists, the plank for political parties, and the despair of hitherto profit-oriented industries, the environment stands out as the dominant issue of the decade and of the years ahead. Usually, the environment is thought of in physical terms and as an invariant in the syndrome structure of what is fashionably referred to as "the ecology." This conception of the environment is, however, amorphous, imprecise, and even inaccurate, for there is no such entity as the environment. In a broader and more meaningful sense, there are many environments, a different one for every articulating observer. Paraphrasing the maxim about truth and beauty, one might remark that the environment is in the eye of the beholder. To achieve some kind of analytical rigor, one might distinguish between a micro-environment and a macro-environment. Environment observed and evaluated by a single micro-unity, such as an individual, differs from the environment, observed by a body of individuals, or a macro-unit. And, among these, wide diversity of conceptualization exists. Certainly not invariant as to observer, neither is environment immutable with respect to time. Environment must be conceived as a living, and hence changing, structure, and therefore, attempts to return to an earlier pristine state, to recapture the past, may be pure, impracticable nostalgia, more quixotic than productive.

Recognition of this fact, inevitably brings us to the problem of optimum environment, and here we struggle with the classical questions relating to optimality, viz. for what purpose, by whose criteria, in what time period, i.e., short, intermediate, or long run? These matters are not easily nor casually handled; they reflect basic conflicts and deep-seated controversies, the outcome of which will dominate public policy not only in this country but in most of the nations of the world as the global environment and its management take on a new reality with advancing technology (such as, for example, earth-orbiting remote-sensing satellites). Acknowledgment that the environment is something other than a sort of static, indivisible monolith is especially necessary because the environment constitutes the bridge to another predominant theme of our times--the quality of life. In a derivative sense, the caveats and strictures applicable to the environment are mandatory with respect to the quality of life, the kaleidoscopic images which mirror particular viewpoints, diverse value judgements, multiple purposes, and plural objectives. To quote an official document, "Environmental quality, as a public policy issue, is a complex of technologic, economic, social, institutional, legal, and political problems."*

There is, despite methodological pretension and the currently-fashionable model-building, no set form or facile equation for calculating the optimal public policy vis-a-vis environment. Nor is there a *tabula rasa*, a clean slate, on which to draw up a balance sheet of costs and benefits of alternative courses of action. Although much has been made of the moral and ethical aspects, the "good" guys are not clearly identifiable, nor are the "bad" guys. Much depends on the issue, the time, and the place. The hero in one sphere can be the villain in another. While there is universal agreement that the quality of life, (and, relatedly, of the environment) needs attention and improvement,

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*Managing the Environment, Report of the Subcommittee on Science, Research and Development to the Committee on Science and Astronautics, U. S. House of Representatives, June 17, 1968, p. 1.

there is almost total disagreement about everything else. In fact, in the confusion, discord, and bewilderment, we are, as has been stated elsewhere, inclined to take fools for experts and experts for fools.

The brief review of issues and positions that follows reflects no one advocacy nor adversary standpoint. Our intent in gathering materials from Congressional Hearings, Presidential Panels, proceedings of meetings of professional societies, journal articles, and widely-read national magazines as well as local newspapers was to ascertain the interest in resource management, the complex web of interrelationships impinging on decisions about resource utilization, the possible need for reorganization of official mechanisms for making and implementing policy with respect to natural resources, and the potential ways in which advancing technology might be a factor in the public decision-making process. Sometimes important issues are obscured by partisan rhetoric, and it is conceivable that better data, utilized wisely, will help clarify pertinent factors and thus improve public policy-making.

The purpose of this effort was to provide a useful and usable perspective for the California Integrated Earth Resources Satellite Technology project, in which data derived through remote-sensing techniques would be put to use in the management of the State's vast resources complex. As the documents indicate, what happens to one resource affects others and what happens to resources in one region has direct or indirect impact on resources in other regions. Comprehensive review and analysis of a broad range of subjects provides abundant evidence of great divergence of interest and opinion and highlights the need for more complete and more up-to-date-information. This is the background for consideration of remote-sensing technology as a potential source of data. The California experience with remote-sensing technology as an aid to resource management and, ultimately, to enhancement of environmental quality will provide worthwhile guidelines for potential applications elsewhere in the United States, and eventually, on a global scale. It is for this reason that we have been preparing for actual reception of ERTS data by investigating the major parameters in the quality of life and some of the issues surrounding them.

2.2.2 Air Pollution

California's huge agricultural industry has been blamed, on the one hand, for contributing to the state's air pollution problems (e.g. through the burning of stubble in fields), and on the other hand, has been praised for providing the plants that are necessary for "purifying" the air we breath. Both statements need to be viewed in relation to the over-all air pollution problems, as detailed in this section.

"Air pollution is a by-product of all the major growth factors of modern society; it is rooted in the way we build our cities, the ways in which we provide transportation for ourselves and our goods, the ways in which we derive energy from our fuel resources, the ways in which we produce and use a multitude of goods and services, and in the ways in which we dispose of all the leftovers of modern life. The effects of air pollution are diverse and often subtle. Polluted air contributes to human sickness, disability, and premature death; it soils and damages buildings and materials of all kinds; it injures and destroys farm crops and other vegetation; and it blights our cities and degrades the quality of our lives."*

2.2.2.1 The automobile as a factor in air pollution

The five major air pollutants are carbon monoxide, sulfur oxides, hydrocarbons, nitrogen oxides, and particles. The millions of motor vehicles on the roads constitute one source of such emissions, because of unburned or partially-burned noxious compounds. It has been estimated that about 15% of the fuel heat value, equivalent to one million gallons of gasoline, is wasted daily in Los Angeles alone because of incomplete combustion. For the nation as a whole, this amounts to a loss of energy corresponding to 10 billion gallons of gasoline per year. And the contribution to air pollution is awesome, the prospects staggering. "Gasoline consumption in the U.S.A. rose from 40 billion gallons per year in 1950 to an estimated 70 billion in 1964. By 1980 the use of gasoline in the Los Angeles area will have increased by a factor of four since smog was first noticed around 1945. Parallel with the increase of fuel is the increase in emission of pollutants. The partial control of emission predicted for the coming years cannot keep up with this increase."**

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*Statement by Dr. John T. Middleton, Director, National Center for Air Pollution Control, Public Health Service, Department of Health, Education, and Welfare, Hearings on Environmental Quality, before the Subcommittee on Science, Research, and Development of the Committee on Science and Astronautics, U. S. House of Representatives, Ninetieth Congress, Second Session, January 17, 18, 19, 31; February 1, 2; March 12, 13, 14, 1968, pp. 89-90.

**Restoring the Quality of Our Environment, Report of The Environmental Pollution Panel, President's Science Advisory Committee, The White House, November, 1965, p. 68.

The State of California pioneered in the setting up of regulations pertaining to automotive exhausts and in the establishing of criteria for clean air, but the legislation was, for all its potential benefits and kudos earned _ex post facto_, not easily achieved. Protest against over-stringency by manufacturers, complaint of unenforceability because of a myriad of difficulties, claims that smog devices if not installed and cared for properly would add to pollution, complications about used cars, technicalities about imported vehicles--all these and many more appear as stumbling blocks in the hearings attendant on the legislation. The Federal Government's Clean Air Act of 1963 and Air Quality Act of 1967 were background for the 1970 legislation that is summarized below:

> More stringent air quality measures are contained in the 1970 Clean Air Act than in any previous legislation. Greater scope and powers for the new Environmental Protection Agency, mandatory state government involvement, stricter air pollutant emission standards, and larger budget appropriations than for earlier Air Quality Acts are provided.
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> The new Act:
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> Authorizes establishment of national ambient air quality standards and emissions standards for stationary air pollution sources and automotive vehicles. Standards for stationary polluters are to be based on state-of-the-art emission control capabilities. For automotive vehicles, carbon monoxide and hydrocarbon emission standards have been set for 1975 or later models at 90% below 1970 model year standards. Nitrogen oxide emissions, for which there are currently no standards must be 90% below those from 1971 model cars in 1976 or later models. The effective date of these standards may be extended one year at automobile manufacturer's requests.
>
> Permits withdrawal of certification of automobile models based on tests of any assembly line reproduction. In the past, only special prototypes submitted by the car manufacturers were tested. The Agency has similarly expanded powers with regard to new stationary air pollution sources.

Requires submission by each state of plans for achieving national air quality standards. The EPA may impose plans on states not submitting acceptable proposals.

Backs directives by specific time limits and fines or legal action for failure to comply. This includes private citizen actions.

Provides for research, for the encouragement of cleaner car and engine designs, and for studies of fuel composition. The EPA may regulate fuel composition based on such studies.

Appropriates funds for research; for aid to states in setting up clean air plans and administrative machinery; and for administration of the provisions of the Act. Total appropriations for a three-year period amount to $1.1 billion.

With interstate and intrastate air pollution a central point of concern, much of the debate on this legislation focused on the regional aspects of air quality standards and implementation plans. Not unexpectedly, the meteorological factors were discussed and the Environmental Sciences and Services Administration was seen to play a key role. Here, an early warning system, or "air pollution potential advisor," based on its prediction capability, seemed to have great promise.* At the Federal level, just as previously at the State level, there was general agreement that something had to be done about the automobile as the nation's primary air polluter but just what, how, and how much became a battle ground on which there is no truce in sight. Two years later, in 1972, the National Environment Policy Act (NEPA), a law that President Nixon chose to sign as his first official act as a symbol of

*Environmental Quality, Hearings cited earlier, in connection with Dr. Middleton's statement.

the new decade, is coming increasingly under attack. A member of the Federal Power Commission has called it "a paper monster of great potential harm" and asks Congress to reconsider. Federal agencies, including the Atomic Energy Commission and the Department of Transportation, request legislation allowing special dispensation from NEPA's crucial requirement of environmental impact statements for proposed major government actions. A welter of law suits and repercussions throughout the body politic have contributed to discernible backlash against NEPA.*

With specific reference to air pollution and automobile exhaust emissions, there is practically no agreement on whether the automobile is the major offender. As previously stated, there are those in California who maintain that this state's agriculture industry is the villain. There is also lack of agreement on how much carbon monoxide can be tolerated, and whether emission control devices effectively cut down on smog. Dr. William G. Agnew, head of General Motor's Emissions Research Division, claimed that the car is only a small portion of the air pollution problem and cited scientific evidence to back his contention. Research sponsored by the Coordinating Research Council, an organization supported jointly by the automobile and petroleum industries and the Federal government, carried on by Dr. Richard Stewart of the Medical College of Wisconsin, in Milwaukee, is the authority for his argument that carbon monoxide, administered during experiments, did not impair people's performance. Dr. Stewart did concede that his

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*Robert Gillette, "National Environmental Policy Act: Signs of Backlash are Evident," Science, Vol. 176, 7 April 1972, pp. 30-33.

subjects were healthy adults and not persons with coronary or respiratory difficulties, but he nonetheless concluded that federal standards were too strict. On the other hand, research reported in Science magazine, April, 1971 found a significant association between death rates and the levels of carbon monoxide already existing in some urban communities. Other things being equal, there were 11 more deaths per day in Los Angeles when the carbon monoxide concentration averaged 20.2 parts per million (the highest point recorded in the four year study) than when it averaged 7.3 parts per million (the lowest concentration observed).

As for efficacy of smog devices, Dr. Agnew of General Motors expressed satisfaction over what he saw as a reduction in emissions and predicted cleaner air for New York City, a position disputed by Mr. Brian Ketcham of the New York City Bureau of Motor Vehicle Pollution Control. Mr. Ketcham pointed out that devices made to accomodate Los Angeles long-distance driving patterns were not only inappropriate for New York's stop-and-go patterns but actually likely to cause more pollution since the idling engine sends off more unburned matter.* The controversy continues unabated. In March, 1972 the federal government released a study** proposing substantial reduction of restrictions on automobile exhaust emissions. Advocated was the easing of the standard for nitrogen oxide, the compound most difficult to control and perhaps most damaging to air quality, plant life, and humans. Experts at the California

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*David Bird, "Car Makers and Ecologists are in Conflict on Auto's Role in Air Pollution," The New York Times, May 23, 1971.
**Tom Wicker, "Pollution or Profits?" The New York Times, March 21, 1972.

Statewide Air Pollution Research Center hold that strict control of nitrogen oxide and hydrocarbons should be maintained with slight relaxation instead of carbon monoxide regulations. Another suggestion included in the government report was to apply more stringent controls on cars for use in areas most susceptible to air pollution. Conspicuously absent, however, was an explanation as to how cars could possibly be limited to certain regions, nor was there recognition of the fact that virtually all urban areas, which, incidentally, are rapidly increasing and spreading, have the potential to develop a photochemical smog problem.* Lee Iacocca, president of the Ford Motor Company, praised the report as "the best news the public has had in years."

2.2.2.2 Industry as a factor in air pollution

Air pollution did not start and will not end with the automobile. Estimates show that about one-fifth of the national tonnage of the five major pollutants, i.e. carbon monoxide, sulfur oxides, hydrocarbons, nitrogen oxides, and particles is generated by industry. Here is an area where public policy must walk a tight rope between economic efficiency and political expediency. Chemical plants, iron and steel mills, petroleum refineries, pulp and paper mills, and nonferrous metals smelters were once welcome members of the industrial community. The jobs they provided and the tax base they produced assured them hospitality anywhere in the country they were situated. In fact, their belching

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*"Managing the Environment," Report of the Subcommittee on Science, Research and Development to the Committee on Science and Astronautics, U. S. House of Representatives, June 17, 1968, pp. 27 ff.

smokestacks symbolized full dinner pails, prosperity, and productivity. Through the years they developed a loyal constituency among so large a cross section of the American public--persons whose fortunes waxed in tandem with theirs--that a kind of national schizophrenia now prevails with respect to regulation. This becomes clearly evident in the various pieces of legislation, national and state, and the legal mechanisms available for circumventing their vigorous application. A few selected news stories indicate the complexities and point up the dilemmas of environmental protection. Chemical Week (February 15, 1971) reported a study, made over a 15-month period for the air pollution control office of the Environmental Protection Agency by the Midwest Research Institute of Kansas City. The report said that 20 million tons of particulates are emitted annually from stationary sources, with electric power generating stations being the greatest contributor, with 6 million tons per year. The major chemical industry emission source was said to be producers of fertilizer and phosphoric acid, with 328,000 tons annually. At the present rate of emission control, American industry will, by the year 2000, spew 52.6 million tons of particulates into the air every year.

Faced with orders to comply with a Federal anti-pollution regulation at one of its plants in Marietta, Ohio, Union Carbide, already in default of an earlier deadline, claimed that it had been given to believe that it had the "tacit consent" of the National Air Pollution Control Administration to miss that date. Instead of trying to meet the standards, which they termed impossible, company spokesmen first proposed a revised schedule, inconsistent with established criteria, and then projected "drastic intermediate consequences." These, translated into action, meant the partial shutting down of operations and attendant lay-off of workers.*

In Clairton, Pennsylvania, the Clairton facility of U. S. Steel covers about a mile and a half along the south bank of the Monongahela River and employs thousands of workers. Since the enactment in 1969 of stringent air pollution standards, Allegheny County Health Department has brought a number of pollution charges and been awarded judgments of $17,000 in fines, all of them appealed by U. S. Steel. The Chief of the County Air Pollution Control Bureau accuses the Works of emitting about 225 tons of contaminants into the air every day. Residents of the city contend that its noxious vapors blight the area, that children cannot play out-of-doors, and that property values have been eroded. The corporation's vice president for environmental control claims that $15 million has been spent for pollution control at the plant, that $25 million has been pledged for further improvements, and that, moreover, "there is no way to bring the Works into compliance."** Most of the pollution was attributed to U. S. Steel's practice of quenching coke with contaminated water, a procedure which sent up dense clouds of steam laden with phenols, sulfates, chlorides, ammonia, cyanide, and particulate matter. The company contends that coke quenching is the only economically feasible way of disposing of waste liquids from

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*New York Times, January 20, 1971.
**New York Times, February 12, 1972.

other plant processes because Pennsylvania Clean Stream Laws prohibit the dumping of untreated contaminated materials into rivers.

2.2.2.3 Electric power plants as a factor in air pollution

Electric power plants constitute the third largest source of air pollution. About 5.6 million tons of fly ash and over 20 million tons of sulfur dioxides are emitted each year, with the largest amount coming from coal-fired steam boilers. Although the technology is available, comparatively few companies have installed equipment to eliminate fly ash, the soot issuing from the utilities' smokestacks. Emissions of sulfur dioxide have been reduced by burning low-sulfur coal and oil, but on the whole, little has been spent in the industry (about 26/100 of one percent of revenues) on research and development of techniques to solve its emission problems. "Not to clean up smoke is inexcusable," said William D. Ruckelhaus, Administrator of Environmental Protection. In a speech to utility executives, S. David Freeman, Director of the Energy Policy Staff of the Office of Science and Technology, stated, "It is awfully hard for outsiders, and for me, to understand the sense of priorities of the electric power industry when they spent in 1969 $90 million for advertising and only $40 million for research and development. It seems to me the priorities are upside down." Two-fold rejoinder from the industry came swiftly. Donham Crawford, president of the Edison Electric Institute, which represents the investor-owned industry, argued that if account were taken of the $105 million, invested annually by companies that supply equipment to the power industry, the amount devoted to research and development could be calculated more appropriately at $150 million. The second point he made was that the utilities themselves do not invest more money directly in research and development because the companies, which are subject to state commissions in setting their rates, could recover their investment only through "the slow-rate-making process."*

Typical estimates of future demand for electric power assume a continuation of the previous growth rate. The Economic Research Division of the Chase Manhattan Bank calculates the demand as multiplying six or seven times by the year 2000.** An editorial in Science projects power consumption by the year 2000 to be eight times that of the present.† Assuming continued dependence on fossil fuels, the likelihood of their ultimate depletion is directly predicted. Need for ever greater quantities of coal would ravage and despoil vast areas. And the resultant pollution would be awesome to contemplate.

The complexity and immensity of the problem defies a mere drawing up of battle lines, i.e., government enforcers vs. polluters; "growth" advocates vs. conservationist-ecologists; or Thoreau-like back-to-nature-lovers vs. technology enthusiasts who seek a solution in techniques still to be devised. Positions are not clearcut, nor are they occupied

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*E. W. Kenworthy, "Little Progress in Cleaning Up the Air," The New York Times, April 25, 1971.

**The Chase Manhattan Bank, Improving the Quality of Life: A Study of the Economics of Pollution, 1972, p. 6

†Philip H. Abelson, "Costs versus Benefits of Increased Electric Power," Science, Vol. 170, 11 December, 1970.

consistently. Government plays many roles; industry serves many masters, publics are fickle.

Hollis M. Dole, Assistant Secretary for Mineral Resources, Department of the Interior, stated that the nationwide "rising tide of opposition" to essential facilities for producing and transporting minerals and electricity was "in danger of over-reaching the proper objective."* He criticized "charges incident to frivolous and capricious acts arising out of ignorance, is rationality, and a misguided excess of missionary zeal" and pointed out that the cost of "rescuing the environment" would be heavy, with increased charges for water, electricity, heating, sewage, taxes, and gasoline especially burdensome on the poor.

Pending proposals to ban all strip mining within six months could, he warned, "reduce coal production by one-third," slash coal-mining jobs by 20,000 and "demoralize the electric power industry." Carl E. Bagge, president of the National Coal Association and a former Federal Power Commissioner, predicted an "alarming crisis" in the nation's energy base. He assailed "political over-reaction" as "frustrating the domestic production of essential fuels," demanding curtailment of power growth, and blocking transport of oil and gas from the Artic. Kerryn King, senior Vice President of Texaco, Inc., decried "regulatory overkill with respect to environmental problems." Adverse policies were, in his view, delaying offshore oil leases in the Gulf of Alaska and Atlantic Coast waters until 1975 or 1976 and to restrict further

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*Peter Kihss, "U. S. Aide Says Pollution Fight Balks Power Growth," The New York Times, July 7, 1971.

the sulfur content of fuels was to "ignore practical and economic realities."

In Mount Storm, West Virginia, a gigantic 1.1 million kilowatt generating plant of the Virginia Electric and Power Company every day consumes 10,000 tons of Appalachian coal, brought to it from the area's strip, or surface, mines.* The Mount Storm operation, strategically situated close to the source of supply and in a remote section where the air pollution problems caused might not be so troublesome, generates electricity for consumers 150 miles away in Virginia. It also generates every hour some 60 tons of fly ash and about 20 tons of sulfur dioxide gas. The inhabitants of Mount Storm regard the plant as an economic boon, providing work for miners and raising property values from $25 to $1000 an acre.

Just across the Potomac River, in Maryland, tolerance was not shared. Some years ago, in a region of wornout farms and abandoned strip mines, a Christmas tree industry had sprung up and was thriving. When the Mount Storm power plant began operations some five years ago, tree growers noticed that the trees were turning orange and brown and were growing in erratic patterns. Many of the trees were rendered unsalable, and those salvageable had to be sprayed with green paint to camouflage the blemishes. The growers complained; the company denied responsibility. In 1969, Maryland officials called on the Federal government to investigate; Federal scientists found that tree damage

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*David Bird, "Rural Power Plant Issue in Pollution Dispute Between 2 States," The New York Times, May 14, 1971.

was caused by sulfur dioxide from the Mount Storm plant. In November, 1970 the Governor of Maryland requested that the Federal government convene an air pollution abatement conference with the participation of both states to ascertain workable solutions. West Virginia's Governor responded by insisting that any such conference would have to consider the air pollution caused by a paper company in Maryland and adversely affecting an area of his state.

The conference, which took place in early May, 1971, provided a forum for many conflicting points of view. Tree-growers claimed financial disasters; power company witnesses cited causes other than plant fumes and cited scientific studies, funded by them, to prove that a tiny translucent four-legged mite was the real offender. The executive director of environmental quality for Virginia Electric said that $7.5 million worth of air pollution control devices had been installed at the facility but were not working satisfactorily. But, he insisted, the quality of the area's air was still not below Federal standards. In Maryland, where state regulations were forcing the paper plant to clean up on a prescribed schedule, the Chief of the Division of Air Quality Control indicated the danger that larger generating plants would mushroom in states like West Virginia, where there is little air regulation, and contaminate people in the adjoining states that were more concerned about air pollution. For him, the situation called for more stringent Federal standards and regulation.

Secretary of the Interior Rogers C. B. Morton reported that the U. S. consumed 69,010 trillion British thermal units of energy last year, a 2.3 percent increase over the previous year and more than ever before in history.* The energy demand in 1971 was met mainly through a combination of increased domestic production of natural gas and petroleum products and increased imports of crude oil and petroleum products. For all purposes, petroleum supplied 44 percent of domestic energy needs, natural gas 33 percent, bituminous coal 18 percent, water power 4.1 percent, nuclear power 6 percent, and anthracite 3 percent. The greatest percentage increase was in nuclear power generation, which rose 68 percent to 36.7 billion kilowatt hours, but this represented only a small proportion of total energy needs. Mr. Morton cautioned, "Only a thoughtful national energy policy will enable us to meet...growth efficiently with a minimum environmental damage."

A very recent OEP report** predicts possible power shortages this summer, especially in New York, Chicago, and Miami, where heat waves are likely to occur and where air conditioners in the past caused great concern about available supplies. The public has been urged, during long hot spells to "avoid unnecessary use of electricity."

Testimony at April, 1972 hearings before the House Interior and Insular Affairs Committee on the developing energy crisis indicated that the public, schooled to abundance, would not automatically shift its demands downward. Mr. Rogers C. B. Morton, Secretary of the Interior, had suggested that the government might restrict advertising

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*Dana Adams Schmidt, "Morton Cautions Nation as Use of Energy Rises," The New York Times, March 31, 1972.

**Report issued by U. S. Office of Emergency Preparedness, Department of the Interior, April, 1972.

by utilities, encourage people to drive smaller cars, or urge stores to put out neon signs at night. (It is to be noted here that (1) on other occasions and under other auspices, authorities had testified that energy consumption by home gadgets was miniscule and important only in a symbolic sense, and (2) experts on crime have urged bright lighting of stores and business areas as a deterrent to night burglary. Reports from New York City indicate a drop in the number of holdups, muggings, etc. in areas where the "Light the Night" campaign has had public support.)

Dr. Edward E. David, Jr., Director of the Office of Science and Technology, told the committee of government programs to develop new methods of harnessing energy from known fuels and from new sources. One new source would be nuclear fusion, a process which, incidentally, is about 25 to 30 years behind the breeder reactor in terms of development as a source for commercial power.

The New York State Society of Professional Engineers, with a membership of aobut 10,000, called for sweeping policy changes by government agencies and the Consolidated Edison Company.* The engineers published 47 pages of studies and recommendations distilled from a 12-month study conducted by a 15 member committee. The engineers reported that a projected 6.2 percent annual increase in power would mean using twice as much electricity in 1980 as now, four times in 1990, and eight times in 2000. They are also warned: "Concomitantly, eight times more fuel will be burned, and the air will be polluted

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*The New York Times, October 3, 1971.

eight times more. If the quality of today's air arouses concern and is considered a potential health hazard, consider how many people will die when the air becomes many times more polluted."

To slow the increase of demand by one million kilowatts by 1980, they recommend "natural ventilation", i.e., windows that can be opened, in all new buildings, curb on use of central air conditioners in buildings with windows that open unless temperatures exceed 75 degrees, and higher rates for increased use of electricity other than by industries. They also proposed discouraging the cutting down of trees any larger than six inches in diameter unless replaced by similar trees and urged massive tree planting to help "natural regeneration" of the air. Their report charged that the gas shortage in the United States is due primarily to "stifling regulations" of the Federal Power Commission. The Society had sponsored legislation that would require utilities' officials responsible for major engineering decisions to be licensed engineers, subject to professional and ethical review by the State Engineering Board of Examiners; to date, Consolidated Edison had opposed such legislation. As for prospects, the engineers predicted "ecological disaster," if demands for power were to continue under present and unchanged policies.

Calling the 21st century "essentially a nuclear electric century," Dr. Ralph E. Lapp, the nuclear physicist, testifying before the House Committee on Interior and Insular Affairs, called for construction of more nuclear power plants and a parallel intensification of efforts to make them safe.* He stated that nuclear power plants now in use

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*The New York Times, April 13, 1972.

present safety hazards, the significant problem being that of cooling the plant's nuclear core, to inhibit radiation. Dr. Lapp, a member of the Manhattan Project team, described himself as an environmentalist but offered certain qualifications. "The environmentalist movement," he said, "is populated by people with some degree of extremism, with no willingness to compromise." In his view, such attitudes create the severe danger of an "environmentalist backlash." As illustration of this point, he referred to the current controversy over a new nuclear power plant (the Quad Cities) at Cordova, Illinois. "If a Chicago factory worker comes home to a blank screen and a lukewarm can of beer, he will ask, 'What do I care about the reproductive habits of fish in the Mississippi River? Turn the plant on!'"

(It might be noted that here, as elsewhere in testimony, the small consumer and his use of appliances were made to appear the big offender. Emphasis on this convenient whipping boy may actually be diverting attention from much more significant users and wasters.)

Dr. Lapp's comment regarding "backlash" appears to have been substantiated.

Robert Gillette, in his commentary entitled "National Environmental Policy Act: Signs of Backlash are Evident,"* states:

"Federal agencies, ranging from the Atomic Energy Commission to the Department of Transportation are pressing for legislation to grant them special dispensations from NEPA's burdensome requirement of preparing

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*Science, Vol. 176, 7 April, 1972, pp. 30-33.

environmental impact statements." "NEPA has two fundamental and apparently irritating purposes: to open to public view a major new source of information about the way in which the government's activities affect the environment and, in so doing, to goad the whole federal establishment into adopting a more sympathetic attitude toward a fragile biosphere."

According to some critics, contravening regulations through legal ruse has become accepted Washington practice. The AEC, prevented by court rulings which delayed operations of six or more power plants, has been unable to complete a single licensing action since last summer. Recently, it struck on the idea of issuing "interim operating licenses" to nuclear plants for low-power test runs before the new impact statements were ready. This legal maneuver would have licensed Commonwealth Edison's new Quad Cities plants 1 and 2 near Chicago. The plan was defeated by a suit brought by the Izaak Walton League and the Attorney General of Illinois, the contention being that thermal discharges from the two reactors might interfere with reproduction in two major species of fish in the Mississippi River. Irrespective of the outcome, in the subsequent appeals to higher courts and so on, the trend is unmistakable. Two bills in Congress would authorize the AEC to issue interim licenses and would thus avoid time-consuming hearings. Environmentalists see the loopholes as opening wider and wider and fear a coherent movement to cripple the NEPA. Financial problems and ideological rifts have weakened the environmental lobby, which has never had the resources, backing, and sophistication of its arch-enemy, the utility industry.

The following headings of recent newspaper articles will serve to sketch out the drama being played and exemplify the enormous complexity of the problems involved in preserving the environment, protecting public health, and providing energy.

John Noble Welford, "Reactor Report Termed Faulty, Scientists Say AEC Plan for Breeder Ignores Peril," The New York Times, October 9, 1971.

"Group of Scientists Urges Shift in A.E.C. Safety Role," The New York Times, October 12, 1971. In a study reported here, the Union of Concerned Scientists said that the A.E.C. "cannot function effectively as the supporter and initiator of a major national program to 'nuclearize' the country and, at the same time, have total responsibility for the most critical aspects of reactor safety."

Richard D. Lyons, "Justices Bar States' Rule on Nuclear Plant Safety," The New York Times, April 4, 1972. By a 7-2 decision, the Supreme Court ruled that, in effect, the Atomic Energy Commission alone has the authority to regulate the discharge of radioactive debris from nuclear power plants.

Richard Colman, "'Nuclear Power Facilities Should be Turned Off', Says Local Expert," The Daily Californian, April 6, 1972. Professor John Gofman, professor of Medical Physics, said that the consequences of nuclear power are so bad that the whole nuclear power industry sould be turned off. Charging that the electrical utility industry is making fradulent claims about the safety of nuclear power, he challenged the industry to drop government assistance on insurance and assume full responsibility for accidents. He criticized A.E.C. Chairman James Schlesinger for proposing that nuclear power plant radioactive wastes be placed in satellites and orbited around the sun. Calling this most dangerous, he said that the suggestion revealed that the A.E.C. had found no realistic solutions to the waste disposal problem.

Edward Cowan, "Administration Pushes for Emergency Licensing of Nuclear Plants," The New York Times, April 10, 1972. Cowan asserts that "The Nixon Administration, fearful that summer power shortages will irritate voters, is pressing Congress for legislation giving it emergency authority to license newly built nuclear power plants that have not fully satisfied the requirements of the National Environment Policy Act of 1969. Environmentalists ask whether power shortages are probable or the danger has been deliberately exaggerated to facilitate the weakening of environmental safeguards."

Spokesmen for the Long Island Lighting Company complained* that A.E.C. procedures in granting construction and operating permits for nuclear power reactors were causing "intolerable delays" for power companies in the United States. Due to these procedures involving hearings and hearings and more hearings," not a single construction or full operating permit for a nuclear power plant and only two interim operating permits at less than full rated power had been issued.

Still another report** urges Congress to reject an administration request for $500-million demonstration model of a nuclear breeder reactor to generate electricity. "Too many serious questions exist about the safety and environmental impact of such a project to make a committent at this point to the commercial development of this technology," the report says. Grave questions were raised about the safety of three aspects of breeder reactors: (1) the plants themselves; (2) the handling of plutonium; and (3) the disposal of plutonium waste products. They also suggested that, with large quantities of plutonium in use, some of it might be clandestinely diverted to the unofficial and illegal manufacture of nuclear weapons. The commission's (AEC) view is that "mishaps are inevitable but that they will not produce the dire consequences foreseen by critics."

The materials selected for presentation in the foregoing pages illustrate the immensity and complexity of several facets of resource management. They underscore dramatically the divergent viewpoints, the conflicting roles of government, the adversary pressures, and, above all, the diverse ways in which information is put to use. Far from being treated as objective and unambiguous, facts become tools, the redundant is made to appear profound and persuasive, and whether a public-be-damned or a public-be-served policy is to be implemented remains a serious, and unanswered, question. In this regard, William D.

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*The New York Times, April 20, 1972
**The New York Times, April 26, 1972

Ruckelhaus, Administrator of the Environmental Agency, has reported* his concern regarding "credibility gaps and cynicism about government."

The following sections, on water pollution and land use, further reveal the underlying conflicts and suggest, as this entire exercise intends, the need for a total restructuring of man's approach to environmental resource management, with ERTS, Skylab, and other remote sensing technology contributing a valuable information source.

2.2.3 Water Quality

Concern with water differs considerably from place to place and from time to time. Just as pioneer America regarded "clearing of forests" as a virtue and hacked away the wilderness in the name of progress, so it made a virtue of harnessing its waterways and "putting its rivers to work." In the United States in its early years, quantity was no problem. The settled areas knew, if anything, a superabundance. But in earlier times and in other lands, water was early recognized as a precious commodity. In fact, some historians, as for instance, Wittfogel, trace the rise of the world's major civilizations to the siting of water and find in the rituals, mores, life style, and culture of peoples much that can be attributed directly to the accessibility of water. Some of the most sophisticated technology of ancient empires was associated with the utilization of water.

In our time, the main preoccupation is to have potable water, free from bacterial contamination. The treatment of wastes and the establishment

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*Peter Kihss, "Publishers Told of Chagrin with U.S. and Press," The New York Times, April 26, 1972.

and maintenance of purity standards are intended to achieve that objective. But industrialization and urbanization complicate and obstruct attainment of this goal, and it becomes ever more apparent that water quality depends on the uses to which water is to be put and upon the priorities assigned these uses. And, as we saw with respect to air, priorities are not divinely designated. Variously defined and vigorously contested on man's accustomed battlegrounds, they appear as issues in jurisdictional disputes, bureaucratic tugs-of-war, and special interest power plays. The disparate views on water come from a vast and complex concatenation of historical, economic, and political factors.

Review of the literature indicates an almost universal, love-and-motherhood kind of rejection of water pollution as an evil. But, beyond the generalities, consensus is fragile. Quality becomes a matter of degree; compromise a way of life: "It is unlikely to be desirable to attempt to maintain a busy industrial harbor in the same degree of cleanliness as a municipal water supply reservoir. Not all streams can be trout streams. Some deterioration or change must accompany the growth of municipalities, the development of industry, and the exploitation of agricultural and mineral resources.*

A recent article entitled "'Extremism' Scored in Pollution Curbs"** illustrates the controversy still in progress. The article points out that Eric F. Johnson, executive director of the American Water Works Association, describing itself as a "nonprofit organization devoting

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*Restoring the Quality of Our Environment, op. cit., p. 70.
**The New York Times, April 19, 1972.

itself to research and education in water quality," charged that water pollution controllers are "anti-people," who have "distorted priorities to the point where the fish kills of the present are held to be more significant than the possible people kills of the future." In other words, he said, "extremism in water pollution control is more concerned with the welfare of fish than with people."

According to another article,* "Montana Fish and Game Director Arouses Governor's Ire with Strict Stand on the State's Ecology," Governor Forrest H. Anderson and others have expressed fear that the Fish and Game director's environmental concern may "inhibit further development that can bring the new jobs." Mr. Frank H. Dunkle, the official under fire, was instrumental in getting the U. S. Forest Service to stop using DDT in its effort to control the spruce bud worm. He also took action to stop feeding elk pesticide-treated hay that had been condemned as cattle feed. During the past year, "Mr. Dunkle has asked questions about the effect of proposed dams on the environment, what a new open-pit copper project for the Lincoln area will do to the streams, what the plans will be for land restoration in the new strip mine development of southeastern Montana's vast coal reserves, and the effects of a big, new Montana recreation spread planned by Chet Huntley, the television newscaster who is retiring in Montana."

The former chairman of the environmental advisory board to the Army Corps of Engineers reportedly has accused the Corps** of "failing

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*The New York Times, July 27, 1970.
**William M. Blair, The New York Times, August 1, 1971.

to respond to the urgency of change to meet critical environmental needs." "Only when monumental countervailing external political pressure was used have the Corps project directions been forced to change," said Mr. Charles H. Stoddard, former director of the Bureau of Land Management of the Department of the Interior and at present a resource consultant in Wisconsin and Minnesota and member of the board of Wisconsin's Department of Natural Resources.

"Mr. Stoddard's strong criticism was another phase of the long fight between the Army engineers and the conservationists who have charged the Corps with being steeped in federal, state, and local politics to gain authority to build dams and other projects."

In yet another article entitled "House-Senate Dispute Holds Up Bills to Curb Coastal Dumping",* it is reported that "legislation to regulate the dumping of wastes into the coastal waters of the United States is stalled by a dispute between the House and Senate over whether the Army Corps of Engineers or the Environmental Protection Agency should control the disposal of spoil from dredging. The dispute is greatly complicated because of overlapping committee jurisdiction in both Houses." (Italics added.)

A memorandum from the Bureau of Sport Fisheries and Wildlife as cited in the New York Times** has challenged the Bureau of Reclamation and, in effect, the parent agency (the Department of the Interior) on its position that there is no alternative to a $58 million dam project

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*E. W. Kenworthy, The New York Times, April 11, 1972.
**William M. Blair, The New York Times, August 28, 1971.

on the Teton River in Idaho. Impact statements from multiple agencies have brought conflicting assessments as to the costs and benefits of the project. "The reservoir behind the earthen dam would wipe out a 17-mile scenic stretch of the river in a deep gorge, destroying a self-sustaining cutthroat trout fishing area and eliminating 2,700 acres of habitat for elk, deer, and other wildlife." However... the project's potential benefits were greater than the loss of the natural river area. These benefits were listed as flood control, more supplemental irrigation water for farms, electric power and lake recreation for more people than can now reach the gorge. On August 6, two members of Congress protested to Interior Secretary Rogers C. B. Morton that the procedures followed by the agencies 'appeared to violate both the letter and spirit' of the National Environmental Act of 1969. This was done, they said, by 'submerging and hiding the comments of other Interior agencies which have expertise concerning the environmental impact of the proposed action.'"

An article in Science* reports that, on recommendation of the Council on Environmental Quality, President Nixon (January 19, 1971) halted construction on the Cross-Florida Barge Canal, in preparation for which the State of Florida had spent some $12 million for rights of way, some local governments had invested heavily in barge terminals, and the Federal government had committed some $50 million. "EDF (Environmental Defense Fund) spokesmen say they seek a judicially ordered permanent halt, since they don't have great faith in the permanence

*Science, 29 January, 1971, p. 357.

of political decisions and want to insure against the possibility of a change of heart by the President or by a subsequent Administration. Members of the Florida delegation in Congress are reportedly organizing to exert pressure in behalf of the project. And environmentalists note that the Corps of Engineers had indicated it would appeal the preliminary injunction. EDF's executive director, Roderick A. Cameron, says that an important contribution to the campaign against the canal was a thorough ecological and economic analysis of the project done by volunteers at the University of Florida at Gainesville. The study covered aspects of the project ranging from hydrologic effects to economic cost-benefit analysis."

2.2.3.1 The California Water Project

The reader is reminded that much of the emphasis which thus far has been given in our Integrated Study to California's total "earth resource complex" has dealt with the California Water Project by which Northern California water has to be transferred by canals to Southern California. The events cited thus far in this chapter are intended to serve as background for what is going on with respect to canal construction in California. This massive project, planning for which began in the 1950's, has been described as "the longest and most expensive aquaduct ever conceived by man." Its financing having been helped by a $1.75 billion bond issue in 1960, its purpose is to divert water from the Sacramento-San Joaquin Delta 444 miles southward, almost to the Mexican border.*

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*Jackson Doyle, San Francisco Chronicle, January 7, 1971.

Writing in defense of the Canal, Mr. W. R. Gianelli, Director of the California State Department of Water Resources, stressed that it "was adopted as the best of several alternatives to protect and enhance the ecological and environmental values of the Sacramento-San Joaquin Delta...As a matter of fact, the record is abundantly clear that the Peripheral Canal concept was adopted because of, and at the insistence of, the fishery and recreational interest groups in our States."*

The Sierra Club, which once conditionally endorsed the Canal, subsequently condemned it as not only a menace to the Delta and to San Francisco Bay, but also as a threat to the major free-flowing rivers of the State's North Coast. The Eel, Van Duzen, Mad, Trinity, and perhaps ultimately, the Klamath would have their water impounded and would consequently "lose their value as a major recreational and scenic resource." Reduction of the flow of Sacramento River water was seen as detrimental to the flushing action needed to keep up the quality of the San Francisco Bay-Delta estuarine system. "Once the Canal is built, political and economic forces may have them compel the diversion of additional water with disastrous results for the Delta.**

Another article† dealing with this controversial issue reports: "Sponsors of the Project assert that outlets spaced along the canal would

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*Letter to the Rt. Rev. C. Kilmer Myers, Bisphop, Episcopal Diocese of California, November 10, 1970, published in The Peripheral Canal and Other Concerns, Information Paper No. 21, The Ad Hoc "Think Tank" and the Ad Hoc Metropolitan Planning Branch of the Diocese of California, March 8, 1971.

**Edwin B. Royce, "The California Water Plan," The Sierra Club, Northern California Regional Conservation Committee, in "The Peripheral Canal," op. cit., p. 32.

†Editorial, San Francisco Chronicle, cited in "The Peripheral Canal," p. 28.

release sufficient water into Delta streambeds to protect that area's environment. But the Sierra Club, after 'critical examination' now finds that the proposed releases fall far below the Delta needs and that the canal would have a 'drastic impact' upon Delta and bay environment, and seriously damage the agriculture, the fisheries, and wildlife resources of this vast and productive area."

The Congressional Record of October 9, 1970 contains a statement prepared by Dr. Paul S. Taylor, an economist on the faculty of the University of California. Dr. Taylor presented a "rear-view mirror of history," important here because it makes readily visible the experience of California's past with water (and land) development. He calls to mind Secretary of the Interior Harold L. Ickes' statement in the 1940s, when giant landowning interests mobilized to scuttle public control over private shares of public water. Ickes called it "the age-old battle over who is to cash in on the unearned increment in land values created by a public investment...(in) great irrigation projects." Marion Clawson, who survived the "160-acre" battles of the '40s and later became Director of the Bureau of Land Management, stated, "I deny the contention that property owners have an inherent right to major gifts in property values at public expense."

Dr. Taylor cited the language of today's market place as indicative of the motivation behind water development. "An advertisement in the San Francisco Chronicle of April 21, 1970 makes the appeal to readers in advance of the coming of water to the Antelope Valley, one of the areas currently being analyzed under our Integrated Study by University of

California scientists on the Riverside campus:

> "Make your money grow in the booming Antelope Valley in sunny Southern California. Everyone knows about the tremendous growth in real estate values in Southern California...and many experts believe that population and industry growth projected for the future will bring even greater increases in Southern California land values. We believe that land in such selected growth areas is a good and safe investment and offers great profit potential for investors."

He cited another advertisement in the San Francisco Chronicle, on June 16, 1970, as critical of these speculative aspects of the California Water Project. It charged that "huge corporations have been busily buying up California land in anticipation of spectacular increases in land values. 'Just five large companies', the ad claims, 'have acquired 380,200 acres that already have appreciated in value by a total of $218,970,400.'"

The Right Reverend C. Kilmer Myers, Bishop of the Episcopal Diocese of California, after considerable review and research, consultation with experts, and interviews with officials, raised a number of points that he considered salient:*

1. Since the Peripheral Canal will, in a large sense, control the quality of water and wildlife in the Delta and San Francisco Bay, who will control the "spigot" that turns it on and off?

2. Who will and can guarantee, once we have taken seven million of the eighteen million acre feet from the yearly flow of the Sacramento River for Southern California's needs, that there will remain sufficient water in the upper reaches of the Sacramento to preclude the necessity of creating other dams and tapping other streams in the north?

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*The Peripheral Canal and Other Concerns, op. cit., p. 46.

3. And what will be the effect on the minds and spirit of a whole generation of young people in our State if we blindly proceed in the absence of answers to those questions? For half of California's nearly twenty million residents are under 25 years of age, and they are the ones who will inherit the legacy of our wisdom or our folly; should we, in our bow to expediency, commit them to the consequences of an ultimately disastrous option? What will be the prospect ever of closing the generation gap and restoring their confidence in those whose decisions so affectingly bind them?..the real issue, I am convinced, is not nearly so much the engineering sufficiency or wisdom of the Peripheral Canal, but the political question of who operates it under what policy and for whose benefit.

Professor David Seckler, an economist whose specialty was water resources in the Giannini Foundation, University of California, supported a moratorium on construction of the Peripheral Canal until an independent study could be made to address adequately the many serious questions involved in the planning. The following points are excerpted from a letter written by Professor Seckler to Archdeacon John Weaver, Episcopal Diocese of California, November 23, 1970 and included in a document entitled "The Peripheral Canal and Other Concerns."

Flood control benefits are suspect...dams induce people to move into flood plains causing loss of life and property when the "big one" comes along.

The value of additional slack water recreation on reservoirs in the northern part of the state is nearly zero because of massive oversupply. The value of stream-based recreation is, on the other hand, very high because of continual destruction of these amenities through dam construction.

The "respite from urban congestion" is a respite from over-development of urban centers partly as a consequence of promoting urban expansion by DWR and MWD and related agencies.

> It is clear that the State Water Project is going to create conditions of oversupply in certain sectors of agriculture with consequent declines in prices of these commodities. This will cause particular hardships to smaller, poorer farmers.
>
> Much of the electrical generation benefits of the project in the North are offset by the electrical use costs of pumping water over the Tehachapi mountains in the South.

The final item in this compendium was headlined under the banner "Big Error Admitted on State Water Plan."* It asserted that "State water officials are finally conceding that they have long planned to transport too much Northern California water to the Southland too soon. State water officials confirmed that tomorrow's report will substantiate charges that water needs of Southern California have been overestimated and that the need for development of additional supplies beyond the annual 2.1 billion acre feet already contracted for can be delayed at least ten years."

In concluding this section, it is important that we emphasize what its purpose _is_, and also what its purpose _is not_. Its purpose _is_ to illustrate that the wise management of earth resources in an area that is rapidly growing and politically and socially turbulent, such as the state of California, is indeed a difficult task. Although remote sensing can facilitate the inventory of earth resources and of certain factors pertinent to their management, it is probable that _no_ plan for the development and management of California's resources would be free of severe criticism by various social and political groups. Many such

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*Jackson Doyle, _San Francisco Chronicle_, January 7, 1971.

groups are frank to admit that they judge any given resource management measure to be good or bad, strictly in terms of the effect which that measure will have relative to the special interests of the group. The specific comments cited in this section have sought to document the nature of this criticism, the better to make our point about the inevitability of such criticism. In citing this criticism, it has not been our intent to side with one faction or another, nor to imply that ours is still another group which presumes to know better how to handle California's resources than do the duly constituted authorities who have been entrusted with that important task.

2.2.4 Land Use Planning

In January of this year, a 3-day symposium on Remote Sensing of Earth Resources was presented to the Congressional Committee on Science and Astronautics and to its advisory panel on Science and Technology. Dr. James C. Fletcher, the Director of NASA, delivered the theme address of that symposium under the title, "NASA's Long-Range Earth Resources Survey Program." He included in his list of proposed investigations for ERTS and Skylab: "Investigations in land use planning, which will be conducted at city, county, State, and megapolis levels, not only to obtain up-to-date information on how land is being used today, but to make extrapolations on how future development can best be accomplished."*

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*Remote Sensing of Earth Resources, compilation of papers prepared for the 13th Meeting of the Panel on Science and Technology, Committee on Science and Astronautics, U. S. House of Representatives, 1972, p. 17.

Although it is difficult to isolate items pertaining to land use from those relating to such matters as urbanization, siting of power plants, and highway construction, the following have been selected, rather arbitrarily, by our group in order to indicate the extent and depth of divergencies of viewpoint relative to land use.

One of the many items of a mostly critical nature* makes the following assertions:

> "Four years of intensive Congressional investigation has failed to produce as yet any clear-cut answers to an extraordinary question: What to do with one-third of the land area of the United States. The land in question is Public Domain owned by the Federal Government--some 700 million acres of prairies, desert, mountain and forests. Unlike the rest of the country's 2.3 billion acres, this land was never conveyed to states or private beneficiaries such as railroads. About one-half of this land is in Alaska, and about two-thirds of it is under the jurisdiction of the Department of the Interior's Bureau of Land Management. The rest is scattered among a number of other agencies. All of it has existed in a sort of confused limbo, subject to an uncoordinated series of laws ranging from the Mining Act of 1872 to the Taylor Grazing Act of 1934. In 1964, Congress created the Public Land Review Commission and gave it $4 million and five years to formulate recommendations for 'disposition of the land.'
>
> The Commission's task has been immensely complicated because of the many interest groups involved. Cattlemen, the timber industry, and the mining industry, among others, would be delighted to have the public domain turned over to them. A number of Western States, where untaxable Federal holdings amount to as much as 80 percent of the land area, would like to whack up the land as a revenue source. Some conservationists would like to see the Federal Government hold on to every square foot of the land, lest in other hands it be lost to public use.

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*Gladwin Hill, The New York Times, September 27, 1969.

Edward C. Crafts, the recent director of the Interior Bureau of Outdoor Recreation, suggested to the convention (American Forestry Association, on 'The Destiny of Use Public Lands') that statutory reforms were only a secondary problem in public land use. 'The issue of environmental quality transcends by far the more conventional questions of fair market value, revenue sharing, and private rights and privileges on public lands,' he said. 'The long-term issue is environmental management,' he continued. 'But the price runs against our grain. It includes a social ethic for the environment, control of the world's population, willingness to forswear profits, pay greater taxes and higher prices, reduce the material standard of living, sacrifice certain creature comforts, revise social priorities, and raise sufficient public opinion against principal industrial offenders to compel change.'"

Another highly relevant citation* says:

Hearings to be held this week in Sun Valley, Idaho will go far to determine whether the country will have its 37th National Park or a gaping open-pit mine yielding molybdenum that will not even be needed for decades to come. For two years the American Smelting and Refining Company has been prospecting in the White Cloud Mountains east of the Sawtooth Valley, planning to penetrate this scenic wilderness with access roads, noise, and a pit 7000 feet long and 700 feet wide. Eventually "ponds" would be created to accomodate the tons of waste dug up to extract the two-tenths of one percent of ore that is molybdenum. A subcommittee of the House Interior and Insular Affairs Committee will take testimony on three approaches to the future of the region. A proposal to set up a National Recreation Area, with virtually no protection against exploration, is naturally the hope of the mining industry, less naturally that of the Forest Service and politically that of Governor Don Samuelson, who is sure that "The good Lord never intended us to lock up our resources." The state's best sentiments are reflected in the declaration of the Boise Idaho Statesman that "The State is not so desperate for dollars that it must be anxious to sacrifice the crown jewels of its natural heritage to relatively short-term dollar benefits."

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*Editorial, The New York Times, August 27, 1970.

In an article headlined "Land Use Policy Asked in Report on Environment--Nixon Unit Backs Matching Resources to Population in an 'Orderly' Manner"* the following informative comments appeared:

> "In the first White House report on 'the state of the nation's environment, analysis was made of the major ecological problem facing the country. Of all the problems relating to environment, the report stressed misuse of the country's available land resources as 'the most-out-of-hand and irreversible.' The report urged the Government to use some of its grant and loan programs--such as water and sewer grants to suburban communities--to require sound community planning instead of alloting funds to development projects 'which merely respond to uncontrolled growth.'"

Still another article appeared in the same publication under the title "Miners and Ecologists Clash on Montana Ore Development".** That article reported that "Mining men and conservationists took opposing stands today on the proposed development of copper, nickel and chromium mining in the Beartooth Mountains of South Central Montana." The area under discussion lies in an exceptionally scenic mountain region northeast of Yellowstone National Park and has long been favored by hunters, fishermen, and others seeking outdoor recreation. Extensive mining exploration work, much of it in recent years, has scarred a good deal of the mountain area; proposed future development poses a threat to streams, ranches, and wildlife, according to conservationists. The Anaconda Company admitted that extensive development would probably entail strip as well as underground mining but their regional general

*Robert B. Semple, Jr., The New York Times, August 11, 1970.
**The New York Times, August 19, 1971.

manager and a member of their environmental engineering department issued the following joint statement: "We assume that the subcommittee (Minerals, Materials, and Fuels Subcommittee of the Senate Committee on Interior and Insular Affairs) shares our conviction that the continuing development of the nation's mineral resources is one of the basic foundation stones in the continuing development of the nation's prosperity." Mr. George Darrow, a State legislator who is a geologist by profession, placed much of the blame for the present situation on the Federal mining law of 1872, still in effect. This permits miners to file claims on public land with virtually no restrictions. He urged repeal of the 1872 law and adoption of new Federal legislation and a new national resource policy to provide a basis for evaluating alternative uses of natural resource systems.

Last year the United States Bureau of Mines reported, in "Mine Subsidence--Extent and Cost of Control in a Selected Area," that the subsidence or caving-in of the surface over the abandoned tunnels of mined-out coal seams has wrecked homes and public buildings, bridges, railroad tracks, pipelines and factories, altered ground water supplies and reversed the flow of sewer lines. The report noted that two million of the eight million acres of the United States already undermined by mine tunnels had experienced some subsidence and predicted that 750,000 more acres of land over previously mined acres would suffer subsidence by the year 2000, by which time five million more acres would be affected by new underground mining. The subsidence report by William Cochran, a Pittsburgh geologist of the Bureau of Mines, suggests that "a simple but often impractical solution" to the cave-in phenomenon in the coal fields might be to "prohibit mining in or near urban areas." The Bureau of Mines, however, has long been loath to advance constraints on mining, and the report concludes that subsidence-causing mining should continue and that surface development should be embargoed.

With reference to the use of forest lands, a major controversy has recently been well stated in an article bearing the title "National Forests: Timber Men vs. Conservationists".* The cited article reports that:

> "The custodians of the national forests are coming under increasingly intense cross-pressures from rival blocs in the sturggle over the future of the vast woodland preserves. The timber industry, fortified by new support fron the Nixon Administration, is demanding that the 187 million acres of national forests contribute more to the country's wood supply. Conservationists, riding the crest of the 'environmental revolution,' are charging that the forests are already over-logged and that recreational and wildnerness needs are being shortchanged as well. The debate has become so heated and the forces so formidable that the question of wilderness uses alone--how much should be maintained as playgrounds for city people, how much fenced off as 'living museums' for hikers and campers--has become an exasperating dilemma for Federal administrators. 'The greatest conflict we face,' says Edward Cliff, chief of the Forest Service, 'is pressure for the preservation of wilderness as opposed to using it intensively for recreation, logging and purposes like that. It's an irreconcilable conflict.'"

The article continues by saying that:

> "Underlying the controversy, it was found in a six-month investigation, was a welter of questionable statistics... Even when all the conventional factors in a national forest timber sale are worked out, there now is posed the question of a logging project's prospective impact on the nation's new scale of environmental values. This tends to impugn statistical or other generalizations about the availability of timber from national forests, and to leave unanswerable, pending more comprehensive studies than have ever been made,

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*Gladwin Hill, <u>The New York Times</u>, November 15, 1971.

the question of how much these forests should contribute to the future timber supply.

That article concludes by saying:

> "Conservationists attribute the slow pace of the program (the National Wilderness Preservation System) in part to commercial bias on the part of the Forest Service. The Senate Interior Subcommittee on Public Lands is continuing its inquiry. Meanwhile, Senator Gale McGee, Wyoming Democrat, supported by some leading conservation organizations and other members of Congress, is sponsoring a bill calling for a thorough investigation of the Forest Service by a 'blue ribbon' commission of outside experts."
>
> "Among the numerous measures before Congress affecting the national forests are two bills that typify opposing viewpoints on how the forests should be managed. One bill, sponsored by Senator Mark Hatfield, Oregon Republican, whose constituency includes big timber interests, is essentially a modification of the National Timber Supply Act that conservationists blocked in 1970 as a 'raid' on the forests. It would divert more than $300 million a year in timber revenues, which now go into the United States Treasury, into a fund to increase the forests' timber production and 'enhance the forest environment.' It also provides for Federal grants to states to promote private timber production. A counter measure drafted by Representative Dingell in collaboration with conservation orgainizations requires the states to develop federally approved management plans for privately owned timber lands; provides for Government regulation of logging to protect environmental values; creates a timber-revenue fund for development of both commercial and noncommercial aspects of national forests, and bans timber exports unless national needs are assured five years ahead."

In April of this year, a conference of 200 "citizen consultants" met at Yosemite National Park to ponder the problems faced by the park system in the next century. They raised a number of critical questions including the following:

To what extent should the national park system be responsible for meeting national recreational needs?

How can the parks be preserved at anything like their pristine state in the face of evermounting public demands on them? Should the parks be operated mainly for passive sightseers or for more energetic seekers of "the wilderness experience"? How can the national park system be made meaningful to the urban underprivileged as well as the far-traveling hinterland middle class?

One of the main conclusions in the study group report as follows: "A national land use planning program and a well-administered national land use policy act are both essential in order for park needs to be evaluated in relation to other national priorities and to protect park settings."

Since we have allowed the press to speak for itself, albeit in many tongues, it is fitting that we conclude this exercise with still one more news story, which underscores the need and indicates the urgency for long-term and far-reaching global management policy. This story, bearing the title "Global Warning Network on Environment Planned"* states that

> "Plans are being drafted for a global network of stations equipped to monitor changes in the earth's environment threatening the life forms that inhabit it. The project, in which scientists from the Soviet Union and the United States are playing leading roles, would identify subtle but potentially disastrous alterations caused by pollution, power plant radiation, chemicals and other factors."

An interim report, circulated in preparation for the meeting, said that "a global crisis exists with respect to environmental quality." It

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*Walter Sullivan, The New York Times, February 12, 1970.

added that solution of the problems arising from pollution and haphazard alteration of the environment required "a global network for monitoring the world's environment".

2.3 CONSIDERATIONS IN CONVERTING ERTS CAPABILITIES INTO AN OPERATIONAL SYSTEM*

There are many ways that an organization may come into being and develop. Some organizations have simply evolved and through this evolution, they have developed from a small fledgling operation to a large bureaucratic structure. Others have been initiated and have developed in conformity with carefully made plans. The Earth Resources Technology Satellite Information System is more akin to the latter than the former, but certain problems are sure to arise because it will not start out small; the operational system, which is likely to develop after ERTS-A and ERTS-B will have vast quantities of data and the impact of these data on the society in which we live will be substantial. It is imperative that the design of an appropriate information dissemination system begin now and that the design be developed in an organized and systematic manner, since a planned design will better satisfy the needs of mankind than one which has merely been allowed to develop. Because the most critical link in the ERTS System is the utilization of the information, the design of an

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*The material appearing in this section was prepared by a member of our group, J. William Gotcher, who is particularly interested in how various organizations come into being and what is the nature of the consequent "model".

information dissemination bureau (under whatever name) will substantially influence this utilization. Crucial elements for the design of an appropriate dissemination system are the policies which will control the effectiveness of the entire system and its impact on society.

Of the many policies which must be established prior to the development of the operational system, perhaps the most crucial are the ones which will determine who utilizes the ERTS data. Who can effectively utilize the data is substantially determined by where in the system the interpretation of the data takes place and to whom the resulting information is made available. This policy is concerned with the operating system, not the experimental system. Research scientists may well be able to interpret the data with which they need to work; however, county, state and industrial enterprises may not have the expertise necessary to do so. Another important policy area concerns the question of how the various costs that are involved in an information system, such as ERTS and its operational successors, should be borne. Policy questions such as these are considered to be among the most important for the development of an ERTS data bureau.

The primary research tool for solving policy problems such as those mentioned above is comparative analysis. Most new governmental agencies and many private industrial agencies feel that their problems are unique and that the development of appropriate agencies must start without the guidance of historical investigations. Though the ERTS System is systemic and, perhaps is destined to become the largest data acquisition and dissemination system ever developed, there are many similarities with previous information systems. Consistent with our portion of the initial "integrated study" proposal that was accepted by NASA, our group is in the process of making such analyses. In so doing it is attempting to make maximum use of similar studies which already have been made or are being made with respect to ERTS and other analogous systems. Comparisons are being made with systems employed by the Bureau of the Census and with the Meteorological Satellite Service operated by the National Oceanic and Atmospheric Administration. Other information bureaus which are being investigated are the National Ocean Survey, previously known as the Coast and Geodetic Survey, and the Communications Satellite (COMSAT). The communications satellite system has just been added to this area of research and this investigation should give additional information in certain important areas.

The measure of a successful program is crucial in the ERTS System and it is most involved and perplexing. There being no single criterion of success, a multiple-criteria solution must be sought. There are several criteria against which each of the suggested policies of the ERTS System will be tested. These include feasibility, gross cost-benefit analysis, estimates, consistency, clarity, minimum necessary set, justification, and adaptability.

Investigation into these matters is of major importance. The value of this study is directed not only to the ERTS dissemination system, but also to other large information systems which have particular requirements. The largest single fast growing industry or group of industries is that of service organizations. An information system is a service facility with unique structural design characteristics that are not clearly understood. An understanding of what factors are important in a large information system and how the designer should examine the factors is a primary aim of this investigation.

This dissemination system is one of the few which have been designed and developed with a systems view from the outset. Examination will be made of the entire ERTS data dissemination system in order that the effects of suboptimization may be minimized. As far as possible, identification of the components of the system will be developed and their probable interactions studied. One of the most difficult tasks is to determine what the approximate measure of performance of a component of the system should be and if there are multiple criteria, how these are to be evaluated. Next, the identification of the client, including the interim client, will be examined. An analysis of the ERTS data dissemination system should lead to a description of the components of the system and an understanding of how the internal and external environmental factors influence the performance of the components and the system as a whole. While the system is not yet operational, projections will be calculated concerning the relationships between the designers of the system and the operators of the system and how these relationships may influence the performance or control of the organization.

These questions are important because as the ERTS data dissemination System is developed, such questions are sure to arise. It is far better to approach them at this time and to design the dissemination bureau rather than to let it evolve from the system which will be utilized for the experimental satellites and which may not have been properly designed for an operational satellite. The results of this research should lead to a set of guidelines which will in turn govern the design of a large and complex information system applicable to some operational successor of the experimental ERTS-A and B satellites. New organizational structures must be developed for new data systems and this research will improve our understanding of what are the correct questions to ask about a new information system. A further benefit is that this investigation will present a clearer view of the Earth Resources Technological Satellite mission and, perhaps, suggest a set of policies which will lead toward accomplishment of that mission.

This portion of the study is on schedule and the data-gathering phase is now being completed. The first part of the final report is in progress and the remainder of the report has been outlined in detail. Completion is scheduled for the summer of 1972 and there is every indication that it will be completed on time.

There are several areas of research, each of which could be an exciting and interesting follow-up to this project. For the full realization of the ERTS potential, mathematical management models must be developed in many areas. It would be enlightening and experimentally sound to develop a mathematical model utilizing the ERTS data for a sample management system. The design of this model would be a forerunner to further models and it should be as automated as possible. In addition, this model should cover a presently required decision-making area and it should economically and accurately solve an existing management problem. For a clear understanding of the variables, it is important that this model be as simple as possible and subject to wide use. One of the major benefits would be a wide acceptance of the ERTS data; therefore the use of this model should be as noncontroversial as possible.

An additional and related investigation would be a study of how the ERTS data may be used in a particular industry rather than a particular application as in the previously described model. For a sample study, a large industrial concern might be utilized as the experimental basis. For optimal results this firm should have multiple branches and be international in scope. The study would then determine how the ERTS data would be implemented into the management information system of this corporate structure and a study would be conducted as to the value of this new information and the cost of its acquisition and its implementation.

A third area of research, which is not directly related to the first two areas of investigation, is the use of ERTS data in archeology. To date, most of the archeological studies have entailed the identification of single areas of historical habitats and the immediately surrounding area. The availability of uniform and accurate earth resources information over very large areas will allow a study to be conducted of living systems as they existed in the past in order that we may better understand the present and the future. This would not be an examination of individual locations, but an examination of an entire operating system from archeologist's standpoint through the utilization of remote sensing data.

2.4 BEYOND BENEFIT-COST ANALYSIS*

In the preceding section, Benefit-Cost Analysis was listed as a major criterion for measuring the eventual success or usefulness of an ERTS-based operational system.

In this section Benefit-Cost Analysis as a method for evaluating ERTS is critiqued from two points of view. One is within the framework of B-C analysis itself and on the question as to whether all appropriate costs and benefits (including non-benefits) have to be included. The approach challenges the appropriateness of the method for this type of decision even if an attempt is made to estimate all relevant costs and benefits. It is argued that ERTS will change the social conditions of the nation and is, accordingly, a system which potentially goes beyond B-C analysis. Methods to aid us in making judgments on values and whole ways of life therefore become necessary.

In our view the Earth Resource Technological Satellite is destined to be a socio-cultural as well as a technical-economic phenomenon. As with any technology, social and institutional changes must take place before ERTS can be introduced, accepted and become a part of the cultural fabric. As it is assimilated it will begin to weave its own warp and woof of values, expectations and aspirations.

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*The material appearing in this section was prepared by Richard O. Mason, one of our team members from the UCLA campus.

Any notion of benefits and costs must ultimately be based on the social-cultural milieu from which they derive and for which they are intended. Herein lies the major conceptual difficulty that faces Benefit-Cost Analysis. It has no explicit methodology for handling social-cultural change.

To be sure the reflective B-C analyst considers the possibilities as to whether it is societal, regional, special interest group or individual welfare that is to be maximized. However if more than one entity exists in any of the categories a problem of equity immediately presents itself. Whose welfare should be benefited more? The analyst cannot ignore this question in those cases where everyone's "welfare" is improved or in the pareto optimal situation where at least no one's is impaired. For, much of one person's perceived benefit resides in his comparative well-being. If, for example, ERTS technology initially favors water, agricultural, energy and recreation interests more than it favors mining, land, and urban development interests, then a redistribution of wealth occurs and a conflict over values persists. Whether he likes it or not the B-C analyst has to take a position in the distribution-of-wealth debate. He essentially says that "those who are winners are more important than those who are losers." This it would seem is beyond his province and entitlement. Nothing in his method, position or credentials permits him to make such pronouncements.

Recently a method known as the "Delphi technique" has offered some promise in helping the analyst identify values. Members of a "relevant" community are pooled as to their preferences (and perhaps the relative "weight" of their preferences). The logical union of these preferences is then formed, and the members are asked to re-evaluate this expanded list. The process is repeated through several interactions or until some degree of agreement or consensus is found.

But, does this Delphi method eliminate the problems mentioned above? No, because the analyst has selected a subpart of the population to examine. If one resorts to the strategy of random sampling, then one assumes that there is a large, more-or-less homogenous population of human values whose characteristics are being estimated by the sample. But this assumption is a very shaky one. For example, the increase of "recreation benefits (that) will accrue if the levels of streams and reservoirs can be higher and steadier..." may be agreed to and valued highly by some delphi participants. But for some, water recreation means swimming; for others it means fishing; for still others it means motor boating and for others yet it means gazing at and contemplating a placid body of water. The actions necessary for securing the benefit for one conflict with the enjoyment of the benefit for another. Even within the sample of respondents, therefore, a real and practical sense agreement did not exist. Indeed, if the analyst obtains too much agreement he is probably not asking a precise enough question. If there is anything we know about people, it is that they seldom fully share the same values nor do they pursue them in exactly the same or in mutually independent ways.

Of course the thoughtful B-C analyst is aware of these points and has often resorted to the assumption that all humans share in one basic value, namely, the economic. But here the analyst has simply placed himself on one side of a great historical debate: whether basic human values are or are not reducible to social economic values. It is safe to say that any simple version of the pro side of this debate can easily be shattered by the very telling arguments of the con.

So, by beginning with the specification of objectives or goals as the dimensions of benefits, the analyst is seeking to determine something which, in the final analysis, doesn't exist or at least, *qua analyst*, is not within his purview to determine.

This limitation, however, may not be the most severe one the analyst faces. Let us, for the moment, assume that the analyst can uncover a tolerable set of objectives upon which to base his benefit analysis. Are they invariant over time? No, because once the process has begun of realizing that a new technology is coming into being, the realization inevitably influences the human value system. The very act of commencing to secure benefits may change the nature of the benefits themselves. Also, what once took generations to change can potentially, in the 1970's, take place in just a few years. Communication, transportation and the sheer magnitude of most modern enterprises contribute to this rapidity with which value changes take place. ERTS will have this kind of value changing impact.

ERTS is really a social experiment, not just a technological one. It will change personalities, social relations and institutions and create new values and outlooks on life. Not only does this qualitative shift in values being into question the usual methods of measuring values, but, it also poses a more fundamental query: "What is the relevant value system to use?" This is a question that translates into "How should one view the whole system of which ERTS is a part?"

Churchman has suggested four concepts for valuing and hence assigning benefits and costs to social decisions. They are:

1. the extent to which a project suggests new means for achieving given ends;

2. the extent to which a project adds to our understanding of the relationship between means and ends and aids in discovering the most efficient means;

3. the extent to which a project facilitates cooperation between two goal-seeking entities within the same environment so that the act of A achieving his ends does not interfere with, but may, in fact, support B's achieving his and vice-versa;

4. the extent to which a project creates new ends.

Benefit-Cost Analysis stresses efficiency and as such falls primarily into category number 2. It receives only a modest score in category number 1. In most studies the primary focus of B-C analysis is to determine the most efficient alternative from among a set of existing or identifiable alternatives; it does not engage in inventing radically new alternatives, although sometimes its output may be suggestive in that regard.

The greatest shortcomings of B-C analysis lie in categories 3 and 4. The method patently ignores the resolution of conflict between competing end-seeking people, and the creating of new ends which they may seek. ERTS as a social experiment will create both cooperation and conflict. Often B-C analyses make implicit assumptions about categories 3 and 4. These systemic assumptions must be exposed, examined and reviewed. Our group is in the process of so doing. The

13 "internal working papers" listed below, most of which are highly relevant to this problem, provide some measure of our concern and level of effort in this regard.

2.4.1 A Listing of Some of Our Recent and Relevant Internal Working Papers

1. On Comparison and Administration: A Philosophical Discourse, C. West Churchman, May, 1971.

2. Can a Manager Teach an Automated Information System?, C. West Churchman, June, 1971.

3. Systems Analysis and Organization Theory: A Critique, C. West Churchman, June, 1971.

4. Policy for Policy Sciences, C. West Churchman, July, 1971.

5. Operations Research Prospects for Libraries: The Realities and Ideals, or Strategies for Operations Research in Libraries, C. West Churchman, August, 1971. Also appeared in Operations Research: Implications for Libraries, Don R. Swanson, ed.

6. Systems Engineering, Operations Research and Management, C. West Churchman, October, 1971.

7. The Measurement of Mood and the Mood of Measurement, C. West Churchman, October, 1971.

8. Management and Planning Problems, C. West Churchman, October, 1971.

9. On Being Informed by a Computer-based Management Information System: A Study in Involvement and Appreciation, Burton Swanson, November, 1971.

10. Some Comments on Land Use Data and the Role of ERTS in Land Use Classification, H. J. Libow, December, 1971.

11. An Earth Resource Debate, Richard O. Mason, February, 1972.

12. Beyond Benefits and Costs: A Study on Methods for Evaluating the NASA-ERTS Program, Richard O. Mason, February, 1972.

13. Perspectives of the Systems Approach, C. West Churchman, April, 1972.

2.5 COMPUTERS IN RELATION TO MANAGEMENT AND PLANNING PROBLEMS*

The purpose of this section is to discuss the role of computers and information systems in management and planning problems, both in the private and the public sectors. Although the discussion of this topic will be presented here in a rather generalized way, most of the points made will achieve their greatest significance when viewed specifically in the context of using computer technology for the analysis of ERTS-derived data, the better to solve problems of the earth resource manager.

We can be very brief about the past uses of management information systems. The reader interested in a report of the current state of the art and the concomitant confusions can consult any one of a number of articles and books dealing with such matters as listed in Section 2.5.8. Our primary intent, here, is to consider the way in which managers ought to interact with computers and allied information systems.

The word "manager" in the English language is apt to connote managing large corporations in the private sector, whereas our intent here is to use that word in a much broader context. "Management" is a concept which refers to both an intention and an ability. The intention is to serve a certain group of people by changing certain aspects of society and its environment. The ability is that of choosing among a set of alternatives, each of which potentially serves the

*The material appearing in this section was prepared by C. West Churchman, co-investigator of our integrated study.

relevant clients. Thus, "management" refers to a large number of human beings and their behaviors: administrators in government, managers in the private sector, heads of families, and so on. Indeed, one can talk about the way in which an individual "manages" his own life, since each one of us as a living being in various times of his life is committed to serving both himself and others. We all believe that we have the capability of choosing between alternatives of our life patterns. As we shall see, this description of managers and management is a description typically used by one type of individual, whom we will refer to as the systems scientist, for lack of a better word. It may very well be that the systems scientist's concept of management is at serious odds with the concept of management as other people use the word. This is a point to which we will return subsequently.

One way to summarize the problem of the role of computers and information in management is to say that the problem is probably as broad and as deeply complicated as the problem of how one ought to manage. That is to say, no one has a clear concept of how computers ought to be used in the management process. But there are a number of different opinions which we will explore, some of them based on rather simplistic notions of management and management information systems.

2.5.1 Routine Data Systems

At this point we need to clear away one whole area of utilization of computers by managers. This is the area where routine regulations or provisions, either of a legal or bureaucratic nature, must be satisfied by management. For example, in both the public and private sectors, the law requires certain organizations to collect information about expenditures and receipts, as well as to report on their assets. Similarly, there are legal and other requirements concerning personnel: payroll, attendance, etc. This area of management information will be of minor concern here, but some remarks should be made about it since it undoubtedly has been of major concern in the last decade.

As the computer became better known to managers, it looked as though it would be a panacea for the very irritating problem of collecting required data banks on accounts, personnel, and related matters. After all, the recording of payroll, for example, is apparently well laid out along manual lines, so that it appears that there would be no difficulty at all in simply translating the manual instructions into a computer program. Or, consider a radically different case, that of the settlement of interline accounts between railroads. This monthly procedure entails a fairly detailed scrutiny of the route by which the freight was carried and the regulations governing the allocation of the customer's payments to the contributing carriers. Anyone experienced with this clerical operation would become fully convinced that it is completely routine, and that there would be no difficulty in getting a computer to do exactly what a clerk can do.

But the idea that one could put payroll of interline accounts onto a computer without much difficulty turned out to be naive in the extreme. In both cases there are a number of aspects which are peculiar to a given company, or to an industry, which are often not well understood. It is no easy matter to make the computer behave as a clerk would do. Certainly the notion that one could find a universal "payroll package" was a faulty one. An analogy could be made between the use of the computer in routine data collection and the automobile in routine transportation matter. It simply took much longer for the public to learn how to use automobiles effectively than one would have expected; it certainly took a great deal longer for management to use computers in routine data collection matters than had been expected.

It seems safe to predict that over the next decade large companies in the affluent nations will have computerized most of their large-scale, routine data collection. It would not be safe to say that this is the most economical way of their conducting their business at the present time, but there is little question that over the years computer-based routine data collection will be standard policy and therefore "economical" policy.

But it also seems safe to say that small businesses in the affluent countries, and any kind of business in the developing countries, will have to wait some time before the computer becomes a realistic aid in their efforts. The writer knows of only one computer company that has developed an interest in small businesses (SERTI in Paris). It still remains the case that most small businesses, for example, farmers, have a very unrealistic concept of profit and assets, and undoubtedly some kind of integrated computer system might very well help them to understand some of the basics of their business much better. The difficulty does not lie in setting up a computer system that would serve a lot of small farmers simultaneously. Rather, the difficulty is that if the farmer is to utilize this type of system adequately he must go through a certain type of training. But the expense of this training may be of an order of magnitude well beyond the farmer's capability of paying for it. This problem of education for computer usage seems to be quite general. A large-scale, centralized computer might well serve a number of diverse customers, but the main expenditure lies in training the organizational personnel to utilize the computers properly and to have management understand the computer output. Large corporations and government agencies in affluent countries in non-depression periods can usually afford the training expenditure. We may, therefore, be witnessing another instance where a technology essentially belongs to the affluent few.

From the systems point of view, one might raise the question whether the advent of the computer in routine data collection procedures has resulted in the cancellation of a large number of jobs. The writer knows of no study that has specifically addressed itself to this topic, but it is probably safe to conclude that the technological displacements associated with computers are no worse than those associated with other large-scale technical developments. For example, the change in national policy with respect to space exploration is probably much worse than any large-scale displacements resulting from computers.

2.5.2 Management Information Systems

We turn now to the major topic of this section. Our concern will be what are called "management information systems" (MIS). A review of the literature shows that MIS has been used in a number of different senses. These range all the way from the very simplistic notion that a management information system should contain "all the information the manager needs" to fairly sophisticated information systems which are geared to the actual decisions the manager must make.

The distinction between MIS as used in this section and routine data collection is that the MIS is primarily geared to managerial decision making. Hence, in order to set the stage for the discussion, it is necessary to discuss two kinds of systems, the management system and the management information system.

The management system of an organization is a system by which decisions are made to change or not to change various aspects of the system. As already mentioned, a management system can be regarded as an organization which has specified goals that are supposed to serve a specified client. The system, which of course may be a single individual, is a "decision maker" who has the power to change certain aspects of the social system. The management system also has components. That is to say, we can regard the system as composed of divisions, each with its own appropriate "decision maker." The system also has an environment which is outside the control of the manager (decision maker) but whose characteristics play a role in the success or failure of the organization with respect to its objectives.

The management information system, as viewed from the point of view of the management system, is a component of the management system whose purpose is to gather information which will best serve the informational needs of the management system.

2.5.3 How MIS Ought to Develop: First Hypothesis

Let us now turn to a discussion of the future of management information systems, with specific emphasis on the desired social objectives of such systems.

To do this it will be necessary to talk not just about the systems but about the people in the systems and specifically about managers and about the systems scientists who attempt to design the management information systems for the managers.

This means that we must try to do something in this section that may not have been done elsewhere, namely, to try to identify the kinds of people who are working in MIS technology and in particular the way they view the world and the value systems which they have come to regard as the appropriate ones. We must do this as a first step in developing the notion of what ought to be, rather than simply what one might forecast will be.

Now, the systems scientists have one value which is a prominent one in their approach to social systems, namely, that it is possible to be reasonable about society and its problems and that reasonableness can guide us in the selection of the methods by which we attempt to solve societal problems. To be sure, in the last two decades the concept of reasonableness has undergone some considerable changes. For example, in the earlier days of urban planning the reasonable approach of the planner was the attempt to develop ways of manipulating peoples' lives so that the city could "grow" in some "successful" manner. But the urban planner has undergone quite a shift in his conception of his own role and what a reasonable approach to urban planning must be. The systems scientist (planner) has come to see that one cannot treat societal problems in isolation. They are interconnected in very deep and complicated ways.

The systems scientists have also gradually come to realize the value of participation in planning; in a changing society, it is reasonable to say that people have a right to expect that they will have something to say about what society does to them.

Finally, the systems scientist has come to see that he does not have all the information that is required to develop an accurate model of society and its environment. He's therefore at least paying lip service to the concept of social experimentation and adaptation. In some cases, a great deal of sincerity has been expressed about the need for wise social experimentation.

Nevertheless, despite the fact that the concept of reasonableness has undergone some changes in the last two decades, the systems scientist does maintain a fairly consistent outlook with respect to society, its environment, and the client whom the systems scientist hopes to serve. It is reasonable, he says, to assume that a society (a specific organization like a city, or the Department of Defense, or a state, or a nation, or a whole world) is in pursuit of certain values or goals and that it has available to it certain resources which can be used in a variety of ways to attain these goals. One can judge whether or not the particular way a manager chooses to use a resource is appropriate by examining whether or not the utilization leads to a state of affairs that is an improvement for the appropriate client (e.g., the public); hopefully the ultimate state of affairs is as good as can be with respect to the client's interests. The recent emphasis on participation of the client in what happens to him is really no shift in this reasonable approach to society and its affairs, because the systems scientist has come to see that participating is a desirable social objective and that therefore he is obliged to consider this objective in his work.

It probably is safe to say that almost every systems scientist in the west today has arrived at some such attitude with respect to the world and therefore with respect to his job in that world. It's not necessary to demonstrate this point, except by some references to what has been written already in the literature. For example, when McLeod waxes enthusiastic about how systems scientists will have some impact on politicians, he tells us that "ideally our leaders should become futurists or futurists should become our leaders."* This, of course, is reminiscent of Plato's plea that the leaders of society should be "philosopher kings." What is being urged is that our politicians adopt the perspective of society and its world that lies in the very reasonable perspective that the systems scientist brings to bear. Or, in the Daetz and Faulkner essay on population, we are told that Jay Forrester suggests that "man's intellect cannot adequately grasp social systems structures which are <u>by nature</u> a multi-loop nonlinear feedback." It's interesting to note in this regard that the

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*"International Cooperation," to appear in a collection of papers to be published by the American Federation of Information Processing Societies (AFIPS).

phrase, "by nature," is supposed to indicate that the expert on non-linear feedback can see the nature of social systems structures far more clearly than a manager who has never been privileged to study multi-loop, non-linear feedbacks. No wonder, then, that Forrester can go on to conclude that "government legislation is often inadequate, based as it is on inaccurate models."*

From these illustrations which are simply representative of thousands of such statements made by systems scientists, one can conclude that the systems scientist, who is himself a kind of "inquiring system," brings to bear on his study of the world a particular perspective which he truly believes to be the realistic and reasonable perspective. Indeed, it rarely occurs to him that there could be another perspective quite different from the one he holds which is equally reasonable and, in some sense, much more plausible to other segments of society. In a paper on medical systems,** this point is brought out quite strongly; the author claims that the doctor in the medical profession does not think in the same terms as the systems scientist thinks. No wonder the systems scientist is highly puzzled by the doctor's behavior and is apt to label it irrational (i.e., unreasonable).

The first hypothesis, therefore, of where we ought to be going with respect to management information systems says that we ought to be going where the systems scientist perceives to be the reasonable

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*"Population Problems," to appear in a collection of papers to be published by the American Federation of Information Processing Societies (AFIPS).

**"Biomedical Problems," to appear in a collection of papers to be published by the American Federation of Information Processing Societies (AFIPS).

outcome of our efforts.

This hypothesis leads us to what could be called a "working axiom" of the systems scientist, namely, that the successful management information system depends very strongly on how well designed is the management system. In other words, the systems scientist has gradually come to realize that the management systems with which he deals are poorly managed, and that the development of better management information systems by themselves cannot cure the ills of ineffective management that plague today's society. Thus the working axiom comes out as follows: <u>if the management system is relatively ineffective with respect to its real purposes and its real clients, then no management information system by itself can expect significantly to increase the effectiveness of the management system</u>.

It is necessary to call to the reader's attention that this working axiom is not obvious and has essentially risen out of the systems scientist's experience with the management of social systems during the past two decades. The working axiom is frequently alluded to in other papers. For example, in his paper on economics, C. Wolf points out that, although computer technology can help in economic problems, he believes that the major solutions are very different from those opened up by advanced computer technology: a more active antitrust policy and a judicious use of liberalized commercial policy are "likely to be much more important in stimulating competition than are advances in computer technology."*

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*"Economic Problems," in a collection of papers to be published by the American Federation of Information Processing Societies (AFIPS).

The working axiom's statement that, given current managerial performance, information alone cannot greatly improve an ineffective management system, is quite contrary to much of the lore that is published in management journals. Many managers believe that if they could only get more accurate information their own decision making would thereby become far better.

There's no denying that one can easily concoct examples where information is the key factor in the ineffectiveness of managerial decision making. If the sailor on watch doesn't shout down to the captain, "There's an iceberg ahead!" or some similar piece of information, then the captain's management of the ship will be faulty, and if the sailor does so shout, then the captain's management of the ship may turn out to be very effective. But these concocted examples do not represent the realities of the management process. The ineffective management systems are not primarily ineffective because they lack certain kinds of critical information. To the systems scientist, they are far more apt to be ineffective because the way in which the components of the system work together is ineffective, and one does not solve the coordination problem of the components simply by creating items of information. For example, the departments of a university typically work in a very ineffective way with respect to one another. One could not expect to solve this universal problem of universities by creating a central data bank which told any department how another department operates. To the systems scientist, the real reason for the lack of coordination of components of the system seems to lie in complicated political battles and not in informational vacuum.

2.5.4 Data Versus Information

The working axiom needs to be explained in greater detail. To this end suppose we center our comments around one very important application of computers to management decision making, namely, inventory control.

The problem of inventories is pervasive and occurs in both the public and private sectors. The social human being devotes a great deal of his time to collecting resources and storing them in suitable places against future needs. The basic and almost trivial management principle is that one cannot produce as the needs occur. One must produce ahead of time and make the resource available by forecasting what the needs will be.

Essentially, then, inventory control consists of attempting to store resources in such a way that they will be available on need and yet in such a way that one will not tie up a large number of assets in unused storage form.

Perhaps at first it would seem that inventory control is a fairly simple matter from the point of view of information. What one needs to do is to obtain information about future needs for a resource, about the cost of storing the resource, and about the cost of shortage (i.e., the costs that are incurred when the resource is not available). There are certain other types of information, like lead time, that may also get into the picture. It would seem, therefore, that if a manager does not have adequate information about future needs, then he cannot control his inventory very well, and that if he does obtain this information and the other relevant information is at hand, then he can manage well. Therefore, it seems as though the working axiom stated above is false. It seems as though there must be many cases where inadequate forecasting is all that keeps management from successfully controlling its inventory.

The fallacy of this point of view, however, lies in the concepts of "needs" and "forecasting." A need is a stated requirement, but from the point of view of the systems scientist's concept of normative management (and here we are only concerned with the normative aspects of management) a need is either correct or not correct. Proper inventory control consists of trying to satisfy the correct needs and does not consist of satisfying incorrect needs. Therefore, the management system of inventory has to pay attention to those aspects of the total system which are generating the needs. If these needs are not being generated properly, then proper inventory control does not occur, no matter how accurate the data may be concerning incorrect needs. Too often in packaged inventory control models that are available on computers, the package merely contains a statistical forecast of demand on inventory items and pays no attention whatsoever to the very critical problem of whether the demand is a proper one. An inventory package which satisfied incorrect needs is not controlling inventory and is, in fact, solving precisely the wrong problem. The management system of inventory, therefore, requires some analysis of the origin of demand and the design of the demand system.

The same remarks apply, of course, to the so-called costs of storage and of shortage. These costs arise from the way in which the other aspects of the system are designed, e.g., the relationship of the system to its financial subsystems or to its customers. Of course, the systems scientist may conclude that he can do nothing whatsoever about the demand. If he does so conclude, then he himself has made a managerial decision, which in effect says that the total management system is ineffective and that the systems scientist must operate as best he can within the ineffective system. If he makes such a conclusion, he is probably concluding that even if he does the best he can, his contribution to the total system effectiveness must be very small. This, then, is the spirit behind the working axiom, that the management information system by itself cannot improve the quality of the management system. If the management system is very ineffective, then the contribution that the numbers make is not very great, according to the working axiom.

The discussion can be illustrated in terms of economic research. Economists attempt, often via the computer, to collect and store significant data about economic conditions and processes in regions and countries and throughout the world. It is important to notice, for example, that input-output analysis does presuppose that the "inputs" are the proper inputs from the point of view of the total system, just as it presupposes that the outputs are correct, _if_ managerial decisions are to be made from the input-output analysis. Of course, a great deal of economic analysis is not conceived by the economist to be anything more than a description of how the system is actually working, and economists often attempt to avoid the pitfalls of making specific recommendations on economic policy from their own analysis. Since, however, in this section we are primarily concerned with the manner in which computers, and specifically management information systems, ought to be helping management in its decision making, then it is essential to point out that the simple amassing of large data banks, no matter how impressive in terms of size, may be completely irrelevant in terms of trying to use the data banks for the improvement of social conditions.

2.5.5 Improved Types of Management Systems: A Thesis

But it would be incorrect to conclude that MIS from the systems scientist's point of view is only a trivial part of the management system. As the management system becomes more effective, then MIS can play a very central role.

In order to understand this remark and, therefore, to become clear about where the systems scientist hopes that tomorrow's systems will be, it is necessary to talk about how the management system can become more "rational" (i.e., reasonable).

In this section, a number of suggestions have been made as to the manner in which social systems can be better managed. These suggestions include concepts like participation, social experimentation, the extensions of the total system concept to the interrelationship of problems rather than the segmentation of problems, and so on. It will be helpful to recapitulate what many of the authors have had to say in terms of a typology of management styles which is supposed to reflect a normative ranking of the styles. That is to say, one proceeds from the fairly primitive, ineffective management style to the more sophisticated managerial style which the systems scientists advocate.

This typology says that one can describe management systems in terms of three types: the reactive, the planning, and the "learning."

2.5.5.1 In the first, or reactive management information system, there is a very strong agreement on the part of the managers as to the nature of the business that they are in and as to the system boundaries, as well as the role and organization of the components of the system. When we say that there is a strong agreement among the managers, we mean that management is not interested in raising the question of the nature of their business, or the components, or the system boundaries. Consequently, the manager of the management information system has no opportunity within this context of raising such questions.

In the reactive management information system, furthermore, there is a minimum of interest in long-range planning. The management information system is regarded to be one that will enable the managers to react effectively to what goes on in what they perceive to be their environment. This does not mean that the reactive manager is indifferent to the future, but it does mean that he sees no great point in pouring a lot of money into long-range planning and forecasting, given the uncertainties of his environment and his urgent needs to be able to react to the crises as they occur day by day. Consequently, the charge of the reactive management system to computerized MIS is that the MIS collect those kinds of information which will enable the manager at least to appear effective in meeting the challenge of the day-to-day crises and problems. The main point about the reactive

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management system is that it takes each problem within its own context and is not interested in seeing how different problems are related, one to the other, or the general framework in which problems arise.

In experience, reactive management systems appear to require rather large data bases which are closely related to the routine data bases. In many cases the chief concern of the reactive management system is to be able to respond to queries that are posed to it by its clientele or by financial companies, government agencies, etc. For example, in a research and development organization, the manager of the project in a highly reactive management system may have to respond to queries from top management about manpower on the project, about the present state of the project with respect to its explicit goals, and so on. An MIS system, in such a reactive management system, would therefore be one in which the project manager can turn to the computer and query it concerning manpower requirements or project status requirements. It is important to note that in reactive management systems, the environment is taken as a "given" and a given that cannot be well predicted. The system boundaries are well laid out and the manager is not responsible for trying to change what goes on outside the system. The key word is "input."

We can find many cases where authors have reacted negatively to reactive management systems. Daetz and Faulkner, for example, point out the extreme danger of letting the population question lie in the hands of a reactive management system which waits to see what happens to the population explosion. To the reactive manager, if there comes the point where millions of people die of starvation or of mass crowding, then at that stage in the game it will be necessary to intervene. He believes that famine, wars, or just a change of values with respect to procreation may make the population problem go away, as so many social problems have in the past. To the systems scientist, this way of regarding the population problem displays a very ineffective management system.

Of course, the systems scientist does not believe that reactive management systems are universally bad. In times of crises where changes are occurring so rapidly, a reactive management system may very well turn out to be the best one, as, for example, in the case of earthquakes or large fires or plagues. But, in general, the systems scientist tends to regard reactive management systems, even when they are best, as a result of poor managerial planning in the past. Thus, according to the working axiom for the systems scientist, the MIS of a reactive management system will contribute very little to the real system performance, even though it often may appear to be highly effective.

2.5.5.2 The second type of management can be called "planning." Here again the management is largely agreed on the business that they're in, as well as on the system boundaries. Their chief concern is to try to predict how the environment will change and to decide ahead of time what kinds of reactions they should prepare for these changes.

Planning management systems have been discussed in a number of places throughout this section, wherever, for example, it has been suggested that one can extend man's capability of forecasting by means of computer technology. The implication has been that these extensions will be especially useful in strengthening man's ability to plan. Again, in discussion of gaming and simulation, it is argued that one can capture the real nature of certain aspects of the social system and understand, say, the competitive environment, either in the private sector or in the international scene. As a result, we should be far better able to understand what the future will look like and therefore plan in a rational ("reasonable") fashion.

In the past, there has been considerable activity in trying to develop computer bases for planning management systems. In the private sector, these generally consist of forecasts of changes in consumer behavior, of economic trends, and the like. In the public sector, for example, in comprehensive health planning, the emphasis has been on trying to forecast what health needs will be and the kinds of services that will be required in order to meet them. The real emphasis, therefore, in planning management systems is on the ability to forecast, and various kinds of forecasting techniques have been generated. Among these are the Delphi technique (Helmer, 1966) and various kinds of statistical methods.

One area where the systems scientists are not in agreement with respect to planning management is with reference to the value of simulation. Some scientists seem to be quite sold on its usefulness. The attractiveness of simulation technology, which apparently provides the scientist with the capability of representing fairly complicated systems, has lured many a systems scientist into trying to sell management on fairly large-scale computer simulations. On the other hand, many argue that it will be some time, if ever, before simulation really plays a significant role, partly because it is so difficult to know which aspects of the real life situation should be included, but also because the whole basic mathematical technology of simulation has not been well explored. There is a further difficulty, which appears to be basic in all systems science work, namely, the difficulty of really making it clear what we mean by the concept of "X simulates Y." The great need that we find in both modeling and simulation is for some clearer explanation of what it is that the scientist thinks he is modeling or simulating. This difficulty, of course, goes back to the very foundations of systems science. As was illustrated earlier, the systems scientist is apt to say that reality is "by its very nature" so and so, without realizing that his description of what reality is comes out of his own approach to reality and can scarcely be said to be shared by all individuals who live in the social system.

2.5.5.3 The <u>third</u> type of management system is one in which agreement about the real purposes of the system and also about the needs of the client does not exist, and the management system is regarded to be one which is trying to understand more deeply its real purposes and its real clientele.

This type of management system might be called "learning management." MIS systems for learning management will have to be radically different from both the planning and reactive management systems. In particular the emphasis will not be on large stored masses of data, but rather on a kind of experimentation. The basic meaning of experiment is a "systematic method of learning." Experiment is not restricted to the method of simply changing a variable and looking at the results, since this method is highly restrictive and probably not applicable to social organizations.

The writer knows of only one example at the present time of a real learning MIS associated with learning management. This is a corporation which has a fairly sizable operations research group. Here the operations research group is not regarded as a staff which "solves" crisis problems, but rather as an integrated aspect of the total learning process of management. As a consequence, a very important part of the OR study is to relate the study results to other problems so that the results are a much more integrated model of the total system. There is a continuing question of where the system is going and what type of clientele the system should be serving. In the learning type of management, the manager regards himself to be an "historical man" trying to learn from what has occurred before in order to pass this learning on through his own decision making in an enriched fashion to his successors.

As has been mentioned in other places, the concept of learning management also includes the concept of participation, since the systems scientist has come to conclude that participation is a very essential social value. The experimenters, therefore, are not to be viewed in the typical way in which experimenters work at a laboratory table. At the laboratory table, the experimenter is, in some sense, independent of that which he is observing. The notion of objectivity in classical science arose from this independence of the observer from that which he is observing. However, in learning management, neither the managers nor the systems scientists should regard themselves as independent of the social systems within which they live. The idea is that everyone is, in some sense, an experimenter, and that the scientist only plays one role in the total system of experimentation.

2.5.6 Management by Everyman: The Antithesis

In his Phenomenology of Mind, Hegel develops a process of philosophy in which he presents a very plausible view of the world (which we can call here the "thesis" in the light of Hegel's later work). Hegel then argues for the thesis and, in a very subtle and ingenious fashion, one finds that the strong argument in its support leads one to quite an opposite viewpoint of the world which we can call the antithesis. The whole point of the Hegelian methodology is not simply the contrasting of different points of view, as happens, let's say, in advocacy planning, but rather the total process of showing how, within one view of the world, there are the ingredients of its opposite.

What all this bit of philosophizing means with respect to our discussion is that, if we look at the world view of the systems scientist and try to develop what it really means, we being to see that there is indeed an opposite and antithetical world view which contradicts in some significant sense what the systems scientist believes.

Systems science would have been in a very comfortable position could it have defended planning management as a successful method of managing. In planning management, all of the pieces seem to fit together remarkably well. One tries, as a planner, to understand the real clients of the system and then to understand how the system, which is controlled by the decision makers (managers), can be used to serve the client by means of making forecasts of how the environment will change. The role of the MIS in such a system seems clear enough. One tries to develop a model which will display alternative decisions of the managers, will predict how each decision will come out, and, by evaluation techniques, will tell how well or ill the client was served by the specific potential managerial decision.

But since, in some important sense, planning management is not effective, in that attempts to make even moderately good forecasts seem doomed to failure, and since the choice of the set of values to be maximized is so uncertain that the planning management style is bound to run into the difficulties of serving the wrong client, then the systems scientist has to turn to what he thinks is an expanded version of his own philosophy, namely, learning management. But here he has laid the groundwork for his own downfall. Learning management argues that social experimentation is essential and that one must, in the process of experimenting, regard everyone as both experimenter and as subject.

But if this point of view is taken seriously, then what has become of the systems scientist and his capability of understanding the system? Apparently, this antithetical viewpoint says that everyone in society has a viewpoint of how society works. The systems scientist has his viewpoint, which may be Forrester's non-linear, negative feedback system, but the particular academic capability of a systems scientist to view the world does not put him in any privileged position with respect to how the system "really" works.

So we seem to arrive at a position which is antithetical to that of the systems scientist. No longer can we say that, "Social systems structures are 'by nature' multi-loop non-linear feedback systems." We can say that they are so "by Forrester's nature." On the other hand, someone who has lived his life in the ghetto and has seen poverty in the form of direct experience also sees what the social system is "by nature," i.e., by his nature.

Furthermore, the problem of different perspectives is not necessarily solved by social experimentation. For the pragmatists, one poses a hypothesis and then sets about trying to test it by seeing whether a particular policy "works out." But if there are different perspectives of what the social structure is "by its very nature," then surely there must be different perspectives as to whether an experiment has, indeed, "worked out" successfully or has "utterly failed."

2.5.7 Summary and Conclusions

For the author of this section to be asked to recommend social management planning and research as well as cost effectiveness would be to ask him to play the role of the systems scientist, since systems scientists see the world of society in terms of problems, pitfalls, and expected cost effectiveness. This is how their inquiring system works. There would be no great difficulty, and indeed the literature is replete with examples, in trying to show how a cost effectiveness study should be made for an organization that is planning to develop an MIS. One tries to design an MIS to so improve management effectiveness from the systems scientist's point of view that it's far more beneficial than the cost of installing the system.

If one goes on to discuss recommended standards for scientific study of the human use of computers in the social problem area, one would then try using the classical methods of science to urge that the systems scientist maintain as objective a position as possible: that he try as best he can to keep his own preconceptions and value system out of the picture, that he try his very best to see what "actually" happened, and that whatever he wanted to happen does not influence what he sees to happen.

However, if we take the antithesis that has just been developed, we can see that the systems scientist cannot conceivably keep his own preconceptions out of the picture, because he views the world in a certain way, and he takes his view of the world to "represent reality." But his view of the world is no more or no less valuable than the view that someone else may hold who is not a systems scientist. It is apparently not correct to say that management consists of maximizing cost effectiveness. This is how the systems scientist sees management, but it certainly is not the way in which most managers perceive their role, as anyone knows who has conversed at length with managers.

Can one draw any conclusions, then in the light of such a devastating antithesis?

The spirit of dialectical reasoning argues that all approaches to the betterment of society demand different perspectives. One can become quite negative about the role of computer and computer-based management in today's society, just as one can become very enthusiastic about it. The philosophical point to be made is that man matures to the extent that he can begin to appreciate a perspective of society which is different from his own. "Appreciate" is a term which tends to be rather watered down in its meaning. In its richest and most powerful sense, it means the capability of putting yourself into some other person's perspective and living the belief in this perspective. To the systems scientist, this would imply quite a revolution. It implies that he should have the capability of truly perceiving what it means to be a manager who does not believe in maximizing cost effectiveness, in modeling the system according to feedback principles, cybernetics and the like, who does <u>not</u> believe in social experimentation, whether it is participatory or not. It means being able to see that "participation," for example, is simply a gimmick by which one group of people tries to put over some of their ideas on another group of people. If I want you to do what I believe to be the correct thing for you to do, what I'll try to do is get you to participate in the decision that I've already made. Of course, the outraged systems scientist may point out that he does not mean by "participation" a deceptive scheme for fooling the public. But the wise manager who knows about managing through direct experience knows very well that this is exactly what happens to so-called participatory schemes. They are used as a device by which one group of people tries to put over something on another group of people.

The dialectical process is an optimistic rather than a pessimistic one, at least in the context of this section of our progress report. The dialectical process, it should be pointed out, is not an attempt to destroy knowledge or even a sense of deeper understanding. All dialectical processes presuppose certain features of the world, which presuppositions, of course, may be wrong, but the process exists from the expectation that they are correct. In this case, the dialectical process is based on the notion that deeper appreciation of other perspectives is one of the most important requirements for management information systems of the future.

Thus, though the writer cannot make a forecast about where management information systems will be, he can say that he has the faith and hope that management information systems of the future will greatly enhance man's capability of appreciating his fellow man's perspective of what the social being is "by its very nature."

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2.6 ERTS TECHNOLOGY IN THE MANAGERIAL AND SOCIAL WORLD: A FIRST LOOK*

2.6.1 Concepts

There is adequate literature to support the assumption that individuals' cognitive organization or perceptual sets differ and are dynamically linked to organizational and behavioral variables. Additionally, organizational and structural variables define environments which support differing organizational and perceptual sets. The validity of these assertions has been well documented in the writings of Rokeach, Menzieo, Trist, Marcuse, McWhinney and others as indicated in the bibliography at the end of this section.

The way that man thinks about earth resources is of particular importance in determining the use to which ERTS data will be put in the management of earth resources. This means that we must look at the psychology of resources as well as their physical characteristics. Of particular importance is ego functioning which is the intervening organization between organismic (id or pleasure systems) and environmental processes. Within an open system context, the ego regulates conflicting preferences; its growth regulates man's ability to deal with his environment and provides the increasing degree of flexibility that is required to live with the turbulent environmental events of our time. Moreover, the ego defines our identities. Bion has applied the Freudian concept to the group. We would like it to be applied to the wider social field--that of social networks for resource management.

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*This section was contributed by Ralph Lewis.

Moreover, it is natural to address these issues at the present time because ERTS itself is partly a process of technological change. ERTS will induce structural, personal and task changes within the fragmented resource system, as indicated by the writings of Taylor and Leavitt. In a previous paper (Lewis, 1971) the present writer has discussed several organizational and structural management modes for the integration of ERTS into resource management. This paper also discussed the role of perceptual sets and cognitive organization as they relate to organizational structure and practices. The proposed action research (or more commonly called applied research) phase of our ERTS effort will begin by looking at the structure of our perceptual sets or cognitive organization vis-a-vis our beliefs about resource management. This will be accomplished by administering relevant psychological and attitudinal measures and then developing a taxonomic structure of cognitive organization. The methodology which we plan to use is as described in the writer's paper entitled "On the Structure of Student Identity, Progress Toward a Reflexive Social Environment."

Our research hypothesis is that attitudes towards resource issues are less based in reality than they are in the core or central belief structures or world views that an individual holds. This is partly indicated in McWhinney's study of professional foresters. If this hypothesis is true, a taxonomic cluster analysis should reveal a structure in the attitudinal and psychological space.

After refinement of this technique it should be possible to reduce our instrumentation to a more refined set and develop an applied instrument. This instrument could be published as part of our text for resource managers. At this stage our previously collected pool of data would be again useful.

An action research chapter in the text could aid the manager in understanding the importance of values in general and as they pertain to the making of earth resource decisions. Mosreover if the results of the applied research instrument could be fed back to the UC/NASA project we could supplement such data with behavioral and structural variables (see James Taylor's work). Then we could develop an introspective shadow system to evaluate the impact of ERTS and ERTS type programs in a new way. This later proposal is currently in the speculative stages. Our current concern is to get the initial psychometric and attitudinal survey under control.

2.6.2 Activities and Progress

The major theoretical view has been completed and is in draft form. This draft looks at the role of ERTS and ERTS-class technologies in the managerial and social world. The proposed action or applied research effort will build from this and the other papers our group develops.

The next step is to develop attitudinal measures from these papers and to construct an appropriate psychometric instrument. The development of attitudinal measures is relatively direct. Currently we are reviewing the existing instruments.*

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*The COMREY scales, the POI and OPI as well as several other sets of scales.

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2.7 AN EARTH RESOURCE DEBATE*

2.7.1 Prologue

What is the true value of ERTS? There is no ultimate answer to this question but it is important to consider how one might go about answering it. Some would say that the answer is essentially simple but computationally insuperable. That is, in principle all one need do is calculate the benefits or savings accruing from snow pack estimation, more efficient water management, blight detection, forest fire detection, new mineral discovery, improved cartography and land use mapping, and so on for each application. Then, merely sum up the benefits over all applications and by subtracting the actual and opportunity costs obtain a figure representing ERTS' value.

But others, on second reflection, find that the answer is more elusive and complex than that. Such a simple method raises serious doubts. When, as in Section 2.4 of this report, one takes a broad view of resource and environmental problems (the problems which in the long run ERTS is to help us to solve) one sees how finely these problems are interwoven with our governmental, industrial, and cultural institutions. The very way that we think and live and view the world is an integral part of the resource problem. If we can only find the right perspectives and institutions for nourishing the earth and insuring its survival, then in a most essential way the resource problem will have been solved. A "solution" of this type is not measurable in Benefit-Cost terms, since

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*This section was contributed by Richard O. Mason.

Benefit-Cost analysis must assume certain institutional frameworks to make its procedures work.

However, there is immense value to be gained if we can find the right perspectives and institutions to aid man in solving the earth resource management problem.

There are three fundamental components to the earth resource management problem. First, there is the physical nature of the earth itself. Second, are the institutions, that is the laws, customs, practices and organizations, that man has devised for dealing with the earth. And, finally, there is the psychological outlook or perspective on the earth that each person, especially those in decision-making capacities, possesses. All of these work together to determine the final dispensation and utilization of earth resources. Dysfunctional uses, such as pollution, result from breakdowns or misunderstandings in all three dimensions.

If the ERTS program is to achieve its ultimate goal of solving mankind's food, water and mineral resource problems, it must deal with all three components of the earth resource management problem. The University of California Integrated Study takes this perspective. While the bulk of the effort is directed toward determining how ERTS can provide better information about the physical nature of the earth, the social science group is addressing the other two dimensions of the problem. Studies are currently under way which look at the questions of what kinds of organizations and institutions will be needed to deal with ERTS data and as to who should be involved in making earth resource decisions. This study is concerned with the psychological perspective man uses to guide him in organizing ERTS data, developing institutions and carrying out decisions.

Perhaps the most intriguing thing about the ERTS program is that it shows great potentiality for producing value in the sense of developing new perspectives on the earth. To be sure, there will be cost effective "applications," but these will flow naturally from the creation of a more lasting impact--a sobering realization of man's place in this "fathomless universe." (Whitman, "O Captain! My Captain!") The astronaut's descriptions and the awe-inspiring space photographs perhaps only herald a new world view to come. At least, there is some evidence in this regard. Take, for example, John Caffrey's letter to the editor in Science (March 20, 1970) in which he related the profound effect that the space photographs had had on him and then went on to say:

> "Looking at the blackness beyond the sharp blue-green curve, trying to see even the place where the thin envelope of atmosphere and the solid earth meet, the curious word 'fragile' comes to mind. To be on Earth and think of it as fragile is ridiculous. But to see it from out there and to compare it with the dreadness of the Moon! I suspect that the greatest lasting benefit of the Apollo missions may be, if my hunch is correct, this sudden rush of inspiration to try to save this fragile environment--the whole one--if we still can."

Such are the potential benefits of ERTS; but, more importantly, this new perspective shed new light on our opening question. The 'true value' of ERTS is not now of primary concern, rather, the question becomes "How can ERTS best be used to secure the value inherent in a more appropriate perspective on the earth?" What follows is an initial response to this question.

2.7.2 Method

ERTS imagery is only data--a set of basic observations of the world. Information is the "meaning" one derives from data. In order to produce information the data must be interpreted from some perspective or point-of-view. Data itself is inert; but, information becomes the basis for action. It is information that determines what decisions will be made and what actions will be taken. Any notion of value must be based upon total short and long range effects of these actions. Consequently, it is vital that we always consider whether the proper point-of-view was used to interpret the data as well as the adequacy and completeness of the databank itself. This is the only way to evaluate the ERTS program in any ultimate sense. This kind of evaluation will require an approach which is different from that employed to review data capturing and processing systems, because perspective or points-of-view are psychologically based.

NASA-sponsored research has led to the development of a new approach for exposing and examining points-of-view or "Weltanschauungen." In this approach, which is dialectical in nature, the data is systematically and logically interpreted from two opposing points-of-view which are in turn debated for the manager. The manager, then, must reflect both on the data and the point-of-view. The assumption is that upon witnessing the thesis-antithesis debate the manager forms a new, broader, more encompassing perspective from which to view the data and the situation--the synthesis. In the context of the ERTS program this synthesis may result in a "better" way of viewing earth, one that pressing contemporary environmental, resource and population problems seem so desperately to call for.

The dialectical method requires the determining of opposing positions, the writing of empathic scenarios for each, and the placing of these positions into conflict over the data and issues via debate. The next section represents the beginnings of such an Earth Resource Debate.

2.7.3 The Debate--An Illustration

2.7.3.1 Background

Our studies have shown that one of the early and perhaps most productive uses of ERTS will be to prepare comprehensive and comparable land use data. Such data will then be interpreted by policy-makers to evaluate past usage and to make decisions about future usage. These evaluations and decisions will depend principally on the perspective such people take in interpreting the land use data.

In order to expose these perspectives for conscious consideration a debate has been prepared between policy-makers possessing two different points-of-view. The sample data for this debate shows land use trends in Los Angeles County from 1940 to Present and as projected through 1990.* In the future one might assume that such data would be produced from an analysis of ERTS imagery. Overlaying the photographic

*The source of this data is a short study prepared by Herbert Libow. The study revealed a definite lack of consistent, coherent and comparable land use data for L.A. County over the last 30 years. Our other research suggests a similar lack of data for such important areas as the coastline. This is a problem that ERTS will help to correct.

image would be a land use map prepared by computer analysis of digitized information from various sensors and augmented by inputs from trained human observers. However for the present we will use the available data as the basis for the debate. A display of the data appears in Table 2.5.

2.7.3.2 The Debate

Two policy-makers--Adam and Bud--debate the "correctness" of this land use policy by interpreting the data from their respective points-of-view. Adam begins.

Adam: Well, our land use policy as reflected by this land use data looks pretty good to me. From the standpoint of regional and national goals it demonstrates much of the great accomplishment of man. We have identified great new resources and have been able to employ them for the betterment of our ever growing population. Just look at the extent to which we have been able to expand our cities as reflected in the increased urban usage data. This means that more people may have their own private home and their own place to work. There is smog, crime and some congestion to be sure but we are making progress and our agriculture land is still adequate to satisfy food needs for some time to come.

Contained here in this single table is a message of great inspiration. We have discovered our earth, subdued it and put it to work for us. Truly earth is now resting comfortably within the dominion of man.

Bud: Oh, the treachery of it all, Adam. The data shows that our obvious policy has been to continue to consume and destroy our land and its resources through too much urbanization. Man can never really be

TABLE 2.5: LAND USE TRENDS IN LOS ANGELES COUNTY, 1940-1970

TABLE 2.5a

LAND USE (1,5,6)		1940	1970	1985-90
Urban used (4, 16)	southern county	25.1%	73.6%	82.0%
Urban vacant (3)	" "	10.1%	5.3%	
Non-urban used (4)	" "	45.3%	7.3%	
Non-urban vacant (3)	" "	19.5%	13.8%	
		100.0%	100.0%	
Urban	southern county	35.2%	78.9%	
Non-urban	" "	64.8%	21.1%	
		100.0%	100.0%	
Used (4)	southern county	70.4%	80.9%	
Vacant (3)	" "	29.6%	19.1%	
		100.0%	100.0%	

TABLE 2.5b

LAND USE (2)	1940	1960	1970	1985-90
Recreation & parks (5,7,8)		**0.83%	1.6%	2.3%
Agriculture (5,9)		9.2%	3.6%	
Crop acreage (5,10,11)	12.7%	5.8%	3.1%	2.3%
Range land (5,12)		7.9%	8.0%	
Freeway mileage (13): in miles	6		405	1,045
Sand, gravel production (14,15): in millions of tons	*11.1		23.2	
Gold production (14,15): in $	258,000	**7,200	**3,200	

*earliest available information is dated 1947, however trend line indicates that 1940 production is about 7 million tons.
**estimated from available data

FOOTNOTES FOR TABLE 2.5

1. The figures represent the percentage of southern Los Angeles County acreage devoted to the particular land use.

2. The figures represent the percentage of Los Angeles County acreage devoted to the particular land use unless otherwise indicated.

3. "Vacant Land" has the possibilities of future development.

4. "Used Land" has minimal possibilities for future land development and may or may not have a current land use. Most land in this category is in use. Vacant land and used land are mutually exclusive categories.

5. Revised Land Use Acreages by Statistical Area, Los Angeles County Regional Planning Commission, April, 1971.

6. Land Use Survey, Los Angeles County Regional Planning Commission, July, 1940.

7. Building for Tomorrow: The Community Improvement Program for Los Angeles County, Los Angeles County Department of Parks & Recreation, 1957.

8. Los Angeles County Regional Recreation Areas Plan, County of Los Angeles, 1965.

9. Land Uses, Los Angeles County Regional Planning Commission, 1960 (based upon Los Angeles Regional Transportation Study and U.S. Bureau of Census).

10. Southern California Agriculture: 1969 in Review, Los Angeles Regional Chamber of Commerce.

11. Southern California Agriculture: A Look Ahead to 1970 and 1980, Los Angeles Chamber of Commerce, 1961.

12. 1970 Crop & Livestock Report, Los Angeles County Agricultural Commissioner and County Veterinarian.

13. Verbal information obtained from Los Angeles Regional Planning Commission, Mr. Ron Mayhew, September, 1971.

14. Mineral Information Service, V.21, 1968 and V.6, 1953.

15. California Journal of Mines, V.50, nos. 3 & 4, 1954.

16. 1990 Land Use, Los Angeles County Regional Planning Commission, September, 1971.

superior to his environment, he's a _part_ of it. What the data shows is that we are in the process of breaking the basic harmony which man must have with his world. Man is such a recent arrival here on earth, a few thousand years is nothing considering the billions that the earth has been around. Don't our predecessors, successors and partners have rights? Flora, fauna and minerals have a rightful place in a harmonious world, too. We are offending these rights and may _not_ live to regret it.

Sure, we derive a lot of pleasure and comfort today from our expansive sprawling urban areas, the products of our mines, our transportation system, and so forth; but the cost of depleting our environment is so high. We must learn to "give and take" with nature, take a little "bitter with the sweet," if Man and this earth are to survive.

Maybe now is the time for man to start looking inward a little more to find himself and his place in the universe. Earth is not an object to be conquered, but a _partner_ with whom to live. If Man could only understand this he would learn to understand himself. And, after all that's the real purpose in life.

I believe that 73.6% of our land in urban usage is far too much. The projections are for it to get worse. Let's cut it down to 20% and let's cut down on the transportation usage as well. Return it all to wilderness where it belongs.

Adam: Come on now, Bud. We have got to _use_ our environment to our own advantage. Nature changes the environment every day of our lives, doesn't she? Why shouldn't we change it? Make it work for us? Besides

I'll never understand your concept of returning to wilderness. Do you mean that you want us to take large sections of land and just set them aside, never to be touched evermore?

Bud: Certainly.

Adam: How ludicrous. I agree with you that we must plan the ways by which we use our land very carefully. We have made mistakes in the past and chopped up wilderness areas much too fast and too rambunctiously. Certainly we aren't making the most efficient use of what we have. Some re-alignments and forethought are most assuredly needed. But to return to primitive times? Ridiculous!

In my view, the best land use principle is quite simple. Take a region of land. Survey it well and make a comprehensive plan for its use. Then make part of it accessible for Man's use and part of it inaccessible. Don't touch the restricted portion until it is absolutely necessary. The 1990 projection seems consistent with this kind of planned land use policy.

Bud: Would you preserve those restricted portions forever?

Adam: No, not forever. You can't take a large area of this country and keep it the way it was a thousand years ago. Nor can man afford to retreat from the most productive lands. We cannot continue to deny man's urgent needs by trying tc create useless wildernesses.

Bud: Wilderness is not useless. A wilderness areas is worth saving or creating in its own right. Man has no business disturbing what lives and resides there naturally. The pollution problem has shown that it doesn't take much to destroy ecological balance. In other areas our land use policy is literally driving some species prematurely into extinction. That's just not morally correct. They are partners in the universe. They have their rights, too. Only the forces of nature can sentence a species to extinction. It is not within man's moral purview to do so.

--In the complete draft, the debate on "whose values?" then goes into the details of the policies worked out by each side in terms of its worldview and the data bank.--

Our research team has devoted a good deal of time during the period covered by this report in trying to determine land use data as a basis of this section. A separate paper has been prepared entitled "Some Comments on Land Use Data and the Role of ERTS in Land Use Classification." This paper which compares different land use classifications will also be avilable in the working paper series. The paper argues for the non-existence in practical terms of comparable and comprehensible land use data, and attempts to develop a methodology of land use computations.

2.8 AN INTERDISCIPLINARY APPROACH TO SCIENCE AND SOCIETY: THE EXPERIENCE OF A DECADE REVIEWED*

An in depth study of the establishment, development, and contributions of the Social Sciences Group and its out-reaching, wide-ranging Seminar is not simply to rehearse and rehash the past. Their history, which reflects an interesting chapter in NASA's university relations, provides fascinating insights into little known dimensions of the national space program, for, contrary to popular misconception, this does not consist solely of a series of glamorized, spectacular events. Much hard work in the laboratories and at the benches of scientists and technicians and a multiplicity of research projects in related social fields have both provided the foundation for and been derived from space exploration. The University of California's Space Sciences Laboratory has been the location for a good deal of this kind of activity, and its social sciences section, although relatively small, has played a significant role. The experience derived from eight years' functioning of the Social Sciences Group is especially relevant as the Space Sciences Laboratory engages the phase of its activities concerned with satellites and remote sensing technology.

Early in the space program, Mr. James E. Webb, then Administrator of NASA, proposed that a likely and valuable by-product of the massive nationwide endeavor that was to carry men to the moon and vehicles to distant planets might be the sophisticated techniques that had been

*The material appearing in this section was prepared by Ida R. Hoos.

utilized in the organization and management of this vast and complex enterprise. His intent, embodied in the 1962 Memorandum of Understanding between NASA and the University of California, was for the university-based program to seek ways in which the benefits of space-derived and related research could be applied to the social, business, and economic structure of the United States. Explicit in this document was the mandate that the environment in which space research was to be conducted would be "characterized by a multi-disciplinary effort drawing upon creative minds from various branches of the sciences, technology, commerce, and the arts." Unlike the product-delivering contracts generally allocated by NASA, this agreement encouraged research and inquiry, placed a premium on a coordination of disciplines, and sought ways in which the talents and technology that had developed for space exploration could be put to socially meaningful use.

The intellectual architects of the Space Sciences Laboratory at Berkeley recognized here a unique opportunity. A program of research with an integrative rather than fragmented thrust seemed all the more desirable because the pursuit of knowledge was taking scholars more deeply into specialized channels; barriers to communcation even within disciplines were becoming so marked as to suggest a revival of the allegorical elephant. And this "gulf of incomprehension"* was widening at the very time when the problems of a technological society

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*C. P. Snow, The Two Cultures and the Scientific Revolution, New York, Cambridge University Press, 1963, p. 2.

were increasingly more inter-related and interwoven. In seeking a way to maximize the social benefits of technological advance and minimize the social costs, NASA was moving in the direction of the kind of technology assessment about which other government agencies had made much but done little.

While not a perfect antithesis nor even a potent force in counteracting the strong and long term trend toward specialization, establishment of the Space Sciences Laboratory with social science research as an intrinsic function represented a significant effort, worthwhile in its outcome. Especially noteworthy is the fact that the U.S. space endeavor, generally conceived as far out and far removed from human concerns, should have been the vehicle for such down-to-earth preoccupation as exploration of the interface between science and society. The Space Sciences Laboratory provided an environment hospitable to this kind of research orientation because of the concern of its first director, Professor Samuel Silver, for the social implications of technological advance in general and the space program in particular. His sustained interest in the Social Sciences Group supplied a valued linkage where there might otherwise have been only physical contiguity. While no on-location interdisciplinary research emerged from the association, for reasons which will become evident later in this section, members of the Group found the relationship beneficial when they sought access for the conduct of their studies to such places as the Radiation Laboratory on the Berkeley campus and Jet Propulsion Laboratory at Pasadena.

The Group and Seminar functioned under the continued direction and guidance of Professor C. West Churchman, Associate Director of the Space Sciences Laboratory at its founding. Professor Churchman, a management scientist and philosopher, conceived of the Group as a kind of inquiring system and, consistent with Immanuel Kant's view of inquiring systems that they approach the world through a broad mode of representing reality, attracted and encouraged the participation of a spectrum of academic disciplines. At various times, there were graduate students, professional research staff, and professors on this and other campuses in the United States and abroad from a diversity of fields that included economics, management sciences, law, philosophy, sociology, psychology, urban planning, and public administration. The research projects were disparate, that is, not conducted as "team" efforts or centrally coordinated. They were, with a few exceptions in which several members worked jointly, designed and carried out by individual investigators sometimes assisted by a graduate student. There was, however, a cohesiveness of purpose, more evident, perhaps, in retrospective review than during the active years. The total experience as now seen transcends personalities and personal achievements, however significant, and provides interesting perspectives on the pursuit of interdisciplinary research.

The weekly seminar played an important part in the history of the Social Sciences Group. Primarily a forum for the presentation and discussion by members of their research hypotheses, designs, methods, and findings, the meetings attracted considerable participation from visiting scholars and specialists with related interests from government and business. Their range of topics was extensive and the seminars reflected the multiplicity of the members.

Ideally, perhaps, there should have emerged from the interaction a kind of synergism, the phenomenon that is supposed to occur when differences, confronted and reconciled, give way to new approaches. The fact that nothing of the sort took place is a matter which will be scrutinized in the context of the Group's experience, for it is here that some of the basic problems become evident. It might be noted at this point that the lack of a fairy tale ending, in which they all lived together happily forever after, does not imply that this particular interdisciplinary effort failed nor that others are doomed to failure. Quite the contrary. This was a beginning and a useful one. Despite the Group's changing composition and focus, the association of its members having been more or less transient, the Social Sciences Group gradually developed an orientation that, while not characteristic of all of the participants all of the time, nonetheless could be considered its own Weltanschauung, the lasting influence of which can be discerned in many of the subsequent research pursuits and writings.

2.8.1 Outline of Interdisciplinary Topics

The purpose of this account is not to describe in detail the projects nor to attempt to summarize the findings. Such capsule views as would be possible could not do justice to the work of many persons over a considerable period of time. Our intent is to distill the total experience into a mere outline of the lessons and insights which, although unique at the time, may have bearing on forthcoming development. To achieve this objective, we have grouped the projects into the natural families to which, sometimes, unanticipatedly, they reveal themselves to belong.

I. Science Policy Decision Making in a Democracy.

  A. Areas of Inquiry.

    1. Philosophy of science.

    2. Social roots of quantum physics.

    3. Ideology of scientists.

    4. Politics of science.

      a. Role of Science Advisory Councils.

      b. Space politics and policies.

        1.) Assessment of public attitudes toward peace exploration, national and international.

        2.) The experimentation with the dialectic.

    5. Can we control technology?--through legislation? social pressure?

II. The Penthouse Experiments--Unanticipated Consequences and Ethical Considerations.

  A. Nutritional aspects and their dehumanizing effects.

  B. Legal structure of the micro-society.

    1. Responses to extreme regulation.

      a. Comparison with and implications for other forms of regulated living.

        1.) Sea Lab.

        2.) Space capsule.

      b. How groups learn to live with themselves.

C. Analysis of social and human aspects.

   1. Effects of interpersonal relations.

   2. Effects on personality structure.

D. Ethics of experimentation with human subjects.

   1. Problems of the "hidden agenda."

   2. Role of "specialists" or "experts" and concomitant trained incapacity.

   3. Deception in social research--intentional and unintentional.

   4. Means and ends.

      a. Purity of objectives as against tainted means.

      b. "Scientific sacrosanctity" as rationale for research purposes.

      c. Mission--directed vs. open-ended inquiry

   5. Who shall be the judge of morality?

      a. Can social scientists be expected to act more ethically than engineers, physical scientists?

      b. Should social scientists be the gate keepers of the social good?

E. Methodology

   1. How do we know what we know?--logs, observations, and tests reviewed.

III. The Design of Inquiring Systems.

A. Information systems as interdisciplinary effort--representing conjuncture of engineering technology, management science, and the social sciences.

B. SASIDS--an attempt to establish communication among scientists.

   1. Obstacles to achieving fidelity of input.

   2. Difficulties in sustaining cooperation of participants.

      a. Pertinence of findings to development of legal and medical information systems.

C. Information systems as purposive inquiry.

   1. Police information networks.

   2. Data base for social intervention strategy--in health, education, welfare, etc.

D. Information systems and the crises of credibility.

   1. AEC and the environmentalists.

   2. Bureau of Labor statistics and "favorable" reports.

   3. DOD and the state of war and peace.

E. Information as power.

   1. Economic

   2. Political

   3. Social

F. Methodology and logistics of the information system design.

   1. Comprehensiveness, the model reviewed.

   2. Basis for selection of input.

   3. Time factors.

   4. Consistency of input.

   5. Compatability of categories and items.

G. Ethics of information systems.

   1. Neutrality of information.

   2. The dossier.

   3. Data-gathering sources.

H. Decisions and data.

   1. Information on a global scale.

      a. ERTS as data-source.

         1.) Who will have access to information? How will it be used?

I. The decision-making process and information.

1. The role of information in public administration.

IV. The Systems Approach.

A. Philosophy and history.

B. The systems approach as special case on inquiring system.

1. The Weltanschauung of the analyst.

2. The role of the "expert."

C. Methodologies reviewed.

1. Simulations and models.

D. The California experiments with the systems approach.

1. Crime.

2. Transportation.

3. Information.

4. Waste management.

E. PPBS as a management tool in government.

1. Cost/benefit considered--in recreation and land use, crime, welfare, education, etc.

F. Systems analysis as outlet for diversification of aerospace talent.

V. Technologies for Study of the Future.

A. "Social indicators," "national goals" and other future-oriented systems analyses.

1. The role of experts.

2. Ethical considerations.

3. The Oedipus theorem and self-fulfilling prophecy.

4. Weltanschauung of the planner.

5. Projections, crystal balls, and other cults.

6. Methodology for devising alternative futures.

2.8.2 Relevant Publications by Ida R. Hoos During Period Covered by This Report

Rothwell, Kenneth J. (ed.). 1972. Information systems and social planning. Administrative issues in developing economics. D. C. Heath and Company.

Fehl, Gerhard J. (ed.). Information planning. Planning, technology and society. Germany.

Cook, Desmond L. and Gregory L. Trzebiatowski (eds.). Systems analysis in social planning. Systems concepts in education. (tentative title) Charles A. Jones Publishing Company.

Western, Alan F. (ed.). 1971. When California system-analyzed the welfare problem. Information technology in a democracy. Harvard University Press. Cambridge.

Western, Alan F. (ed.). 1971. Systems experts: foxes in the henhouse. Information technology in a democracy. Harvard University Press. Cambridge.

1971. Information systems and public planning. Management science. (Applications) June.

1972. Systems analysis in public policy: a critique. University of California Press.

1971. Review of Jon M. Shepard's Automation and alienation (for American sociological review). The MIT Press. Cambridge.

Chapter 3

USER REQUIREMENTS FOR THE APPLICATION OF REMOTE SENSING IN THE PLANNING AND MANAGEMENT OF WATER RESOURCE SYSTEMS

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3.1 INTRODUCTION

The literature abounds with statements of potential applications of remote sensing techniques for obtaining data about earth resources. However, few attempts have been made to analyze present methods of earth resource data acquisition in terms of the parameters required by the users and in consideration of the relative merits of acquisition of such data by remote sensing techniques.

The research results reported in this chapter analyze hydrologic and water resource systems; establish the major parameters needed to meet the informational requirements of water resource managers; specify when and where data are needed; and suggest possible remote sensing applications for acquisition of the acquired data. It is recognized that data acquisition and interpretation methods are in a state of continuous improvements which constantly alters the relative merits of a particular technique; however, basic parameters for research and applied water resource management needs should remain relatively constant.

3.2 WORK PERFORMED DURING PERIOD COVERED BY THIS REPORT

The fundamental framework within which the analysis was made is a model of the hydrological and water resource systems, and their discrete subsystems, which we have reported upon previously. (Annual Progress Report, May 1971, NASA Grant NGL 05-003-404). The following subsystems are identified within the model:

(1) EVAPORATION (EVAPOTRANSPIRATION)

(2) VEGETATION (Includes soil-vegetation interrelation)

(3) RAIN AND SNOW (PRECIPITATION)

(4) STREAMS AND ESTUARIES

(5) RESERVOIRS AND LAKES

(6) UNSATURATED SOIL ZONE

(7) SATURATED ZONE

Although the analysis of each subsystem is reported separately, it is recognized that considerable interdependence exists between parameters within the discrete models as well as between the subsystems.

3.2.1 Evaporation Subsystem

The atmosphere serves as a tremendous source or sink for water within the hydrologic cycle and for energy exchange near the earth's surface.

Water remains in the atmosphere above the earth's surface as vapor or precipitates out as rain, hail, or snow. The classic or traditional methods of measuring precipitation are well known and need no elaboration.

Although the sun is the primary energy source, interaction of solar energy with the atmosphere and earth surface results in several identifiable energy components. Emission of energy in the form of electromagnetic waves is referred to as radiation. Energy balance at the earth's surface has two broadly defined radiation components, solar (short-wave) radiation, and thermal or terrestrial (long-wave) radiation. The total energy spectrum is of interest here.

The solar and terrestrial radiation is important in hydrology and water resource management because it is the source of energy to regulate phase changes in water, to provide energy necessary for photosynthesis, and to influence mass transfer within the hydrologic cycle. The classical or traditional method of obtaining radiation data employs a radiometer that is filtered to be sensitive to radiation in the wavelength region of interest. The resulting measurement is a point estimate of radiation that may be instantaneous or time averaged.

The process of evapotranspiration includes the loss of water from a vegetated surface through evaporation from the soil surface and through evaporation from the plant surface (transpiration). Traditional methods of determining evaporation or evapotranspiration rates generally fall into two technique classes, (a) direct measurement using some weighing device (lysimeter), or (b) calculation of rates using parameters known to influence evaporation, such as, water vapor gradient, temperature gradient, wind, radiation, etc. Some of the commonly used methods are: (1) weighing lysimeter which gives a direct measure of evaporation or evapotranspiration over periods as short as a few minutes, (2) evaporation pan which gives a direct measurement of evaporation of water from a specially designed tank, and (3) empirical equations which have been developed for estimating evapotranspiration using one or more of the meteorological parameters known to influence evaporation rate. Pan evaporation has been used to estimate evapotranspiration for daily rates using a pan coefficient obtained from lysimeter values from the same region (Pruitt, 1960).

One of the commonly used empirical equations is the Jensen-Haise equation (Jensen, 1966) given as $ET_p = (0.025T + 0.08)R_s$ where ET_p = predicted potential evapotranspiration rate, T = temperature in centigrade degrees, and R_s = solar radiation expressed as the equivalent depth of evaporation per unit time.

Perhaps the most frequently used research method of estimating evapotranspiration is the energy balance method. The energy balance equation as given by Tanner (1960) is:

$$LE = \frac{-(Rn + G)}{1 + \gamma(\Delta T/\Delta e)}$$

where L = latent heat of vaporization

E = evaporation rate

R_n = net radiation flux

G = soil heat flux

T = temperature gradient

e = vapor pressure gradient

γ = psychrometric constant

All of the methods of measuring or calculating evapotranspiration rates have limitations and undesirable features. Lysimeters are expensive and hydrologically dissimilar to the field. Since evapotranspiration rates are not always a function of the energy supply, equations based on meteorological parameters are not always correct. The principal parameters and user requirements in the evaporation subsystem are tabulated in Table 3.1. The methodology suggested herein for utilizing remote sensing technology in the determination of evapotranspiration (ET) rates relates the potential for measurement of surface temperature, solar radiation, atmospheric water vapor and other parameters, to rigorous mathematical and empirical equations described herein for indirectly deducing ET. Alternatively, vegetative cover (i.e., type, composition, density, and volume as measured by remote sensors) may be useful in making volumetric estimates of potential ET with an accuracy suitable for many watershed management and water resource planning purposes. Within phase III of the proposed research, currently being implemented, user applications of remotely sensed parameters will be tested in operating systems.

3.2.2 Vegetation Subsystem

The vegetation subsystem plays several concurrent roles in the hydrologic cycle which are identified in Figures 3.3, 3.4, 3.5, and 3.7 of the Annual Progress Report of May 1, 1971 (NASA Grant NGL 05-003-404). It is implied but not specifically identified in the stream and lake subsystems that nonvascular aquatic plants are indirectly related to the hydrologic cycle. Aquatic plants are given special treatment in Tables 3.3 and 3.4.

TABLE 3-1. THE EVAPORATION SUBSYSTEM

HYDROLOGIC PARAMETER and APPLICATION	MEASUREMENT a. Parameter b. Est. Range c. Desired Accuracy	a. Frequency b. Point Est. or Avg.	a. Ground Resolution b. Area Tolerances	STANDARD USER REQUIREMENTS User Techniques	Standard Data Acquisition Methods	REMOTE SENSING DATA ACQUISITION Parameter and Instrumentation Direct and Indirect	Range in E M Spectrum
<u>EVAPORATION</u> from free water surfaces (eg. lakes) for water resources planning & operations	a. flux b. 1-6 cm/wk c. ± 0.25 cm/wk	a. daily b. average	a. 1 km b. ± 10 km^2	1. direct measurement 2. estimate (no seepage) 3. prediction equation	evaporation pan water level indicator Eq. Penman equation $E_o = \frac{m H + 0.27 E_a}{m + 0.27}$	1. surface temperature - thermal IR scanner 2. multispectral imager	3-5μm, 8-14μm 0.2 - 14μm
<u>EVAPORATION</u> from free water surfaces for hydrologic research on the evaporation process	a. flux b. 0-1 cm/day c. ± 0.05 cm/day	a. continuous or hourly b. hour avg.	a. 0.4 km b. ± 0.4 hectare	1. direct measurement 2. direct measurement measured 3. water vapor profiles	recording evaporimeter recording evaporation pan infrared spectrometer	1. surface temp. - thermal IR scanner 2. temperature & water vapor profiles - infrared spectrometer 3. multispectral imager	3-5μm. 8-14μm 5 - 20μm 0.2 - 14μm
<u>EVAPOTRANSPIRATION</u> evaporation from a vegetated surface for water resources planning & operations	a. flux b. 1-5 cm/wk c. ± 0.25 cm/wk	a. daily b. average	a. 1 km b. ± 10 km^2	1. direct measurement 2. estimate with coefficient 3. calculate using meteorological data	non-weighing lysimeter evaporation pan Eg. Jensen-Haise equation $ET = (aT + b)R_s$	1. surface temp. - thermal IR scanner 2. reflectance - multispectral scanner 3. water content - microwave radiometer	3-5μm, 8-14μm 0.2 - 14μm 10 - 40 GH_z
<u>EVAPOTRANSPIRATION</u> evaporation from a vegetated surface for hydrologic research on evapotranspiration processes	a. flux b. 0-1 cm/day c. ± 0.05 cm/day	a. continuous or hourly b. hour avg.	a. 0.4 km b. ± 0.4 hectare	1. direct measurement 2. derive by energy budget analysis 3. prediction equations	accurate weighing lysimeter Eg. Tanner equation $LE = \frac{R_n - S}{1 + \beta}$ Eg. $E = f(u)(e_o - e_a)$	1. temp. & water vapor profile - grd. data collection platform (Bowen instruments) 2. temp. & water vapor profile - infrared spectrometer 3. water content - microwave radiometer	 5 - 20μm 10 - 40 GH_z
<u>VEGETATION WATER STRESS</u> as an indicator of soil water and meteorological conditions	a. water potential b. 0 - 20 bars c. ± 0.5 bar	a. daily during drought season b. average	a. 100 m b. ± 10 hectares	1. ground reconnaissance 2. water potential 3. water content	visual examination visual reading of water potential sensors field measurement of water cont. & relate to tension curve	1. multispectral imager 2. surface temp. - thermal scanner	0.3 - 3.0μm 3-5μm & 8-14μm

TABLE 3-1. (CONT'D.)

HYDROLOGIC PARAMETER and APPLICATION	MEASUREMENT a. Parameter b. Est. Range c. Desired Accuracy	a. Frequency b. Point Est. or Avg.	a. Ground Resolution b. Area Tolerances	STANDARD USER REQUIREMENTS User Techniques	Standard Data Aquisition Methods	REMOTE SENSING DATA ACQUISITION Parameter and Instrumentation Direct and Indirect	Range in E M Spectrum
<u>RADIATION</u> Incoming solar radiation as weather data for estimating ET and energy available	a. flux b. 200-700 ly/day c. ± 50 ly/day	a. daily b. average (daytime only)	a. 10 km b. ± 100 km^2	1. direct measurement 2. direct measurement 3. estimate from weather data	Eppley-type radiometer integrating radiometer radiometer or sunshine recorder	1. reflectance - multi-spectral imager 2. radiance - infrared imager & cloud co-efficient	0.3 - 4.0μm 8 - 14μm
<u>RADIATION</u> solar and net radiation for energy balance and photo-synthesis research	a. flux b. 0-2 ly/min c. ± 0.1 ly/min	a. continuous or 10-min b. 10 min avg.	a. 0.1 km b. ± 1 km^2	1. direct measurement 2. est. photosynthesis radiation	recording radiometer filtered recording radiometer	1. reflectance solar data collection - multispectral imager 2. solar radiation - data collection platform & recording radiometer 3. polarization - polarizer	0.3 - 4.0μm
<u>TEMPERATURE</u> basic weather data for hydrologic planning & thermal energy related operations	a. temperature b. -40 to +60 °C c. ± 1 °C	a. hourly or 4-hr b. average	a. 10 km b. ± 100 km^2	1. contact measurement 2. non-contact measurement	Thermometer, thermistor or thermocouple long-wave pyranometer	1. temperature - thermal scanner 2. radiance - multispectral imagery with special data system	3 - 20μm 0.3 - 1.1μm
<u>TEMPERATURE</u> temp. profiles and surface temperature for thermal exchange research	a. temperature b. 0-50 °C c. ± 0.5 °C	a. continuous b. instantaneous	a. 0.1 km b. ± 1 km^2	1. contact measurement 2. contact measurement 3. non-contact measurement 4. non-contact measurement	thermistor or thermocouple resistance thermometer infrared Thermometer radiosonde	1. surface temp. - infrared thermometer 2. temp. profiles - IR interfermometer spectrometer 3. surface temp-thermal scanner	3 - 20μm 6 - 6.5μm 3-5μm, 8 - 14μm
<u>WATER VAPOR</u> atmospheric profiles for water transfer research involving the hydrologic cycle	a. relative humidity profiles b. 10-90% rh c. ± 2% rh	a. continuous or 30-min b. Point estimates	a. 1 km b. ± 10 km^2	1. direct measurement 2. direct measurement	radiosonde humidity sensors	1. water vapor - radiosonde 2. infrared - interferometer spectrometer	6 - 6.5μm 2 - 14μm
<u>WIND</u> weather data and wind function data for prediction equations	a. speed & direction b. 0-80 km/hr; 0-360° c. ± 10%	a. daily or hourly b. point estimates	a. 1 km b. NA	1. direct measurement 2. indirect measurement	cup anemometer sonic anemometer	1. speed or direction - data collection platform & instruments 2. speed - sonic anemometer 3. wave analysis on water	
<u>VEGETATION COVER</u> as an indicator of evapotranspiration potential	a. % cover b. 0 - 100% c. ± 5%	a. Once per month b. Average	a. 100 m b. ± 10 hectares	1. photo interpretation 2. ground reconnaissance	aerial photographs visual examination	1. reflectance - infrared imager 2. reflectance - multi-spectral photography (with image enhancement)	0.7 - 3.0μm 0.3 - 1.1μm

The planning of water resource developments and the management of water resource systems requires an understanding and a quantitative evaluation of the influence of watershed vegetation on the basic hydrologic cycle. For example, Burgy's studies on the Hopland and Placer Experimental watersheds and on the Upper Putah Creek watershed have directly involved the quantification of runoff increments from vegetation manipulation (Burgy, 1970). Several vegetation characteristics are of importance in hydrologic studies and can be analyzed by remote sensing techniques. Species, areal extent, and plant volume are the three main parameters influencing the "interception losses" and the "evaporation elements" of the hydrologic balance. Species determination and areal extent measurement of the formations are currently done by multispectral analysis and color enhancement techniques (Colwell, 1968).

There is considerable promise for the use of remote sensing techniques in the monitoring of soil instability, erosion, and land slumps resulting from natural vegetative changes and recording man-induced changes from logging and vegetation conversion. Following subsections relate both lake and stream-estuary subsystems to the possible user application of remote sensing in assessing sediment transport and deposition phenomena.

3.2.3 Rain and Snow Subsystem

Utilizing the principle of radar signal attenuation by rainfall, Russian investigators and others have found good correlation between rain-gauge measurements and estimates based on radar attenuation-rainfall relationships (Volynets et al., 1965). The use of an active sensor is almost mandatory for measuring precipitation rates. Most bands of the E-M spectrum except in the microwave and thermal IR range are fully attenuated under the meteorologic conditions which would be associated with the occurrence of measurable precipitation. For example, Moore et al. reported on the work of Medhorst who found that radar is truly an all weather sensor and that systems operating at wavelengths beyond 10 cm are essentially unaffected by any meteorological condition (Moore et al., 1967). It should be obvious that in many user applications in water resource management such as flood forecasting and weather modification research, an all weather sensor would be indispensable. The monthly synoptic photographic coverage, scale 1:100,000, obtained by NASA during the winter of 1970-71 of the snowpack at the Bucks Lake test site when interpreted by personnel of the Forestry Remote Sensing Laboratory showed a high correlation between such data and actual stream discharge and snow survey measurements. Hence that work has revealed the potential of remote sensing in the monitoring of snow for watershed yield predictions and spring snowmelt flood potential forecasting. Unlike rainfall, the rate of snowfall is less important than the characterization of the areal extent and water content of the accumulated snowpack (see Chapter 4 of this report).

Table 3.2 lists the user needs and data requirements for both the vegetative, and the snow and rain (i.e., precipitation) subsystems.

TABLE 3-2. THE VEGETATION AND PRECIPITATION SUBSYSTEMS

HYDROLOGIC PARAMETER and APPLICATION	MEASUREMENT a. Parameter b. Est. Range c. Desired Accuracy	a. Frequency b. Point Est. or Avg.	a. Ground Resolution b. Area Tolerances	STANDARD USER REQUIREMENTS User Techniques	Standard Data Acquisition Methods	REMOTE SENSING DATA ACQUISITION Parameter and Instrumentation Direct and Indirect	Range in E M Spectrum
SOIL WATER CONDUCTIVITY for water flow characteristics of soil in hydrologic analyses	a. hydraulic conductivity b. < 0.05-> 10 cm/hr c. ± 0.05 cm/hr	a. One time at several water contents b. Point estimate	a. 100 m or soil boundaries b. ± 10 hectares or given soil area	1. lab water outflow 2. field water potential	visual reading of volume outflow visual reading of tensiometers	1. water potential - data collection platform and water potential instruments 2. water content, data collection platform and water content sensors	
SOIL WATER CONTENT for water storage estimates, flood forecasting, and antecedent watershed conditions	a. % by volume b. 5 - 60% c. ± 2%	a. daily b. average	a. 100 m b. ± hectares	1. gravimetric 2. neutron scattering	weighing and oven drying of soil samples visual reading of scaler counter used with neutron probe	1. water content data, data collection platform and water sensors 2. surface temperature - thermal scanner sequential analysis 3. microwave - radiometer	 3-5 μm & 8-14 μm 10-35 GH_z
SOIL WATER INFILTRATION for deducing runoff estimates in water resources planning and operations	a. flux b. < 0.1-> c. ± 0.05 cm/hr	a. Once for a given soil over a range of water contents as a function of time b. Average	a. 1 km or soil boundaries b. ± 1 km^2 or given soil area	1. lab infiltrometer 2. field ring infiltrometer 3. field sprinkling infiltrometer	visual reading of water volume flow through soil cores visual reading of inflow depth record application & runoff rates	1. reflectance - multispectral photography (with image enhancement) 2. land forms and soils - radar	0.4-1.1 μm 1.5-100 cm
SOIL TYPE as an indicator of physical and chemical properties of the soil and assoc. land forms affecting hydrology	a. soil system b. variable c. ± 10% error	a. once b. average	a. boundaries within a few meters b. ± 20 hectares	1. soil survey and classification 2. photo interpretation with ground truth	visual & physical exam of soil profiles & land forms aerial photographs and ground reconnaissance	1. reflectance - multispectral photography 2. land forms - side looking radar 3. microwave - radiometer	0.4-1.1 μm 1.5-100 cm 1.5-35 CH_z
VEGETATION as an indicator of precipitation interception, runoff & water extraction potential	a. plant species and density b. variable c. ± 10% error	a. once per month b. average	a. boundaries within a few meters b. ± 10 hectares	1. ground reconnaissance and survey 2. photo interpretation	visual examination and mapping aerial photographs	1. reflectance - infrared imagery 2. multispectral imagery (with image inhancement)	0.7-3.0 μm 0.3-14μm
PRECIPITATION rain or snow as weather data for water resources planning and operations	a. depth (snow--water equivalent) b. 0-15 cm/day c. ± 0.2 cm/day	a. daily b. average	a. 1 km b. ± 10 km^2	1. direct measurement 2. snow depth & water content 3. areal extent (snowpack)	rain gauge sample tube--water equiv. snow survey	1. rainfall - ground data collection platform and instruments 2. rainfall distribution - snow - radar 3. reflectance - multispectral scanner 4. imagery	 1.0 - 4cm 0.2-14 μm .3-.7 μm
PRECIPITATION rainfall or snowfall for hydrologic research on runoff and flood prediction	a. flux b. 0-10 cm/hr c. ± 0.1 cm/hr	a. continuous or 30-min cum. b. 30 min avg.	a. 1 km b. ± km^2	1. direct measurement 2. snow depth	recording rain gauge snow recorder	1. a. rainfall rate - data collection platform and recording gauge b. radar - 2. reflectance for distribution - multispectral scanner and special data system	 1.0-4 cm 0.2-14 μm
WATER VAPOR precipitable water in the atmosphere for water resource planning and operations	a. mixing ratio b. 0.01-20 g/Kg c. ± 0.2 g/Kg	a. hourly or 4-hour b. average	a. 10 km b. ± 100 km^2	1. direct measurement 2. direct measurement	radiosonde humidity sensors	1. infrared - interferometer spectrometer 2. water vapor - radiosonde	6-6.5 μm 2-14 μm

3.2.4 Stream and Estuary Subsystem

A distinction has been made in this report between the user requirements for streams and for estuaries, even though the subsystem parameters are identical with the exception of flow reversal possibilities in estuaries.

Both streams and estuaries are hydrodynamic systems whereas lakes and reservoirs are virtually static except for internal circulation. Volume-storage characteristics are of importance in lakes and reservoirs while rates of flow are important in stream systems.

Although streams and estuaries are placed here under the same heading on the basis of their hydrodynamic characteristic, they constitute two totally different environments. The use of remote sensing in monitoring these two systems must therefore be based on different approaches.

The generally small width of the stream course requires large scale and high resolution imagery to produce valuable information. Stream channel and bank vegetation can be used as indicators of the water conditions, bank storage, sand bar movements, flood frequency, etc. (Viktoros, 1969). Sediment load in the water can be scaled on color or color-infrared images. Thermal analysis of streams on thermograms provides much useful information for ecological, hydrodynamic (natural thermal contrasts) and pollution studies (artificial thermal contrasts) (Taylor, 1969).

Concurrent work of the UCLA investigative team of Shubert and Lingenfelter relates stream morphology, as revealed by meander patterns, to some value of stream discharge of average precipitation over a tributary drainage area. The statistical analyses necessary to correlate channel changes with river hydraulics are not yet completed but offer a user possibility not considered in Table 3.3. It is important to recognize that the work of Shubert et al. could be of inestimable value in water resources planning, yet the need for instantaneous characterization of stream hydraulics cannot be obviated as the criteria for more responsive and sophisticated methods of operation for water resource systems evolve.

The estuary, being the site of the meeting of fresh and saline water, presents a much more complex and continuously changing ecology. The sea water and river water interface is generally characterized by a difference in water temperature; tidal currents can therefore be monitored by using thermal infrared imagery (Taylor, 1969). Depending on further clarifications of the influence of dissolved salts on the emissivity of the water, isohaline maps could be drawn. This last application may have a dramatic impact on the monitoring of changes brought about in a river delta system by regulation and diversion of flows. Water quality and wildlife studies can be performed with the help of image interpretation of plant species indicators or algae blooms (Anderson, 1970).

Concurrent interest by industry and water quality enforcement entities in the detection and surveillance of water pollutants in inland and coastal water masses has stimulated many studies. Two types of approach are used:

1. an analysis of the spectral characteristics of polluted water (reflected and emitted radiation),

2. remote detection of indirect indicators of water quality (algae content, shifts in vegetative distribution and density), (Anderson, 1970; Mattson, 1971; Edgerton et al., 1969; Hom, 1968). Table 3.3 suggests the application of remote sensing technology to the measurement of stream and estuarine hydrologic and hydraulic phenomena.

3.2.5 Lake and Reservoir Subsystem

Special interest in the management of lakes and other impoundments in recent years has centered on the process of eutrophication, or aging. The phenomenon is closely linked to the limiting growth factors for the lakes' primary producers, algae. The most common criterion for judging the eutrophic potential of a lake is the abundance of the macronutrients, nitrogen (N), and phosphorus (P).

The possibilities of determining concentrations of N and P successfully using remote sensing techniques appear slight; however, the monitoring of the mixed standing crop of algae is feasible though an important distinction must be made; the detection of algae blooms is easily made on color or color-infrared images (if spectral signatures from particular algae species are previously defined). On the other hand the measurement of the amount of chlorophyll matter present in the euphotic layer is a much more complex problem. The measurement is based on the principle that the light scattered upward from beneath the surface of the water in certain wavelengths is a function of the chlorophyll concentration. But due to the numerous reflections, scattering and absorption of the light at the surface and in the

TABLE 3-3. THE STREAM AND ESTUARY SUBSYSTEM

HYDROLOGIC PARAMETER and APPLICATION	MEASUREMENT a. Parameter b. Est. Range c. Desired Accuracy	 a. Frequency b. Point Est. or Avg.	 a. Ground Resolution b. Area Tolerances	STANDARD USER REQUIREMENTS User Techniques	 Standard Data Acquisition Methods	REMOTE SENSING DATA ACQUISITION Parameter and Instrumentation Direct and Indirect	 Range in E M Spectrum
OIL & OTHER HYDROCARBON SURF. FILMS for water quality control	a. concentration & distribution b. 0.007 - 50 mg/l c. ± 5%%	a. as required b. average	a. 30 m. b. ± 0.1 ha.	1. surface surveillance 2. aerial surveillance	1. sampling and analysis 2. B&W/color photography (distribution only)	hydrocarbon surface film - 1. microwave radiometer 2. uv imager 3. t° or E.	8.5μ - 12.5μ or 13.5-19mm 2900-4000 Å 8-14μm
SURFACE VELOCITY & DIRECTION for hydraulic characterization	a. velocity b. 0.1-6 m/sec c. ± 0.5 m/sec	a. as required b. average	a. 10-30m b. ± 0.1 ha.	1. field measurement	1. current meter 2. slope area	1. wave form - temp. patterns turbidity patterns	0.5-0.7μ B&W
STREAM MORPHOLOGY for geophysical characterization	a. physical change b. --- c. ---	a. 1-5 yr. b. average	a. 10-30m b. ± 0.1 ha.	1. field surveys	1. transit/tape traverse	meander, slope, depth - 1. camera	0.5-0.7μ B&W
SUSPENDED SEDIMENT for sediment protection and deposition studies (concentration gradient)	a. suspended solids b. 0-5000 mg/l c. ± 10%	a. as required b. average	a. 30m b. 0.5 ha.	1. field sampling and lab analysis	1. gravimetric analysis	suspended sediment plume 1. aerial camera 2. multispectral scanner	0.5-0.7μ BW and color 0.9μ 0.3-0.4μ near UV
WATER CHEMISTRY for water quality management (total dissolved solids)	a. total dissolved solids b. 100-35,000 mg/l c. ± 10%	a. as required b. average	a. NA b. NA	1. in situ measurement 2. field sampling and lab analysis	1. elec-chem probe 2. Wheatstone bridge or gravimetric	total dissolved solids (salinity) 1. microwave imager 2. multispectural analysis	7.5 cm .3-14.0μm
SURFACE TEMP. & TEMP. ANOMALIES for water quality management, hydrology	a. temperature b. 4-20°C c. ± 1°K	a. as required b. point estimates	a. NA b. NA	1. thermograph	1. in situ direct measurement	surface temperatures - IR radiometer	8-14μ Thermal IR
PHYTOPLANKTON DENSITY for eutrophication rate determinations	a. mg/m³ chlorophyll b. .1 - 15 mg/m³ c. ± 10%	a. as required b. average	a. 10-30m b. ± 0.1 ha.	1. sampling and lab analysis	1. cell counts per unit volume	phytoplankton chlorophyll - - aerial camera - uv detector - T-11 camera	0.7-0.9μ Color IR 0.3-0.4μ UV (near) 0.5-0.7μ Color
EMERGENT AQUATIC PLANTS for water quality management	a. density & species b. 10-100m² c. ± 50m²	a. annually b. average	a. 50m b. ± 50m²	1. shoreline survey	1. biological inventory	macrophyte density -aerial camera - uv detector	0.7-0.9μ Color IR 0.3-0.4μ UV (near) 0.5-0.7μ Color
SURFACE DISSOLVED OXYGEN for rate of reaeration	a. dissolved oxygen b. 5-10 mg/l c. ± 1 mg/l	a. seasonally, as required b. point estimate	a. NA b. NA	1. in situ measurement 2. sampling and lab analysis	1. dissolved oxygen - electro-chem. probe 2. winkler determinations	dissolved oxygen - correlate to saturation DO for particular surf. temp. & barometric press. wind vel. & wave pattern	8-14μ Thermal IR 13.5-19 mm Passive microwave
FINFISH LOCATIONS & POPULATIONS for finfish management	a. number & location b. 50-5000 orgs. c. ± 20%	a. seasonally, as required b. point estimates	a. 30 m b. ± 0.1 ha.	1. in situ fish counts	1. numerical counter	fish - UV detector Gamma radiometer	0.3-0.4μ UV (near)
STREAM STAGE AND/OR DISCHARGE for flood forecasting & channel storage	a. discharge b. 100-10,000 m³/sec c. ± 10%	a. continuous b. average	a. NA b. NA	1. in situ measurement	1. stage-discharge recorder	discharge - --- (see velocity)	---
MAPPING ICE - WATER BOUNDARIES for limnological research in inclement weather	a. type & quantity of ice b. --- c. ± 0.1 ha.	a. as required, seasonally b. average	a. 30m b. ± 0.1 ha.	1. field surveys and observations	1. field survey teams	Ice - passive microwave	13.5-19 mm Passive microwave

water body (together with the ever-changing character of the phyto-plankton community) a precise relationship between the measured back radiation and the chlorophyll concentration is difficult to define. Multispectral analysis and polarization will certainly help to solve that problem (Clarke et al., 1970). These possibilities will be explored by the Davis group working closely with other members of the integrated research team in the delta and coastal estuarine elements of the study.

The studies of Silvestro (1970) and Clarke et al. (1969) have shown that state of the art instrumentation and interpretation can be used to quantify suspended materials in water. Silvestro found the spectral region 0.6 to 0.7 particularly sensitive to changes in suspended material concentrations (1970).

The ability to study the heat and energy balance of a lake system may be greatly simplified by the use of remote sensors. Surface thermal patterns can be mapped seasonally; thermal enrichment and diffusion of heat energy within the water body can then be inferred on the basis of a knowledge of the internal currents (Turner, 1969).

The oxygen resources of a lake system are also of prime importance in the management of the biota of the system and in protecting the uses of water which require potability and a general good appearance, as for example to a recreationist. Measurement of dissolved oxygen concentration directly, however, does not appear feasible with the present state of the art. Possibilities for estimating the saturation concentration for the surface water zone by deducing values using a dissolved oxygen model and other measurable parameters such as temperature, reaeration constant from wind and wave analyses, and vapor pressure need further study.

The measurement of subsurface phenomena and parameters will depend to a great degree on the technological advances made in active sensors which can penetrate water or other materials, and in a more enlightened understanding of passive microwave emittance in the aquatic environment.

Table 3.4 lists lake subsystem parameters and user requirements for which remote sensing appears feasible.

3.2.6 Unsaturated Soil Subsystem

The application of remote sensors to an understanding of the unsaturated soil subsystem is more severely restricted due to the occurrence of many phenomena and processes below the ground surface beyond the effective region of presently used portions of the electo-magnetic spectrum.

Four possible approaches appear to be useful for soil moisture evaluation using remote sensing:

1. Reflectance characteristics of soils can be used to infer the surface moisture content although many variables greatly influence the accuracy of the measurement (Planet, 1970).

2. The soil moisture plays a predominant role in the thermal behavior of the soil:

   a) water content influence on the thermal characteristics of the soil (heat capacity, thermal conductivity) (Van Wyck, 1963)

TABLE 3-4. THE RESERVOIR AND LAKE SUBSYSTEM

HYDROLOGIC PARAMETER and APPLICATION	MEASUREMENT: a. Parameter b. Est. Range c. Desired Accuracy	MEASUREMENT: a. Frequency b. Point Est. or Avg.	MEASUREMENT: a. Ground Resolution b. Area Tolerances	STANDARD USER REQUIREMENTS: User Techniques	STANDARD USER REQUIREMENTS: Standard Data Acquisition Methods	REMOTE SENSING DATA ACQUISITION: Parameter and Instrumentation Direct and Indirect	REMOTE SENSING DATA ACQUISITION: Range in E M Spectrum
LAKE SURF. AREA for volume - surf. area relationships	a. area b. 0.1-0.24 ac. c. ± 0.2 ac.	a. as required b. average	a. 100 or ≅ 31 m b. ± 0.5 ha.	1. deduce from water level & known lake geometry 2. traverse offsets & Simpson's 1/3 Rule	1. water level recorder 2. fathometer soundings 3. field survey	1. area - B&W photo	visible, infrared
LAKE DEPTH for lake geometry & sedimentation rate (gross lake morphology)	a. depth b. 0-100 m c. ± 1%	a. as required b. point est.	a. NA b. NA	1. direct hydrographic measurement	1. fathometer 2 lead line	1. bottom reflec-multi-spec. 2. wave analysis-Fourier transf. 3. thermal anomalies 4. laser ranging	0.55-0.58μ 0.8 -1.0 0.62-0.66 0.5-0.7μ B&W 8-14μ direct depth meas.
DEPTH TO THERMOCLINE for limnologic determinations	a. depth °c/m b. 0-50 m c. ± 10%	a. seasonally, b. point estimate	a. NA b. NA	1. temperature - depth profile	1. bathythermograph	1. instrument buoy or/ aircraft	passive microwave 13.5-19 mm
WATER CHEMISTRY STRATIFICATION for redox potential measurements	a. TDS b. 50-1000 mg/l c. ± 10%	a. seasonally b. point estimate	a. NA b. NA	1. sampling & analysis 2. S-channel probe (electrochemical)	1. lab. chem. analysis 2. in-situ field measurement	1. instrument buoy	-
PHYTOPLANKTON DENSITY for nutrient enrichment determinations & eutrophication studies	a. mg/m^3 chlorophyll b. .1-15 mg/m^3 c. ± 10%	a. seasonally as required	a. NA b. NA	1. sampling & analysis	1. cell counts per unit volume	1. phytoplankton chlorophyll, IR film	0.7-0.9μ color infrared 0.3-0.4μ UV (near) 0.5-0.7 color see also Table 3
EMERGENT AQUATIC PLANTS for eutrophication and lake morphology studies	a. density & species b. 10-100 m^2 c. ± 50 m^2	a. annually b. average	a. 50 m b. ± 50 m^2	1. shoreline survey	1. biological inventory	1. macrophyte chlorophyll, IR film	0.7-0.9μ color infrared 0.3-0.4μ UV (near) 0.5-0.7 color see also Table 3
CHANGE IN STORAGE for water resource operations	(same as LAKE SURFACE AREA above)			-	-	-	
SURFACE DISSOLVED OXYGEN for rate of reaeration	a. dissolved oxygen b. 5-10 mg/l c. ± 10%	a. seasonally as required b. point estimate	a. NA b. NA	1. dissolved oxygen probe (electrochemical) 2. Winkler determinations	1. field determinations, direct measurement 2. sampling & lab. analysis	1. correlate to satur. DO for particular surf. temp. & barometric pressure & wind & wave action	8-14μ thermal IR 13.5-19 mm passive microwave
SURFACE TEMPERATURE for thermal enrichment studies & heat bal. determinations	a. temperature b. 4-20°C c. ± 1°K	a. as required b. point estimates	a. NA b. NA	1. thermograph	1. field determination, direct measurement	1. radiometer-temperature	8-14μ thermal IR
TURBIDITY for water quality control & algal growth potential studies	a. turbidity b. 0-10^4 JKU c. ± 10%	a. as required b. average	a. 30 m b. ± 0.5 ha.	1. sampling & lab. analysis	1. Jackson turbidimeter	1. turbidity - multispectral imager	0.5-0.7μ B&W & color visible 0.9μ near IR 0.3-0.4μ near UV
LIGHT TRANSMITTANCE for algal growth potential studies	a. light transmittance b. 0-1000 ft-candles c. ± 10%	a. as required b. average	a. NA b. NA	1. submerged photoelectric cell 2. deduce by susp. solids concentration	1. photo cell	1. light reflectance from backscatter - multispectral	0.55-0.58μ 0.8 -1.0 μ 0.62-0.66μ
SUSPENDED SOLIDS for concentration gradient determinations & algal growth potential studies	a. suspended solids b. 0-5000 mg/l c. ± 10%	a. as required b. average	a. 30 m b. ± 0.5 ha.	1. sampling and lab. analysis	1. field measurement & lab. determination	1. susp. sediment plume	0.5-0.7μ visible B&W & color

b) water movement in the profile under thermal gradient with the associated energy transfer (Pouquet, 1968; Rose, 1968)

c) water evaporation from the surface (cooling process).

The relative importance of these soil moisture phenomena is still to be investigated.

Due to the periodicity of the temperature variations, remote sensing analysis based on sequential thermograms would probably yield the maximum information. Thermal scanning has been proven to be highly useful for delineating soil moisture where no vegetative canopy exists to destroy the surface temperature effects (Schmer, 1970).

3. Water status in plants as sensed by infrared imagery has been correlated with the soil moisture profile. Plant species distribution and density may be used as indicators of soil moisture (Werner and Schmer, 1971).

4. Microwave emission (0.8 - 21 cm) of soil at different moisture conditions is currently being investigated (McClain, 1970).

Present efforts are confined to lower elevation platforms because of the physical requirements of the apparatus. Again, advancement of active sensor technology previously described suggests future opportunities for inferring infiltration under all weather conditions. The parameters and user applications comparing traditional data acquisition and remote sensing possibilities are presented in Table 3.5.

3.2.7 Saturated Subsystem

Some excellent possibilities exist for the acquisition of certain data relating to hydrologic characteristics in the saturated zone.

TABLE 3-5. THE UNSATURATED ZONE SUBSYSTEM

HYDROLOGIC PARAMETER and APPLICATION	MEASUREMENT: a. Parameter b. Est. Range c. Desired Accuracy	a. Frequency b. Point Est. or Avg.	a. Ground Resolution b. Area Tolerances	STANDARD USER REQUIREMENTS: User Techniques	Standard Data Acquisition Methods	REMOTE SENSING DATA ACQUISITION: Parameter and Instrumentation Direct and Indirect	Range in E M Spectrum
DIRECTION OF FLOW for miscible displacement studies and salt transport in soil water	a. direction up or down b. - c. -	a. as required b. average	a. 30 m b. ± 0.5 ha.	1. measure soil moisture tension & apply Darcy's law	1. tensiometers, resistance blocks or neutron probe	salt incrustation	.5-.9μm
POROSITY for determination of percent voids in soil	a. porosity b. 0-30 percent c. ± 5 %	a. as required b. average for soil body	a. NA b. NA	1. undisturbed soil sample, lab analysis	1. laboratory analysis	-	-
THICKNESS OF UNSAT. ZONE for drainage characterization of soil body & depth to saturated zone in unconfined aquifers	a. meters b. 0-300 m c. ± 0.5 m	a. as required b. average over discrete area	a. 30 m b. 0.5 ha.	1. auger, well log, water level recorder	1. field direct measurement	native vegetation, deep rooted species - rooting depth multispectral analysis sequential thermal imagery analysis	- .3-14μm 8-14μm
MOISTURE CONTENT for agrl. operations & water res. systems management incl. flood forecasting	a. percent b. 0-100 c. ± 5%	a. as required b. average over discrete area	a. 30 m b. 1 ha.	1. measure soil moisture tension & relate to water content 2. soil sample and analysis	1. tensiometers, resistance blocks or neutron probe 2. gravemetric methods	(see vegetative sub-system SOIL WATER CONTENT)	
INFILTRATION	(see vegetative system, SOIL WATER INFILTRATION)			3. native vegetation	3. visual examination	native vegetation multispectral imagery	.3-14μm
SALINITY OF SATURATED SOIL EXTRACT	a. total dissolved solids b. 0-5000 mg/l c. ± 10%	a. as required b. point estimate	a. NA	1. deduce from soil water conductivity 2. gravemetric analysis of soil water sample	1. Wheatstone Bridge 2. laboratory analysis	-	-

The saturated zone subsystem cannot presently be directly detected by passive remote sensors. Indicators must therefore be used. The "indicational association" between the indicator and indicator object is based on definite physical, physiological or biochemical processes which are currently generally well defined. The value of those indicators as remote sensing targets must still be studied.

Surface evidence of high water table and associated features is generally easily detectable. Discharge of ground water in effluent streams or into the ocean is currently being investigated by thermogram analysis (Taylor, 1969).

Remote sensing is certainly a good research tool for definition of the influence of ground water bodies on the soil temperature regime. Thermodynamic considerations indicate that a shallow aquifer may act as a heat sink or a heat source whose influence is detectable at the surface of the soil. Further refined analysis is necessary to define the respective influence of the numerous parameters involved. An optimal sequence of remote sensing survey must be defined to include the local factors (climate, soil thermal properties, water table depth, thickness of the aquifer, topography, type of bedrock, etc.) (Meyers, 1970) in order to come out with a useful relationship between soil temperature anomalies and the occurrence of ground water. Other indications such as occurrence of phreatophytes may be used to define the existence of subsurface waters involving vegetative vigor or other plant characteristics. Technological breakthrough in the immediate future may enable the use of active sensor systems which will enable remote sensors to penetrate to useful depths for subsurface water detection. Laboratory studies of thermal properties of soil in columns with controlled water table levels are under way at Davis by members of this project staff. The temperature regime of the soils will be correlated with the depth to water table and other factors. Results are expected to be useful in interpreting and predicting responses for field investigation using thermal imagery in ground-water and soil moisture surveys.

The user applications and traditional hydrologic problems of importance in the saturated zone are outlined in Table 3.6.

3.2.8 Summary

The data developed herein to relate hydrologic systems and subsystem models to user applications and remote sensing technology hold promise in the planning and management of water resource systems and in shorter term hydrologic forecasting activities.

Prototype testing of remote sensing user applications suggested are being pursued and will be developed for operational testing within the term of the project. Parameter specifications have been updated and revised by interchange between the project team members. Continuing analysis is expected to produce additional refinements. Suggested supplemental details like specifying spectral requirements are being incorporated in the tabulations.

Willingness of the potential users within the test site to make remote sensing technology work by assisting the research teams in testing and in ground truth study, and in exploring other methods and procedures for utilizing new data sources in operational programs will contribute in great measure to the eventual success of the research effort.

TABLE 3-6. THE SATURATED ZONE SUBSYSTEM

HYDROLOGIC PARAMETER and APPLICATION	MEASUREMENT a. Parameter b. Est. Range c. Desired Accuracy	a. Frequency b. Point Est. or Avg.	a. Ground Resolution b. Area Tolerances	STANDARD USER REQUIREMENTS User Techniques	Standard Data Acquisition Methods	REMOTE SENSING DATA ACQUISITION Parameter and Instrumentation Direct and Indirect	Range in E M Spectrum
WATER TABLE GRADIENT for groundwater basin outflow determinations (Piezometric level)	a. meters b. 0-300 m c. ± 0.5 m	a. as required b. average over discrete area	a. 30 m b. 0.5 ha.	1. auger, well log, water level recorder	1. direct field measurements	native vegetation, deep rooted species - rooting depth multispectral analysis thermal gradient	- .3-14μm 8-14μm
AQUIFER DIMENSIONS for safe yield and total groundwater reservoir storage determinations (shape of hypervolume)	a. meters b. varies c. ± 100 m^3	a. once as required b. -	a. 30 m b. 0.5 ha.	1. well logs, geologic structure	1. direct field measurements 2. aerial photos of basin surface area	geological features thermal gradients	.3-.7μ 8-14μm
GROUNDWATER BASIN RECHARGE ZONES for groundwater basin management	a. area b. varies c. ± 5 ha.	a. once as required b. -	a. 100 m b. ± 5 ha.	1. geologic field 2. aerial photo interpretation	1. field measurements 2. photo interpretation	1. geol. discont. - aerial camera - soil types	0.3-0.7μ .3-14μm
COEFFICIENT OF PERMEABILITY for groundwater movement studies	a. $m^3/day/m^2$ b. varies c. ± 5%	a. as required b. average	a. NA b. NA	1. undisturb. soil sample and analysis	1. laboratory analysis	-	-
GROUNDWATER TEMPERATURE	a. °C b. 6-25°C c. ± 1°C	a. as required b. point estimates	a. NA b. NA	1. thermograph	1. direct measurement	geothermal waters and anomalies	8-14μm
GROUNDWATER WITHDRAWALS for groundwater basin management	a. m^3/month b. varies c. ± 20%	a. continuous b. average	a. NA b. NA	1. pump operation analysis 2. flow meter each pump, totalized for basin	1. direct measurement	-	-
GROUNDWATER DISCHARGE ZONES for groundwater basin management	a. area b. 1-5 ha. c. ± 0.1 ha.	a. as required b. average	a. 30 m b. ± 0.1 ha.	1. direct field measurement	1. aerial photo interpretation 2. field surveys	soil, vegetation, soil moisture - aerial camera surface temperature	0.5-0.7μ color & B&W 0.4-0.7μ color IR 8-14μm
GROUNDWATER CHEMICAL QUALITY for salt balance and salinity changes	a. total dissolved solids b. varies c. ± 10 mg/l	a. as required b. average	a. NA b. NA	1. sampling & lab. analysis 2. electro-chem. probe	1. lab. analysis 2. field measurement	-	-
SALT WATER INTRUSION for groundwater basin management	a. location & flux b. m^3/m^2 c. ± 10%	a. as required b. average	a. NA b. NA	1. field observation in test wells	1. water levels in saline fresh water zone	-	-
SPECIFIC YIELD SPECIFIC RETENTION for groundwater basin characterization	a. sp. yield b. percent c. ± 1%	a. as required, once b. average	a. NA b. NA	1. undisturb. soil sample & analysis	1. lab. analysis	-	-

3.3 FUTURE PROPOSED WORK

Broadening of the scope of the current analysis of hydrologic systems to include greater emphasis on the aquatic components of water resource systems has been accomplished. Consistent with this intent it may be noteworthy that at the state level an extensive monitoring program is presently being updated and reprogrammed to meet more rigorous requirements for management of water resources in all areas of environmental interest. An excellent opportunity is thereby provided to expand the ongoing research efforts of the U. C. Integrated Study and the activity of the Davis Campus research team to this vital sector of the management of the state resources.

Field studies have been initiated using on-site ground characterizations in both the terrestrial and in the aquatic regimes to verify indicated remote sensor responses. Recently acquired imagery from NASA high flights in the San Francisco Bay Test Site during Spring of 1971 and the ongoing U-2 series are now in use for image interpretation based on the ground-truth studies. Water quality measurements and composition of aquatic populations are being made on a repetitive basis in selected sites in the Sacramento-San Joaquin Delta Region this spring and summer. Coordination with remote sensing work on other California water bodies is being explored.

The studies outlined under the expanded scope of the program defined in the May 1, 1970 Annual Report and detailed in the ERTS and Skylab proposals previously submitted can be implemented immediately with support augmentation requested. The essential features of these research plans will be retained and supplemented to reflect progress in technology.

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Chapter 4

REMOTE SENSING DATA AS AN AID TO RESOURCE MANAGEMENT IN NORTHERN CALIFORNIA

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4.1 INTRODUCTION

During this funding period two major studies are being carried out in Northern California, namely:

1. Measurement of hydrologic resource parameters through the use of spacecraft and aircraft data in the Feather River Headwaters area (see Plate 4.1).

2. Analysis of the Northern Coastal Zone Environment with the aid of spacecraft and aircraft data (see Plate 4.2).

An explanation of the objectives and relationship between Item 1, above, and certain of our previous studies can be found in Chapter 4 of the 1971 Annual Progress Report for the Integrated Study. The following text provides background information and defines the objectives of the analysis of the Northern Coastal Zone Environment.

4.1.1 Background

It is becoming increasingly apparent that the coastal zone of California is in itself an important resource. As population increases, the coastal lands will come under mounting pressure for development,

STATE COUNTY OUTLINE MAP

SIZE 8½ x 11

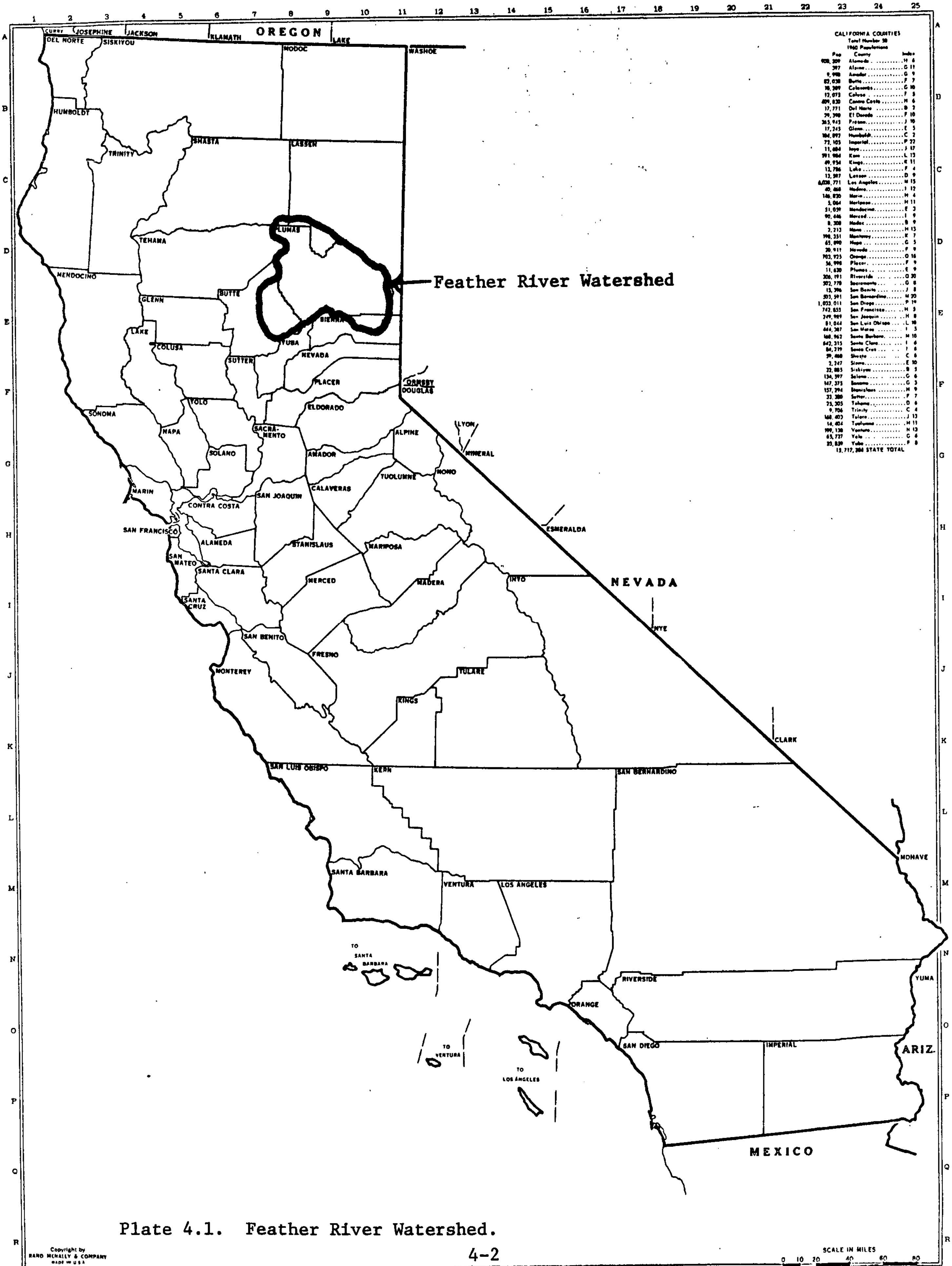

Plate 4.1. Feather River Watershed.

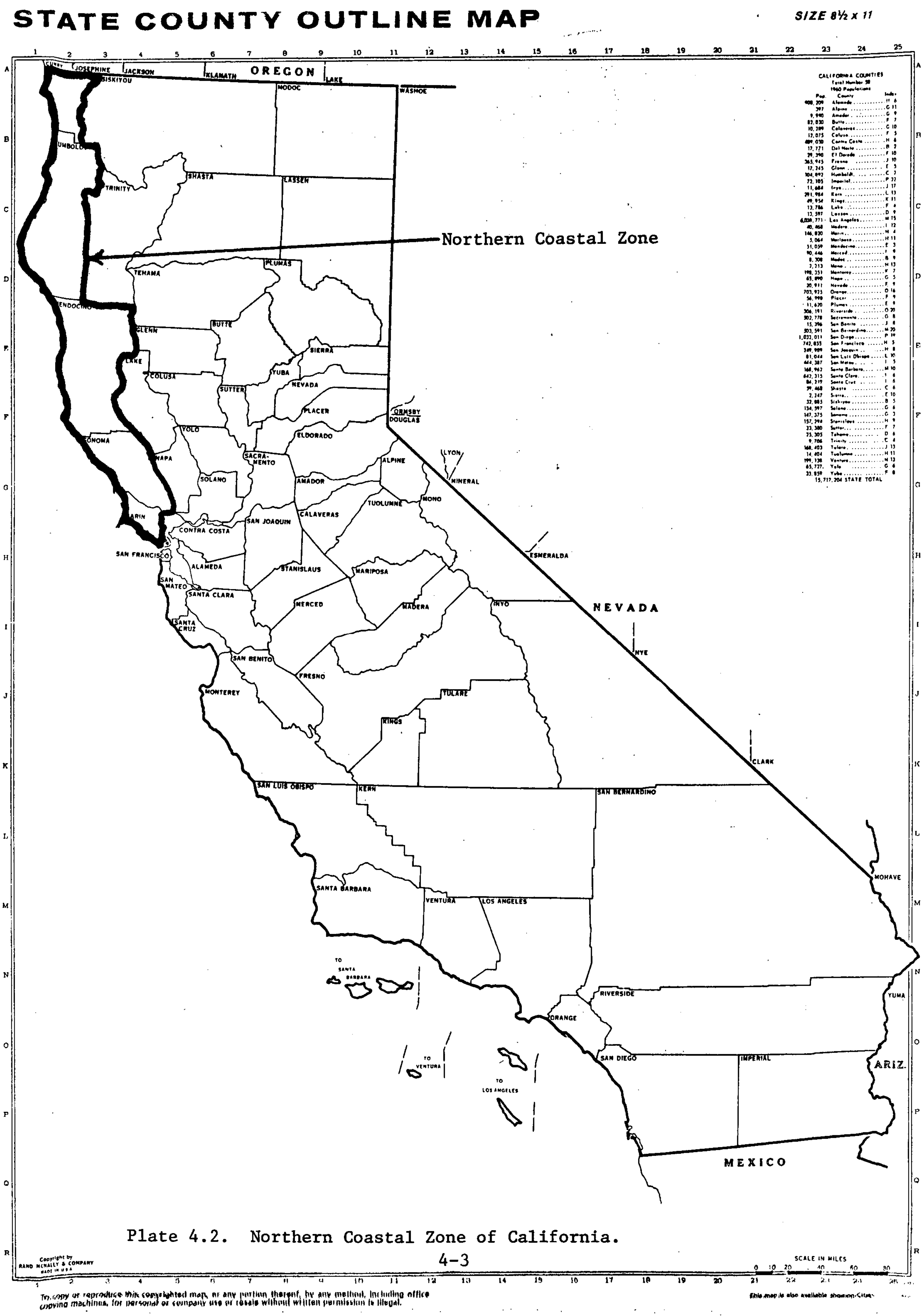

Plate 4.2. Northern Coastal Zone of California.

both as a place of human habitation and as a place for more intensive use and development of natural resources. From San Francisco southward, the coast is already the site of numerous urban centers, and the problem of planning entails not only how to plan for future development, but also how to deal with currently existing development. In many ways the northern coastal region presents somewhat different problems. In general the north coast (consisting of the counties of Marin, Sonoma, Mendocino, Humboldt, and Del Norte -- see Plate 4.2) is relatively rural, with an economy based on agriculture, timber, commercial fishing, and tourism. However, it is expected that intensive resource use resulting from increasing population will soon become a serious problem unless wise land use planning is undertaken. Thus the north coastal zone presents an excellent opportunity for intelligent, informed planning of development before intensive land use activities become widespread.

One prerequisite of intelligent land use planning of any region is a detailed and comprehensive knowledge as to the environment of the area in terms of its effect on potential resource management and use. In the north coastal area, one urgently needed type of information is an integrated inventory and evaluation of the physical characteristics of the region as they relate to the suitability for various types of land use.

Due to the fact that the bulk of the region can be calssified as essentially wild land, the capabilities of the Forestry Remote Sensing Laboratory, Berkeley Campus, lend themselves particularly well to investigations of the ways in which remote sensing and other supporting data may be used in conducting such potential land use evaluations.

4.1.2 Objectives

The purpose of this study is to evaluate the usefulness of remote sensing data in providing general land-use planning information pertaining to the coastal zone of Northern California. The test area covers the entire coast of California extending from the San Francisco Bay Area to the Oregon border.

In particular, we are attempting to enumerate those physical parameters of the landscape which are of particular importance in determining the potential of an area in terms of land-use, be it natural resource utilization, urban development or industrial development. This determination is being made with a consideration of the needs of land-use planners now involved in the formulation of long range land-use plans. A quantitative evaluation will then be made of the degree to which these parameters can be mapped or otherwise extracted from remote sensing data by means of both human interpretation and automatic feature classification. In conjunction with this information extraction phase, attempts will be made to utilize our computerized "data bank" for storage and retrieval of the information thus derived such that it might provide maximum utility for the ultimate users. Finally, the results of the experiment will be evaluated in terms of the information and accuracy requirements of those agencies actually responsible for the formulation of land-use plans in the north coastal region.

The experiment is structured such that initial work is centered on gross features which almost certainly can be identified on high altitude spacecraft and aircraft imagery, and will progress to more detailed features. Thus it will be possible to ascertain that point at which small scale imagery with poor spatial resolution must be supplemented (through some form of multistage sampling) with other types of data in order to provide the required detail of information. In those cases where the required parameters cannot be directly measured, an attempt will be made to ascertain ways in which initial stratification using small scale imagery can be of aid in determining the optimum allocation of subsamples in the form of aircraft photo coverage or on-the-ground surveys.

4.1.3 Approach

Our experience to date has convinced us of the necessity to use a systems concept and team approach in solving problems of interest to the earth resource manager. Consequently, the Forestry Remote Sensing Laboratory has been organized to include five functional units (see Plate 4.3). These units address themselves to the most important problems which must be solved if a remote sensing system is to be employed successfully for earth resources inventory purposes. The five problem areas investigated under this team approach are as follows:

1. Determination of the feasibility of providing the resource manager with operationally useful information through the use of remote sensing techniques;

2. Definition of the spectral characteristics of earth resources

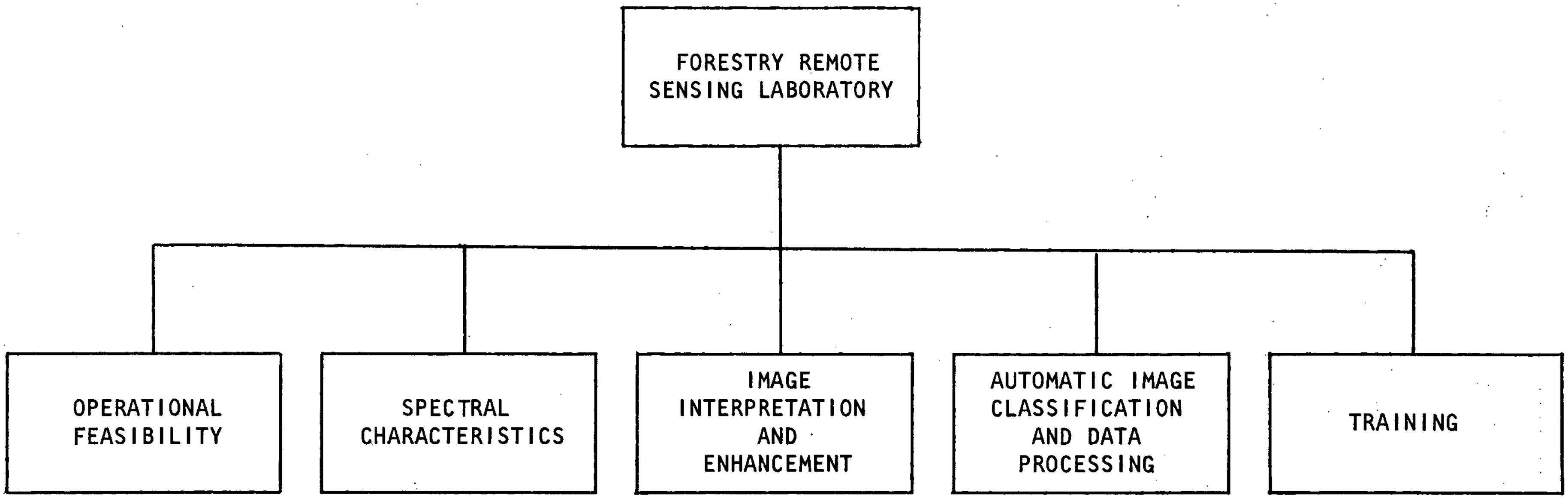

Plate 4.3 Organizational diagram of the Forestry Remote Sensing Laboratory, University of California, Berkeley, California.

and the optimum procedures for calibrating multispectral remote sensing data acquired of those resources;

3. Determination of the extent to which humans can extract useful earth resource information through a study of remote sensing imagery either in its original form or when enhanced by various means;

4. Determination of the extent to which automatic data handling and processing equipment can extract useful earth resources information from remote sensing data; and

5. Effective dissemination of remote sensing results through the offering of various kinds of training programs in which the interaction between users and scientists can be emphasized.

The units of our Forestry Remote Sensing Laboratory which are engaged in these five problems are, respectively: (a) the Operational Feasibility Unit, (b) the Spectral Characteristics Unit, (c) the Image Interpretation and Enhancement Unit, (d) the Automatic Image Classification and Data Processing Unit, and (e) the Training Unit. Consistent with this team appraoch the remainder of this Chapter consists of five units.

4.2 REPORT OF THE OPERATIONAL FEASIBILITY UNIT

The primary areas of responsibility of the Operational Feasibility Unit consist of: (1) definition of specific problem areas upon which efforts of the Forestry Remote Sensing Laboratory might best be focused in light of operational needs of the prospective data user, (2) determination of optimum methods for evaluating remote sensing techniques, and (3) evaluation of techniques developed by other units of the FRSL in terms of their actual usefulness to potential users of remote sensing data.

As was discussed in previous progress reports, the efforts of the Unit during the first year of this study centered around the compilation of a list of physical parameters important in terms of the hydrologic phenomena occurring in the Feather River Watershed, and which were of interest to watershed management planners. This list was developed in cooperation with Professor Burgy and his colleagues at the Davis campus, and was meant as a guide for the technical units of the FRSL in choosing those specific interpretation problems upon which to focus their efforts. It was decided that the technical units would attempt various mapping processes using the available small scale imagery of the test site, and that techniques would be developed to allow quantitative determinations of the accuracy of such mapping.

4.2.1 Work Performed during the Period Covered by This Report

Field Data Collection

In cooperation with the Image Interpretation Unit, a system for ground data collection in the Feather River Watershed was developed. The objective of this data collection process was to gather sufficient information pertaining to the physical parameters of the areas that were to be subsequently mapped on aerial photography to allow a quantitative evaluation of the accuracy of the mapping to be performed.

Ground data were collected at a number of ground plots which were systematically located (with a random start) throughout the 3600 square miles of the upper Feather River Watershed. Eighty plots scattered regularly throughout the entire watershed are to be used in testing those general mapping procedures which will involve the entire test site. In addition, five smaller watersheds, comprising approximately 20% of the total area, were intensively sampled with an additional 80 plots. It is planned that these "sub-watersheds" will be the subject of tests involving fairly detailed mapping procedures. Thus a total of 160 ground plots were established.

Through use of the list of relevant parameters which had been compiled earlier, a set of classification information to be collected at each plot was established. This included: (1) vegetation-terrain type, (2) density of vegetation cover, in percent, (3) species composition, (4) average canopy height, (5) geologic type, (6) soil depth and color, (7) aspect, (8) slope, and (9) elevation.

All of the data collected by the field crews have now been tabulated. The tests of mapping accuracy will proceed upon completion of various terrain feature maps to be produced by the Image Interpretation and Enhancement and the Automatic Data Processing Units. A more detailed description of the ground data collection process and status of the interpretation and mapping which is underway can be found in the contributions to this report made by those two units.

Resource Mapping Evaluation Studies

A preliminary step was taken in the quantitative evaluation of maps made using small scale aircraft and ERTS imagery. (The evaluation will be an important part of our studies during the coming year.) This step entailed the surveying of methods of resource mapping evaluation which have been used by researchers in the past. Our objective is to determine the utility of those techniques for specific kinds of mapping problems.

Forest stand delineation was chosen as a case study example for analysis. The preliminary step was an attempt to define exactly the need for forest stand maps by land managers, and accuracy requirements. This was accomplished primarily through personal interviews with both government and private employees directly involved with management decisions. In essence, the results of these interviews established the following:

1. Forest stand maps are indeed used on a regular basis for planning the management of forest lands on a local, state or regional level. Uses range from layout of logging roads to stratification prior to regional inventory samples.

2. In general the users have adapted their use to fit the quality of map presently available. Nearly all agree that an improvement in accuracy would be desirable, but few are able to state definitely what gains or benefits would accrue from such improvement.

3. Due to the difficulty of determining marginal benefits, a strict cost-benefit ratio analysis to determine the usefulness of mapping from remote sensing data is nearly impossible. Probably the most fruitful approach is to attempt to demonstrate that in specific cases, increased map accuracy can be obtained at a cost less than or equal to

that of conventional techniques, thus avoiding the more difficult analysis entirely.

It has been our experience that these conclusions are not characteristic of foresters alone, but apply equally as well to most persons engaged in land management decisions.

Once it was established that a quantitative determination of mapping accuracy is a worthwhile objective, a literature survey was conducted, and various technqies used for resource mapping evaluation in relation to remote sensing analysis were investigated. There are surprisingly few papers which deal with this subject, a fact which may be indicative of the difficulty of the task. It appears that the major problems encountered are a lack of "ground truth" data for comparison, and the difficulty of determining the various kinds of interpretation or mapping errors which can be made.

In general, a map can be tested for accuracy (once ground truth is known), either on the basis of the location of delineation lines, or on the coincidence of delineated areas. In either case an analysis of the results is complicated by the fact that typing or mapping consists of two operations, namely, the drawing of boundaries between types, and the assigning of a particular identification label to each delineated type. In terms of ground truth, the problem stems from the fact that in most cases involving large areas, the only possible way to obtain comprehensive mapping data is through the use of aerial photos; hence there is difficulty in obtaining independent and objective information against which to evaluate the mapping procedure in question. Usually some method of sampling to obtain "ground truth" is necessary.

The literature review yielded two papers, one dealing with boundary coincidence testing methods (Vermeer, 1968*) and one dealing with area coincidence methods (Young and Stoeckeler, 1956**), which presented some guidelines for a seemingly feasible evaluation technique. In order to combine both methods and try out a system using both boundary and area criteria, a test was carried out using a forested tract in Finland for which stand boundaries had been mapped on the ground by trained foresters and for which independent photo interpretation of forest stands had also been carried out. The objective of the test was not to evaluate the photo interpretation process, but rather to simply become acquainted with the testing procedures themselves in a pilot study, and to attempt to iron out troublesome details in the procedure before the techniques were applied to large areas such as the Feather River Watershed in actual interpretation tests.

In conclusion it was felt that techniques for both boundary and area coincidence testing which will be used in the near future have been adequately developed, and that such tests can proceed as soon as interpretation results are available.

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*Vermeer, J. 1968. Results of an objective comparison of film-filter combinations applied to an example of photo interpretation for soil surveys. Eleventh Congress of the International Society for Photogrammetry. Presented paper for Commission VII, Lausanne, Switzerland.

**Young, H. E. and E. G. Stoeckeler. 1956. Quantitative evaluation of photo interpretation mapping. Photogrammetric Engineering 22(1):137-143.

Coastal Zone Studies

A necessary initial step in the design of a remote sensing experiment dealing with the coastal region of California is the determination as to exactly what kinds of information will be needed by those charged with planning or management of the coast. It is an easy matter to ascertain generally the kinds of information required, as nearly anyone involved in planning in any region will list such things as soils, geology, vegetation, land-use, potential land-use, and land ownership as being basic input data. Our problem is considerably more complex, however, as it is necessary to first define "coastal zone" in a usable fashion, and then to determine specific kinds of information on which our studies should focus. Then, in order to conduct an evaluation of the performance of remote sensing systems to supply this information, specific criteria as to categories and accuracy are necessary. The following discussion represents the beginning of an attempt to resolve the question of the scope and objectives of the proposed "Coastal Zone Studies".

A. Review of County Plans

Our initial efforts were directed toward gathering county statistics and reviewing the existing county master plans in order to determine the potential value of small scale remote sensing data to county planners. A summary and evaluation of these plans is presented below:

1. The most current master plan for Del Norte County, written in 1965, is now being revised due to the advent of the Redwood National

Park and the revision of certain regulations regarding land-use. This represents a common problem facing most of the north coast counties. As prime commercial timberland is converted to parkland, the county must find alternate sources of income, because the economic return to the county on recreation land is usually much less than for timber land with respect to employment and the tax revenue.

2. The master plans for Humboldt and Mendocino Counties have forestry oriented economies which, with the present slump in the lumber market, are in decline. The objectives of the Mendocino County plan are as follows:

Community Values:

- Sound neighborhood standards, designed for maximum convenience and safety.
- High quality of services: water, sewage, drainage, fire and police protection, streets and highways.
- Adequate open space, aesthetic controls, park, recreation and scenic highway developments.
- Educational and cultural facilities to meet growing demands.

Economic Base:

- Increased industrial activity for strengthened tax base, with proper types in proper locations.
- Expanded retail sales and services, wholesale and distribution.
- Increased local processing of area resources.
- Increased sustained yield operations in forestry.
- Increased production and processing of mineral resources.

- Increased agricultural production and processing.

Preservation of Natural Resources:

- Protection and planned use of natural scenic features.

- Provision for compatible private and public developments in, and access to, scenic and recreational areas.

- Conservation measures to protect natural resources.

- Appropriate land-use planning and zoning to conserve and protect agricultural soils.

It should be noted that many of the objectives that are proposed to strengthen the economy of the counties will come under close scrutiny by conservation groups throughout the state. This was quite evident in northern Humboldt County where a major timber company was pressured by conservationists and others to sharply cut back logging of redwood and Douglas fir in the north coast area even after the company's logging proposal was approved by the California State Board of Forestry. In addition to mining and logging practices, it can be anticipated that freeway and highway development proposals which both counties feel are needed for increased economic diversification will be watched closely by these same conservation groups in order that areas of natural beauty will not be unduly disturbed by engineering activities designed to improve transportation networks.

3. Currently, there is no county-wide master plan for Sonoma County. However, in July 1971 the county began a two-year effort to develop such a plan under funding from national and state government sources. At present there are about 25 specific plans for sub-areas of

the county which include city general plans, county traffic, sanitation and recreation plans, sanitation district plans and water distribution plans. Undoubtedly, many of these existing plans will be incorporated into the overall county plan.

4. The major concern of Marin County planners is that of preserving the environment. The exceptional environment of this county, which represents a bedroom community to San Francisco and a recreational area to the entire San Francisco Bay area, is suffering due to continuing increases in population pressure:

> "It is also common knowledge that as Marin has grown, its environment has deteriorated. A drive along 101 today compared with last year reveals that there is a little closer to a Los Angeles type of merge; and here and there ridge tops which only yesterday were topped by trees and grass now are capped by flatland houses hanging off new notches in a hillside."*

The fear of becoming "a little closer to a Los Angeles type" and a realization that prompt action will be required to preserve the county's environment are factors which have brought about the publication of the most comprehensive master plan of all the five northern coast counties. It is evident that for the preparation of this plan, a thorough inventory of the county's developed and undeveloped land was made. From this information, the county was divided into six zones -- coastal foothills, central uplands, inland valleys, bayside foothills, bayside plains and bay shore -- upon which the merits of all development and zoning proposals should be evaluated. The following

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*Marin County Planning Department. "Can the Last Place Last". 1971.

recommendations summarize the findings and specific proposals of the county planners:

A. Marin County's communities are identifiable with the natural subdivisions of the county and are separated by natural greenbelts of hills and ridges. This characteristic must be preserved despite the tendency for these communities to expand into urban sprawls.

B. Development should respect the sense of "place" created by the six basic land forms of the county.

C. Protection of the local environment should be accomplished by a county-wide Environmental Impact Review Board with legal authority over environmental violators.

D. Developmental controls are urgently needed now in the eastern urbanized corridor of Marin County to save the existing open space.

E. More controls are needed to regulate private development.

F. A balanced transportation system should be developed to prevent further deterioration of the environment due to the automobile.

G. Marin County towns must strengthen their local identities.

H. Incentives should be provided for meeting high standards of development.

I. Maximum holding capacity on the land should be related to desirable transportation, utility, hydrological, open space and general livability objectives.

The review that has just been given of various county plans indicates that small scale imagery as obtained from high altitude aircraft or even from a spacecraft such as ERTS-A might be a valuable tool to north coast county planners, but for different reasons for the different counties.

It appears that the four northern counties -- Sonoma, Mendocino, Humboldt and Del Norte -- still have an inadequate inventory of their total environmental complex. Small scale imagery would be useful in enumerating those physical parameters of the landscape which are of particular importance in determining the potential of an area in terms of land-use, be it natural resource utilization, urban development or industrial development.

Marin County, unlike the other four, has a good inventory of those features which have a significant impact upon scenic resources, recreation and the general quality of life, so that small scale imagery for resource inventory purposes may be of little extra value. However, the synoptic view provided by such imagery could still be put to good use. First, it can be used in the evaluation of the relative merits of three regional plans already proposed for the county, viz., the ABAG (Association of Bay Area Governments) Preliminary Regional Plan, the BCDC (Bay Conservation Development Commission) Plan and the Marin County Preliminary Open Space Plan. Secondly, the imagery might be a better medium than planning maps for use in presenting information to the public concerning the unfortunate consequences of past zoning policy decisions and the probable results of present zoning proposals.

B. Review of Other Coastal Surveys

In addition to county planning agencies, a number of regional and state organizations are concerned with land use planning in the north coastal region, and several have at least begun to map or gather data pertaining to that area. In particular, the State of California Department of Navigation and Ocean Development as a part of its Comprehensive Ocean Area Plan (COAP) Development Program, has mapped land use and site characteristics of the entire coastline of the state to a distance of at least 1/2 mile inland. The Association of Bay Area Governments (ABAG), as a preliminary step in the preparation of a Regional Ocean Coastline Development and Conservation Plan, conducted an Ocean Coastline Study in which maps were included of the four bay area counties which have an ocean coastline (Sonoma, Marin, San Francisco, and San Mateo). These maps include natural features and other features pertaining to land-use to a distance averaging two or three miles inland from the coast.

The COAP maps represent an operational application of remote sensing techniques to the problem of land-use and natural feature mapping in coastal areas. The entire coastline of Caifornia was photographed with 35 mm color transparency film from an altitude of 5000 feet. Photo interpretation was performed by COAP personnel on projected images and transferred to base maps at a scale of 1:24,000 (1 inch = 2000 feet). Areas as small as two acres in size were delineated. The interpretation process was such that an initial stratification was made between "developed" and "undeveloped" lands, the primary criterion being whether or not the area contained human uses identifiable by the interpreter. Developed areas were then subdivided into the appropriate land-use categories, and the undeveloped areas classified as to the dominant natural condition present. It has been estimated that in general the area accuracy, by category, of the finished maps is ±5%. Land-use categories used for developed areas were:

- Agriculture
- Communication
- Commercial
- Extractive
- Public Facilities
- Industrial - Manufacturing
- Parks and Recreation

The site characteristics used to categorize "undeveloped" areas were:

- Land Form
  - Beaches
  - Cliffs, steep slopes, landslides
  - Dunes
  - Island, sea stack
  - Mud flat
  - Sea stack, rookery
  - Spit, bar
- Natural Vegetation
  - Barren
  - Coastal forest
  - Redwood forest
  - Grassland
  - Hardwood
  - Woodland grass
  - Kelp
  - Marshlands, saltwater
  - Marshlands, freshwater
  - Riparian
  - Coastal sage
  - Cut-over redwood
  - Other vegetative types
- Water Areas
  - Open water, estuary
  - Open water, lagoon
  - Lakes and ponds
  - Reservoirs
  - Rivers and streams

In addition, the coastal areas were categorized as to ownership.

The ABAG study maps did not contain data gathered specifically for the project, but were compiled from a variety of sources. In general the maps are not very detailed, the smallest mapping unit being roughly 80 acres. Mapping topics presented in this study included gross geologic types, generalized soil types, slope class, land-use, vegetative cover, and ownership. Categories for land use were:

- Residential
- Industrial
    - Manufacturing
    - Warehousing
- Military
- Commercial
- Open Space
    - Regional recreation
    - Non-cultivated agriculture
    - Cultivated agriculture
    - Woodlands
- Transportation
- Institutions

and categories under vegetative cover were:

- Coniferous forest
- Hardwood forest
- Grass and forbs
- Chaparral and mountain brush
- Cultivated and pasture
- Barren
- Urban

In addition to the simple compilation of map data, both agencies express the need for a more comprehensive inventory system which would provide data amenable to continuous updating and rapid retrieval by interested persons. Also the data produced should be easily interfaced with exogenous data for purposes of environmental analyses.

C. Review of Legislation

It was hoped that perhaps some clue as to the appropriate scope of our investigations might be derived from a survey of the recent or pending state and federal legislation regarding the coastal areas. Certainly coastal land-use planning has been a popular issue for legislators during the past several years. In 1971 for example, no less than 9 bills were introduced into the Legislature of California which directly pertained to the coastal area. The only bill which passed, however, was one merely expressing legislative intent to protect coastal areas. No bills which would have required specific action became law.

During the 1972 session the Coastal Zone Conservation Act (Senate Bill 100) was introduced, and at the time of this writing was being considered by the Natural Resources Committee. A similar bill passed the Assembly during 1971, only to die in the Senate Committee. This bill "Creates the California Coastal Zone Conservation Commission and prescribes its membership, powers, and duties. It also requires such commission to develop, adopt, and submit to the Legislature the California Coastal Zone Conservation Plan, as prescribed, for the coastal zone as defined".

The bill defines the coastal zone as "extending inland to the highest elevation of the nearest coastal mountain range", but limits it to five miles inland in Los Angeles, Orange and San Diego Counties. Very little is specified as to the kinds of data that would be required by the Commission other than to state that its plan "shall be based upon detailed studies of all the factors that significantly affect the coastal zone". In general this is characteristic of all legislation reviewed, i.e., details of evaluations and inventories are left up to the specialists who would constitute the investigative body.

4.2.2 Future Proposed Work

During the next six months, the efforts of the Operational Feasibility Unit will consist almost entirely of preparation for the analysis of ERTS-A data which should become available in mid-1972. Probably the most important aspect of our work will involve the coordination of the Forestry Remote Sensing Laboratory activities with those of persons in the State of California directly concerned with the analysis of ERTS-A data for purposes of actual land use inventories and management. Most of the state agencies involved with resource development and management are aware of the fact that ERTS data will be available. However, considerable education and coordination of tasks will be necessary during the next several months to ensure that ERTS-A data are used to maximum advantage. The role of the Operational Feasibility Unit will be to establish lines of communication between the FRSL and those state agencies concerned with land use planning and wildland resource management in order to ascertain which specific problem areas should be the focus of the research carried out by the FRSL. It is hoped that in this way the research capability of the FRSL and the operational capabilities of the state agencies can be combined in such a way that the best use can be made of ERTS data. In essence, tasks must be chosen which are both important in an operational sense, and in the performance of which ERTS data might be useful.

ERTS data will probably be most useful for fairly gross land-use delineations and as the initial stage in regional resource inventories which will require supplemental aircraft imagery or ground data for their completion. An important preliminary step would seem to be a determination of a common land-use delineation system which would be of use to as many different agencies as possible. Hopefully, such coordination would also result from our discussions with the State agencies.

In addition to these coordination tasks, the unit will assist in the quantitative evaluation of mapping techniques applied to small scale aerial and space photography of the Feather River Watershed which has been described previously. Again, these exercises should be viewed as a learning process in anticipation of similar analyses which will be applied to ERTS-A data when they become available.

Finally, work will continue on the definition of specific studies pertaining to the coastal zone which will be undertaken in the future by personnel of the FRSL.

4.3 REPORT OF THE IMAGE INTERPRETATION AND ENHANCEMENT UNIT

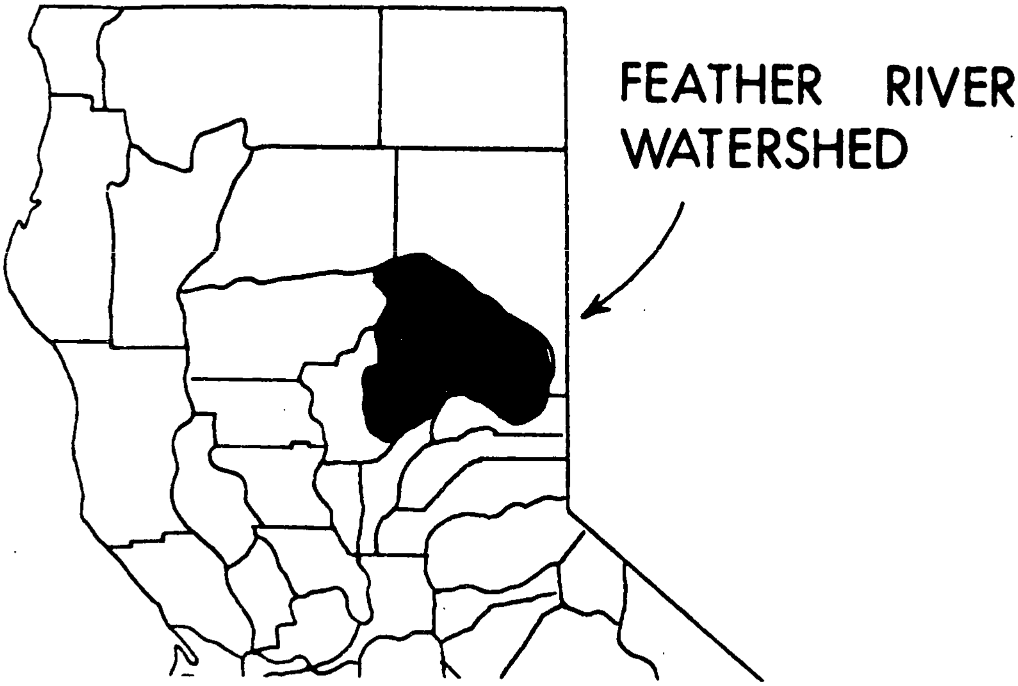
The primary objective of the research being performed by the Image Interpretation and Enhancement Unit (II&E) of the FRSL is to develop and refine methods for extracting useful resource information from remote sensing imagery -- using manual image interpretation techniques. Prerequisite to our work is an understanding of both the procedures used by a skilled analyst, when performing an image interpretation task, and the concepts on which those procedures are based. Thus, the many image quality factors (i.e., film-filter, scale, resolution, etc.) which govern the perception and interpretation of various kinds of features are being studied. By employing rigorous testing procedures when possible, we attempt to define the optimum combination of factors needed to solve specific resource inventory and/or monitoring problems with the aid of remote sensing. However, developing methodologies which may be applicable for resource surveys, not only in different wildland regions of the Unites States but also in other parts of the world, entails more than defining specifications for image acquisition and interpretation. We have found that we must define methods for (1) familiarizing personnel with the important resources of an area, (2) acquiring and preparing imagery for that area, (3) selecting photo interpreters, (4) training photo interpreters, (5) performing photo interpretation tasks, (6) compiling photo interpretation results, (7) collecting ground data information, (8) correlating ground and interpretation data, (9) evaluating interpretation results, and (10) disseminating results. Consequently, we are devoting considerable time and effort to the development of an understanding of the components of the entire image interpretation process.

Members of the II&E Unit at the FRSL have been studying for many years image interpretation technqiues applied to wildland environments, particularly within (1) the Bucks Lake test site (NASA Site #20) located in the heart of the Feather River watershed, and (2) the San Pablo Reservoir test site (NASA Site #48) in the California Coast Range. With the availability of high-flight (U-2 and RB57F aircraft) imagery and with ERTS-A and Skylab imagery forthcoming, we now, or soon will, have the opportunity to test certain techniques, proven to be useful in the localized test sites, in the adjacent and analogous, but much larger areas. Emphasis in the work that is being performed in these "extended" study areas is being placed on developing methods for effectively utilizing low resolution, synoptic view imagery, similar to that which might be obtainable from ERTS and Skylab vehicles. Specifically, three kinds of resource surveys within these important regions of California are being sought with the aid of manual image analysis techniques. They are (1) forestland vegetation/terrain surveys, (2) snow surveys, and (3) rangeland vegetation change surveys. Progress made since our last reporting date, January 1, 1972, in developing and applying the components of the interpretation process to these survey problems is presented below.

4.3.1 Work Performed During the Period Covered by this Report

Forestland Vegetation/Terrain Surveys in the Feather River Watershed

During this last year, personnel of the II&E Unit have concentrated their efforts on the following items which relate to the image interpretation process: (1) familiarizing themselves with each vegetation/terrain type occurring within the Feather River watershed and considered to be important by the hydrologist or watershed manager (for a complete listing, see the May, 1971, Annual Progress Report), (2) familiarizing themselves with available imagery and preparing high-flight imagery for image interpretation (see Figure 4.1), (3) preparing a series of



UPPER FEATHER RIVER WATERSHED (2-1/4 MILLION ACRES)			
Type of Data	Scale	Format	No. of Photos
Conventional B/W Photography (stereo)	1/15,840	9" x 9"	2,600
High-flight CIR Photography (stereo)	1/120,000	9" x 9"	58
ERTS-A RBV Imagery (non-stereo)	1/1,000,000	9" x 9"	1

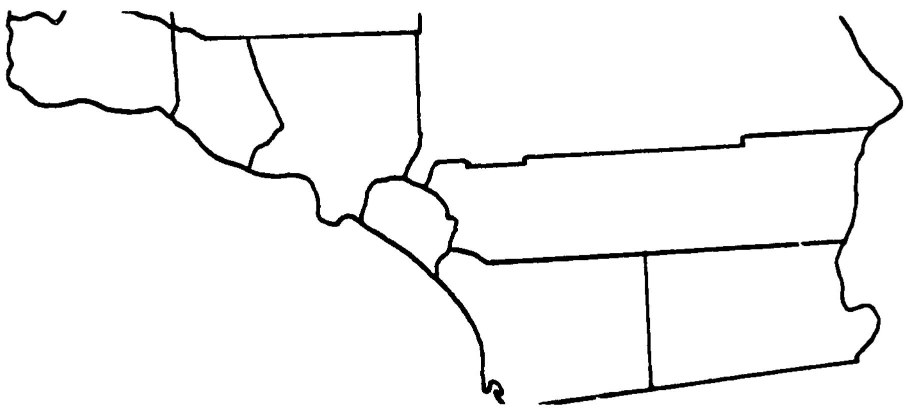


Figure 4.1. The entire Feather River Watershed, comprising over 2,250,000 acres of wildland, has been outlined on this map of California. Compare the number of photos required to cover this vast area when utilizing conventional photographs, high flight photographs or ERTS-A imagery, which should be available for study sometime this summer.

interpretation training aids (i.e., image interpretation keys) that will allow an interpreter to train himself to detect, identify and delineate each important vegetation/terrain type seen on the imagery, and (4) collecting ground data throughout the entire Feather River watershed, which can be used to further train the image analyst and to correct and improve his interpretation results.

A comprehensive listing of all imagery taken of the Feather River watershed and on file in the FRSL film library is given in Table 4.1. Note that an extensive amount of high-flight imagery, procured with the RB57 and U-2 aircraft, is now available for study.

In addition, several interpretation training aids (i.e., reference materials) have been prepared such that they could be used in conjunction with high-flight imagery. For example, one of the interpretation keys is for nine dominant vegetation/terrain types that are encountered in the Bucks Lake-Meadow Valley area.

Table 4.2 gives a summary of the image characteristics for each of the nine types, based on high-altitude, small scale, false-color infrared imagery. Once the image characteristics are well understood, an image interpretation key can be constructed which includes (1) a general description, terrestrial photography, a list of principal species and a discussion of image characteristics for each type (see Figure 4.2), or (2) a listing of image characteristics in a two-branched "dichotomous" fashion (see Table 4.3). The task of image interpretation is greatly simplified once the interpreter is familiar with the various resources within an area and has adequate reference

TABLE 4.1. IMAGERY OF THE BUCKS LAKE TEST SITE (SITE #20) AND FEATHER RIVER WATERSHED

ACQUISITION DATE	FORMAT	SCALE	IMAGERY TYPE: PAN	B&W IR	COLOR	CIR	MULTIBAND (FILTERS)	THERMAL IR	MISSION NUMBER	COVERAGE	ACQUISITION SOURCE	PLATFORM	INDEX MAP	SENSOR SYSTEM	LENS FOCAL LENGTH
9-29-41	9 x 9	1:20,000	X							B[1]	USFS		File[3] (Mosaic)	Fairchild K-17	6"
9-15-44	9 x 9	1:10,000	X (25A)							B	USFS		File	Fairchild K-17	8-1/4"
9-15-44	9 x 9	1:5,000	X (25A)							B	USFS		File	Fairchild K-17	8-1/4"
9-8-56	9 x 9	1:15,000	X (25A)							B	USFS		WCD[4]	Fairchild K-17	6"
5-59	9 x 9	1:5,000			AERO NEG					B	Airview Specialists		WCD		
6-4-65	70 mm	1:160,000						X	MX8	B	NASA	Convair 240A		Reconofax IV	
6-4-65	9 x 9	1:22,000			X	X			MX8	B	NASA	240A	WCD	Fairchild T-11	6"
6-4-65	9 x 9	1:8,500			X	X			MX8	B	NASA	240A	WCD	Fairchild T-11	6"
6-4-65	9 x 9	1:20,000	X (25A)	X (89B)					MX8	B	NASA	240A	WCD	Fairchild T-11	6"
8-4-65	70 mm	1:30,000								B				Hass	80 mm
9-26-65	9 x 9	1:10,000			X	X				B	NASA	240A	File	Fairchild T-11 Wild RC-8	6"
9-26-65	9 x 9	1:30,000	X (25A)	X (89B)						B	NASA	240A	File	Fairchild T-11 Wild RC-8	6"
10-29-65		1:170,000	K-Band Radar (SLAR)						99W-APQ-97	B	NASA	240A	CRES[5]	SLAR	
5-17-66	35 mm	1:30,000	TIR Linescan (a.m.)					X		B	Michigan	C-47	File	Multispectral Scanner	
5-18-66	9 x 9	1:6,000	X (25A)							B	NASA	240A	File	Fairchild K-17	6"
5-20-66	9 x 9	1:3,000	X (25A)							B	NASA	240A	File	Fairchild K-17	6"
5-20-66	35 mm	1:30,000	TIR Linescan (6 channels & 16 channels					X		B	Michigan	C-47	JDL[6]	Multispectral Scanner	
1966	Mosaic	1:62,000	X (12)							B	Cart[10]	Piper Com	WCD		
6-11-66	Mosaic	1:250,000				X				F[2]	Cart		WCD		
6-11-66	Mosaic	1:500,000				X				F	Cart		WCD		
6-11-66	Mosaic	1:1,000,000				X				F	Cart		WCD		
6-11-66	9 x 9	1:30,000			X	X				F	Cart	Piper Com	File	Zeiss RMK-A	6"
6-19-66	9 x 9	1:15,000	X							B	USFS		File	Fairchild K-17	6"
6-28-66	9 x 9	1:15,840	X							B	USFS		File	Fairchild K-17	6"
9-1-66	9 x 9	1:20,000				X	X		MX30	B	NASA	240A	File	Wild RC-8	6"
9-1-66	9 x 9	1:7,000			X	X			MX30	B	NASA	240A	File	RC-8	6"
9-1-66	70 mm	1:7,000					X		MX30	B	NASA	240A	File	ITEK (9-Lens)	
9-1-66	70 mm	1:20,000					X		MX30	B	NASA	240A	File	ITEK (9-Lens)	
10-24-66	9 x 9	1:30,000	X (25A)	X (89B)	X	X	X (47B,61,25A)			B	Cart	Piper Com	File	Zeiss RMK-A	6"
6-30-67	9 x 9	1:30,000	X (25A)			X				B	Cart	Piper Com		Zeiss RMK-A	6"

TABLE 4.1 (Cont'd.)

ACQUISITION DATE	FORMAT	SCALE	IMAGERY TYPE: PAN	B&W IR	COLOR	CIR	MULTIBAND (FILTERS)	THERMAL IR	MISSION NUMBER	COVERAGE	ACQUISITION SOURCE	PLATFORM	INDEX MAP	SENSOR SYSTEM	LENS FOCAL LENGTH
8-8-67	2 x 5	Variable					X (25,47B, 58,89)			B	LIU		JDL	ITEK (4-Lens)	7"
9-10-67	70 mm	1:7,000			X	X				B	Heller				
10-17-67	70 mm	1:130,000						X	MX59	B	NASA	240A	File	Reconofax IV	
10-17-67	70 mm	1:20,000	X (25A)	X (89B)			X		MX59	B	NASA	240A	File	ITEK (9-Lens)	
10-17-67	9 x 9	1:25,000			X	X			MX59	B	NASA	240A	File	RC-8	6"
5-28-68	9 x 9	1:20,000			X	X			MX73	B	NASA	NP-3A	File	RC-8	6"
5-28-68	9 x 9	1:7,000			X	X			MX73	B	NASA	NP-3A	File	RC-8	6"
5-28-68	70 mm	1:40,000	X			X	X (25A,47B,58)		MX73	B	NASA	NP-3A	File	Hass	
5-28-68	70 mm	1:10,000	X			X	X (25A,47B,58)		MX73	B	NASA	NP-3A	File	Hass	80 mm
6-25-68	70 mm	1:7,800	X	X (89B)	X	X	X (25A,47B,61)			B	Cart	Piper Com	File	ITEK (4-Lens)	
6-25-68	70 mm	1:7,500	X	X (89B)	X	X	X (25A,47B,61)			B	Cart	Piper Com	File	ITEK (4-Lens)	
6-25-68	70 mm	1:7,000	X	X (89B)	X	X	X (25A,47B,61)			B	Cart	Piper Com	File	ITEK (4-Lens)	
6-25-68	70 mm	1:5,300	X	X (89B)	X	X	X (25A,47B,61)			B	Cart	Piper Com	File	ITEK (4-Lens)	
6-25-68	9 x 9	1:10,000				X				B	Cart	Piper Com	File	Zeiss RMK-A	6"
6-25-68	9 x 9	1:6,000				X				B	Cart	Piper Com	File	Zeiss RMK-A	6"
7-3-68	70 mm wide	1:16,000			X					B	NASA			HYAC	12"
7-20-68	9 x 9	1:7,000			X					B	Cart	Piper Com	File		
7-20-68	9 x 9	1:2,000			X					B	Cart	Piper Com	File		
9-3-68	9 x 9	1:10,000	X (25A)							B	Cart	Piper Com	WCD	Fairchild K-17	8-1/4"
9-3-68	9 x 9	1:5,000	X (25A)							B	Cart	Piper Com		Fairchild K-17	8-1/4"
4-23-69	70 mm wide	1:60,000	X (25A)			X			HF-2	B	NASA	NP-3A		HYAC	12"
4-23-69	35 mm	1:920,000	X	X (89B)		X	X (25,58)		HF-2	F	NASA	NP-3A			
5-21-69	35 mm	1:760,000	X	X (89B)		X	X (25,58)		HF-3	F	NASA	NP-3A		Nikon	21 mm
5-21-69	35 mm	1:61,000	X (25A)			X	X (25,58)		HF-3	F	NASA	NP-3A		Nikon	21 mm
7-17-69	35 mm		TIR Linescan					X		B	Michigan	C-47	PFK[7]	Multispectral Scanner	
7-18-69	70 mm	1:240,000	X (25A)	X (89B)	X	X	X (25A,58)		ERTS MX100	F	NASA	RB57	PFK	Hass	3"
7-18-69	9 x 9	1:120,000			X	X			ERTS MX100	F	NASA	RB57	PFK	RC-8	6"
7-18-69	9 x 9	1:60,000				X	X (25A,58)		ERTS MX100	F	NASA	RB57	PFK	Zeiss	12"
7-18-69	70 mm	1:65,000	X (25A)						ERTS MX100	F	NASA	RB57	DTL[8]	HYAC	12"
7-20-69	9 x 9	Variable		X (89B)			X (25,47B,58)			B	LIU		WCD	ITEK (4-Lens)	7"
8-5-69	35 mm	1:920,000		X (89B)		X	X (25A,58)			F	NASA	RB57	WCD	Nikon	21 mm

3

TABLE 4.1 (Cont'd.)

ACQUISITION DATE	FORMAT	SCALE	IMAGERY TYPE: PAN	B&W IR	COLOR	CIR	MULTIBAND (FILTERS)	THERMAL IR	MISSION NUMBER	COVERAGE	ACQUISITION SOURCE	PLATFORM	INDEX MAP	SENSOR SYSTEM	LENS FOCAL LENGTH
8-5-69	70 mm	1:65,000	X (25A)			X				F	NASA	RB57	PFK	HYAC	12"
7-25-70	9 x 9	1:60,000				X			ERTS MX139	F	NASA	RB57	PFK	Zeiss	12"
7-25-70	9 x 9	1:120,000			X	X			ERTS MX139	F	NASA	RB57	PFK	RC-8	6"
7-25-70	70 mm	1:450,000		X (89B)	X	X	X (25,58)		ERTS MX139	F	NASA	RB57	SJD[9]	Hass	40 mm
3-17-71	70 mm	1:100,000	X							B	Cart	Piper Com	SJD	Hass	3"
4-19-71	70 mm	1:100,000	X							B	Cart	Piper Com	SJD	Hass	3"
5-71	70 mm	1:100,000	X							B	Cart	Piper Com	SJD	Hass	3"
6-14-71	70 mm	1:100,000	X							B	Cart	Piper Com		Hass	3"
6-2-71	5 x 5		K-Band Radar						ERTS MX167	B	NASA	NC130B	SJD	DPD-2 SLAR	
6-4-71	9 x 9	1:20,000			X	X	X (3 Bands)		ERTS MX167	B	NASA	NC130B	PFK	RC-8	6"
9-3-71	70 mm	1:420,000	X			X	X		ERTS 71-027	F	NASA	U-2	SJD	Vinten-A	1-3/4"
9-21-71	70 mm	1:420,000	X			X	X		ERTS 71-033	F	NASA	U-2	SJD	Vinten-A	1-3/4"
10-15-71	70 mm	1:420,000	X			X	X		ERTS 71-049	F	NASA	U-2	SJD	Vinten-A	1-3/4"
10-27-71	70 mm	1:420,000	X			X	X			F	NASA	U-2	SJD	Vinten-A	1-3/4"
12-8-71	70 mm	1:420,000	X			X	X			F	NASA	U-2	SJD	Vinten-A	1-3/4"
12-20-71	70 mm	1:420,000	X			X	X			F	NASA	U-2	SJD	Vinten-A	1-3/4"

[1]Bucks Lake -- NASA Test Site No. 20
[2]Feather River Watershed
[3]Forestry Remote Sensing Lab Film Library Files -- see S. L. Wall
[4]See W. C. Draeger
[5]Center for Research, Lawrence, Kansas
[6]See J. D. Lent (ADP Unit)
[7]See P. F. Krumpe
[8]See D. T. Lauer
[9]See S. J. Daus
[10]Cartwright Aerial Surveys

TABLE 4.2. IMAGE CHARACTERISTICS FOR NINE VEGETATION/TERRAIN TYPES FOUND TO OCCUR IN THE BUCKS LAKE-MEADOW VALLEY AREA

Based on High-altitude, Small Scale, False-color Infrared Imagery

FEATURE	TONE OR COLOR	TEXTURE	TOPOGRAPHY	LOCATION/ASSOCIATION
CONIFERS	Variable: purple-red to red-blue	Variable: rough, spiked	Mountainous slopes, ridges, gullies, all topographic types	Understory of brush and grass sometimes is visible
HARDWOODS, DRY SITE	Bright pink	Variable: medium texture, billowy	Mountainous slopes, and gullies	Usually associated with drier slopes
HARDWOODS, RIPARIAN	Bright red	Medium texture, billowy	Flat areas and gully stringers	Red fir forest; meadow areas
MEADOW, DRY	Light pink to pink	Smooth	Flats, depressions	Sometimes with streams and/or riparian hardwoods
MEADOW, WET	Bright red	Smooth	Flats, depressions	Sometimes with streams and/or riparian hard-woods; with alpine forest
LOW HERBACEOUS AND GRASS	Grey, grey-pink, grey-blue	Smooth	All topographic types	Burned areas; serpentine soils; under forest canopy
BRUSH	Medium pink	Smooth	Mountainous slopes and gullies	May be scattered trees; usually associated with drier slopes
WATER	Blue or black	Smooth	--	--
NON-VEGETATED	White to light white-pink	Variable: medium to rough	Any topographic types, especially steep granite	Granitic outcroppings; mining operations; cleared areas

Description:

The chaparral vegetation type is composed of multi-stemmed, woody, perennial shrubs ranging in height from 2 to 12 feet. The shrubs are often closely spaced and frequently found in large stands relatively free of other vegetation types. Mountain chaparral occupies both aspects of the western Sierra, ranging in elevation from approximately 4000 feet (Ponderosa pine belt) up to 9000 feet (Subalpine belt). It occupies both poorer soil sites unsuitable for timber production and disturbed timber areas. The primary use of mountain chaparral is to protect the watershed and secondly as forage for deer and livestock.

Principal Species:

Deer brush	Ceanothus integerrimus
Mountain whitethorn	Ceanothus cordulatus
Snowbrush ceanothus	Ceanothus velutinus
Littleleaf ceanothus	Ceanothus parvifolius
Fresno mat	Ceanothus fresnensis
Green manzanita	Arctostaphylos patula
Pinemat manzanita	Arctostaphylos nevadensis
Huckleberry oak	Quercus vaccinifolia
Bush chinquapin	Castanopis sempervirens
Bitter cherry	Prunus emarginata
Service berry	Amelanchier alnifolia
Mountain misery	Chamaebatia foliolosa

Image Characteristics (small scale, false-color infrared):

Mountain chaparral type as seen on high-altitude false-color infrared imagery appears medium pink with a smooth texture. The chaparral is conspicuously lower in height than coniferous and hardwood types. It is generally found in fairly large, continuous areas, though scattered trees easily may be seen rising above the brush. Chaparral can be found on all aspects and should not be confused with the generally flat meadow areas.

Figure 4.2. A portion (illustrating the mountain chaparral type) of a selective image interpretation key for nine vegetation/terrain types is shown here.

TABLE 4.3. A DICHOTOMOUS IMAGE INTERPRETATION KEY FOR NINE VEGETATION TYPES FOUND TO OCCUR IN THE BUCKS LAKE-MEADOW VALLEY AREA

Based on High-altitude, Small Scale, False-color Infrared Imagery

1.	Texture, smooth	2.
1.	Texture, medium to rough	6.
2.	Topography, flat	3.
2.	Topography, mountainous	5.
3.	Color, blue or black	Water
3.	Color, not blue or black	4.
4.	Color, bright red	Meadow, wet
4.	Color, light pink to pink	Meadow, dry
5.	Color, pink	Brush
5.	Color, grey or grey-pink	Low herbs & grass
6.	Texture, very rough	Conifers
6.	Texture, medium	7.
7.	Color, white or light pink	Non-vegetated
7.	Color, bright pink or red	8.
8.	Association, dry sites	Hardwoods, dry site
8.	Association, wet sites	Hardwoods, riparian

or training aids at his disposal. For example, a land classification scheme for the Bucks Lake-Meadow Valley area is given in Table 4.4 and preliminary interpretation results (boundaries only) for a portion of the area using this classification scheme and a comprehensive image interpretation key are shown in Figure 4.3.

While working closely with the Operational Feasibility Unit staff, we decided that a vast amount of ground data would be needed to allow us to evaluate image interpretation results in terms of type delineation and identification accuracy. Thus, during the four-month field season last summer, members of the II&E Unit concentrated on gathering ground data representative of all major vegetation/terrain types found throughout the Feather River Watershed. A justification for this activity and a description of the procedures used have been presented in section 4.2 of this chapter. Suffice it to say, that nearly eight man-months of time and effort were expended to gather both point data and type data at 160 ground positions systematically located throughout the watershed. Due to the watershed's immense size, rugged terrain and lack of accessibility, the field crew used a number of modes of transportation (driving, boating, hiking, etc.) to reach the plots and collect ground data pertinent to this study. We found that more than 90% of the field crew's time was used to travel using high-flight imagery as a guide from one plot on the ground to the next. Once the crew reached a ground plot, it was a relatively simple matter to record observations and measurements and procure representative terrestrial photographs of the site. The information gathered was recorded

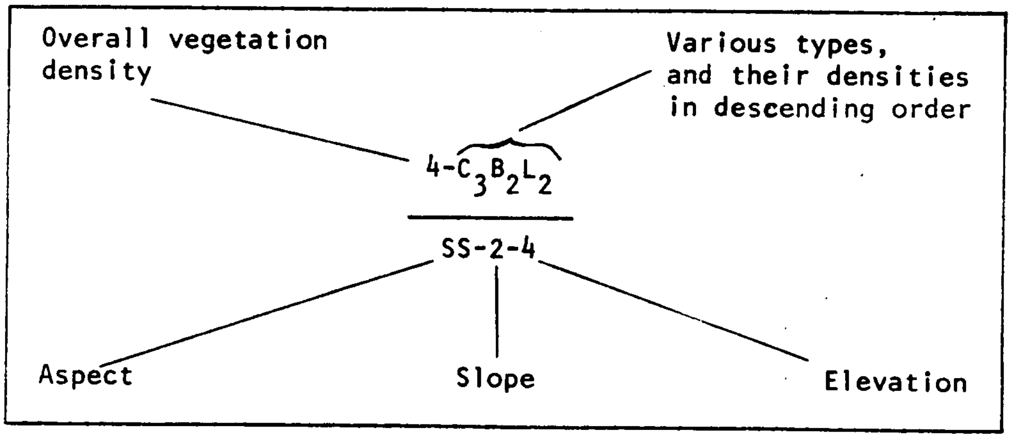
TABLE 4.4. A WILDLAND VEGETATION/TERRAIN CLASSIFICATION SCHEME FOR THE BUCKS LAKE-MEADOW VALLEY AREA

<u>Vegetation Density</u>

1 - 0-5%
2 - 5-20%
3 - 20-50%
4 - 50-80%
5 - 80-100%

<u>Vegetation Type</u>

C - Conifers
H - Hardwoods, dry site
R - Hardwoods, riparian
Md - Meadow, dry
Mw - Meadow, wet
L - Low herbs & grass (not M)
B - Brush
W - Water
N - Non-vegetated, bare soil or rock



<u>Aspect</u>

NN - North
NE - Northeast
EE - East
SE - Southeast
SS - South
SW - Southwest
WW - West
NW - Northwest
LL - Level

<u>Slope</u>

1 - Level; 0-3%
2 - Gentle; 3-10%
3 - Moderate; 10-50%
4 - Steep; >50%

<u>Elevation</u>

2 - 2000-3000 feet
3 - 3000-4000 feet
4 - 4000-5000 feet
5 - 5000-6000 feet
6 - 6000-7000 feet

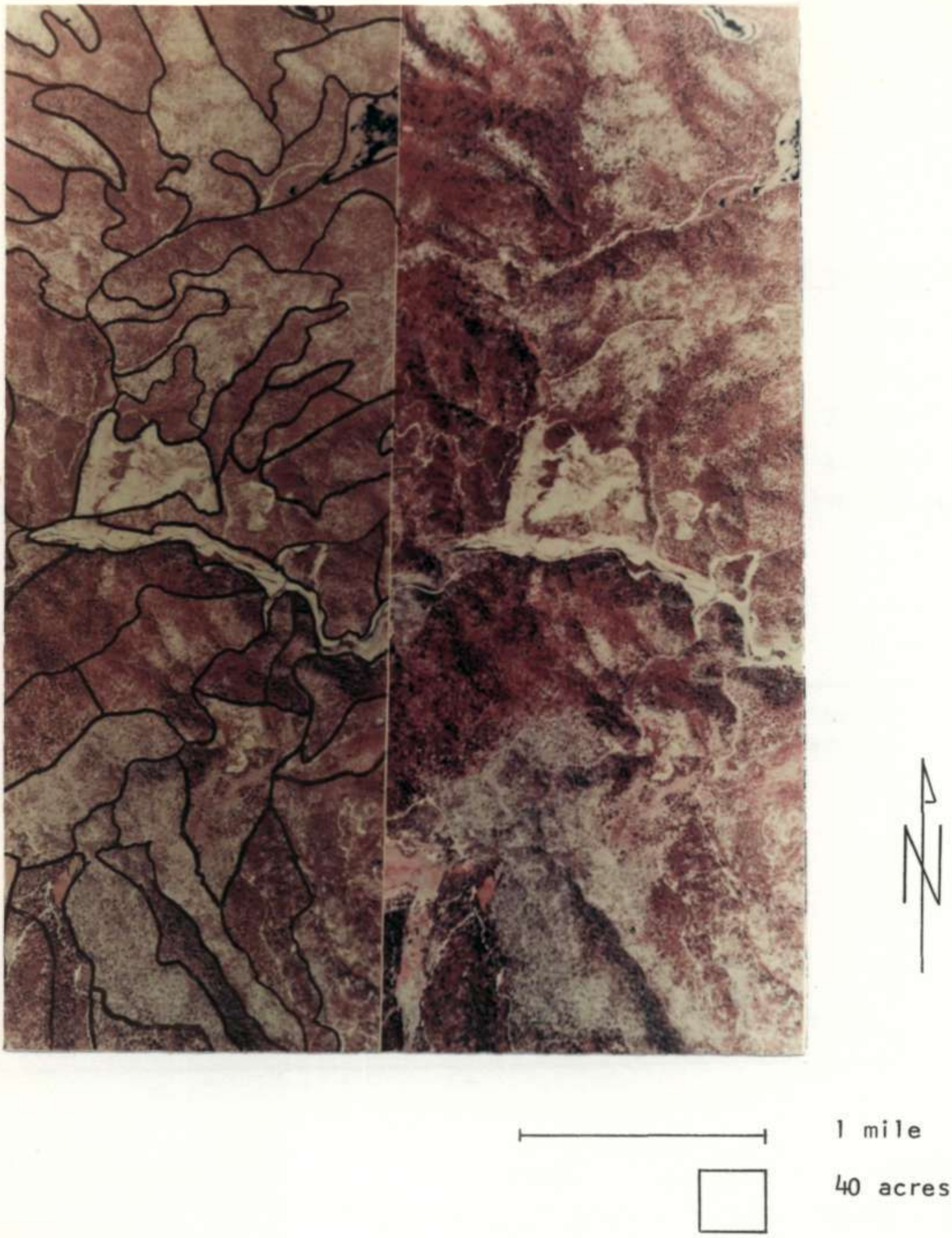


Figure 4.3. Preliminary interpretation results (boundaries only) obtained using high flight color infrared imagery are illustrated in this stereogram showing a portion of the Bucks Lake-Meadow Valley area. Note that vegetation/terrain units as small as 40 acres in size can be mapped on high flight imagery when the original photos are enlarged to a suitable scale. In this case the original imagery, obtained by the NASA RB57F aircraft, scale 1:120,000, has been enlarged to a scale of 1:45,000.

on 5" x 7" index cards (see Figure 4.4). In the future as additional ground data are collected, the information appearing on these cards can be easily transferred to IBM cards and entered into a computer. The information then can be efficiently and economically stored, retrieved, analyzed and correlated with image interpretation results.

Snow Surveys

The objectives of our snow survey work in the Feather River Watershed area are twofold -- viz., developing optimum image interpretation techniques for delineating snowpack on sequentially procured small scale, synoptic view imagery, and determining the accuracy with which snowpack boundaries can be delineated. There is little doubt that accurate, sequential and timely data on areal extent of snow would supplement conventional snow course data and, therefore, aid the California Department of Water Resources to forecast water yield (see Figure 4.5). Work performed during the winter of 1970-71, and reported upon in the January, 1972, Progress Report, involved (1) becoming familiar with snowpack conditions occurring within the study area, (2) acquiring at 5 different dates small scale (1:100,000) 70 mm photography of the Spanish Creek Watershed (Bucks Lake Test Site), (3) preparing the imagery for analysis, (4) training an image analyst to recognize snow boundaries even though their appearance can be greatly influenced by a variety of terrain features or conditions, (5) performing the interpretation task using a viewer-enlarger, and (6) compiling the interpretation results. Examples of the small scale imagery are illustrated in the

(front of card)

SURVEY: A PLOT #: 10 DATE: 19 July 1971 CREW: JPM & RMC

Veg.-Terrain Type: Mountain Chaparral	Geology: Volcanic
	Soil Depth: 1½'
Veg. Cover %, All Veg.: 95 %	Soil Color: 10YR 4/3
Veg. Cover %, Trees: 25 %	
Veg. Cover %, Shrubs: 90 %	Aspect: flat
Veg. Cover %, Herbaceous & Grass: 5 %	Slope: flat
	Elevation: 4500'
Avg. Canopy Ht., All Cover: 10'	
Avg. Canopy Ht., Trees: 40'	Location
	Survey: T28N R8E Sec. 15
	UTM: Chester Quad

(back of card)

SPECIES PRESENT

TREES: Pinus ponderosa, Abies concolor

SHRUBS: Arctostaphylos patula, Ceanothus cordulatus, Ceanothus prostratus

HERBACEOUS: Grasses, flowers (Compositae)

REMARKS: Brush field with scattered pine and fir coming in. Very few old trees. Some disease in the pines. Site seems pretty good based on yearly growth on young trees.

AERIAL PHOTO #: Z 195

GROUND PHOTOS: 1-6-11 thru 13

Figure 4.4. Ground data were collected for 160 preselected plots and recorded on field cards such as the one shown here. The information written on the card can also be punched onto the card's border using a digital code; therefore, specific information relative to ground locations or type characteristics can be rapidly retrieved.

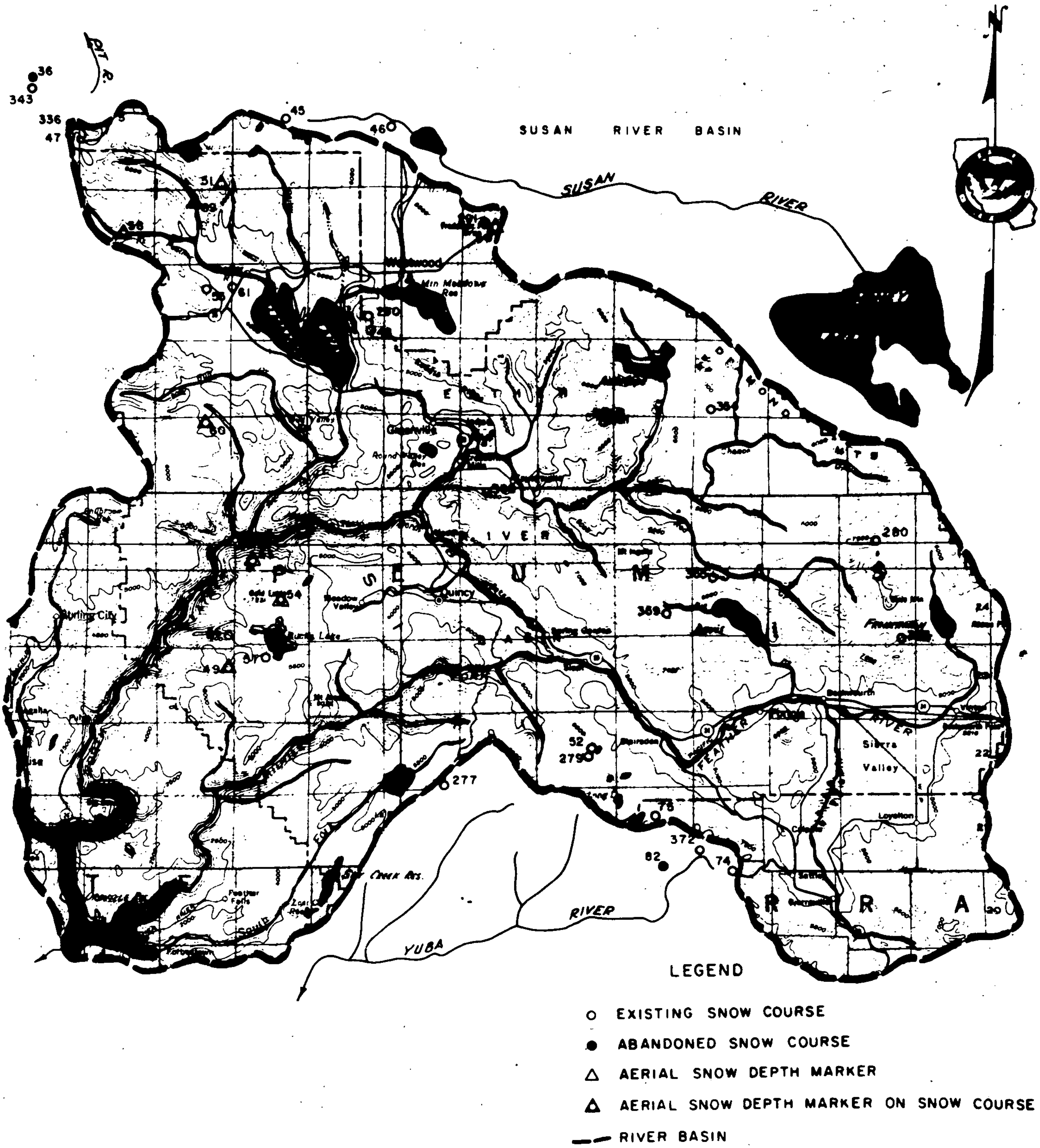


Figure 4.5. Section 228 of the California Water Code states that the Department of Water Resources will coordinate gathering and correlating snow and allied data, through the California Cooperative Snow Surveys Program, in order to forecast seasonal water supplies. Many county, state and federal agencies and private organizations participate in the program and obtain snow data by standard snow survey methods on established courses as well as supplemental measurements obtained from aerial snow depth markers. Note that for the 2-1/4 million acre Feather River Watershed, snow data are collected at 25 point locations from which water inflow forecasts are made for the Oroville Reservoir facility.

January report. We were able to conclude from this preliminary work that the task of delineating a snow boundary on sequential imagery often is a simple one. However, one component of the interpretation process was missing, namely, the collecting of ground data which could be used to further train the image analyst and evaluate his results. Consequently, we did not know if the plotted boundaries were in the correct position, and without adequate ground data it was impossible to determine this. Nevertheless, we learned that four environmental factors greatly influence the appearance of a snow boundary, viz., elevation, slope, aspect and vegetation/terrain type. For example, in certain areas the snow boundary appeared to follow a line of equal elevation but dropped down in elevation considerably on north facing slopes. In addition, we found that the presence or absence of snow and consequently the snow boundary was (1) easily detectable in meadows and bare areas, (2) sometimes but not always detectable in sparse coniferous forest and (3) nearly impossible to detect in dense coniferous forest. Thus, we concluded that if the image analyst were properly trained to recognize various combinations of environmental conditions, and if he were aware of the relationships among these various conditions and the appearance of snow associated with them, he probably could accurately place a snow boundary around the existing snowpack as seen on small scale imagery. Consequently, the principal objective of our work this winter and spring has been to develop the necessary training aids which will allow an interpreter to efficiently and accurately map the areal extent of snow.

The emphasis of our work has been placed on collecting ground data in conjunction with the NASA U-2 high-flight missions conducted on an 18-day cycle over the Feather River Watershed. However, there were times when no ground data were collected because either (1) snow was absent or (2) clouds obscured the area at the time of photography. As of this writing the status of this work is as follows:

U-2 Missions	Remarks	Ground Data Collected
9/3/71	no snow	no
9/21/71	no snow	no
10/15/71	no snow	no
10/27/71	cloud cover	no
12/8/71	cloud cover	no
12/20/71	good	yes
1/31/72	good	yes
2/21/72	cloud cover	no
3/6/72	good	yes
3/28/72	good	yes

The uncontrolled U-2 photo mosaic illustrated in Figure 4.6 shows the entire Feather River Watershed on December 20, 1971, a period of complete snow cover.

Permanent snow survey ground plots were established within the Bucks Lake Test Site and were visited each time when suitable high altitude imagery was acquired over the area (January 31, March 6, and March 28). These plots were located purposely at different elevations, on steep to moderate slopes, on several different aspects and under

Figure 4.6. The U-2 imagery currently being procured on an 18-day cycle over the entire Feather River Watershed will be analyzed for determining the accuracy with which snowpack boundaries can be mapped. Coverage obtained on December 21, 1971 is shown here in the form of an uncontrolled photo mosaic. FRSL field crews have established additional snow survey ground plots within the Bucks Lake test site. These sites are visited each time suitable U-2 high flight imagery is acquired over the area.

different types and conditions of vegetative cover. Personnel with the Snow Surveys and Water Supply Forecasting Section, Department of Water Resources, State of California, cordially offered to the FRSL use of two Mount Rose snow sampling tube sets. This equipment allows our field crews, travelling by snow mobiles when necessary, to measure snow depth, snow condition and water content at each permanent plot. The photo examples in Figure 4.7 show the locations of these permanent plots, and a crew member collecting a sample. Furthermore, during each high-flight mission, a FRSL crew obtained low altitude oblique aerial photographs of numerous snowpack boundary conditions which are not necessarily associated with any of the permanent plots.

After a sufficient amount of ground data has been collected, training aids will be compiled which will illustrate, as clearly as possible, the influence of elevation, slope, aspect and vegetation/terrain type on the image characteristics of snowpack conditions and boundaries. For example, three U-2 photographs sequentially obtained of the same area are shown in Figure 4.7. A deciduous hardwood forest type, on a 40% slope, facing to the north and at an elevation of 3600 feet is circled on these photo examples. The area is without snow in October and is snow covered in December and January. The snow was measured to be 2 feet deep on this site at the time of the January mission. Training materials, similar to what is shown in Figure 4.8 are being prepared for a wide variety of conditions found throughout the Feather River Watershed.

Possibly one of the first requirements during this study will be

Figure 4.7. In addition to the 25 snow courses maintained by the California Cooperative Snow Survey in the Feather River Watershed, FRSL personnel have located a series of permanent snow survey field plots (white triangles, top photo) in the Bucks Lake Test Site in areas considered to be reasonably accessible during the winter months. During each suitable U-2 overflight, the field crew measures, using a Mount Rose snow sampling tube set, snow depth, snow condition and water content at each permanent plot.

October 15, 1971 December 20, 1971 January 31, 1972

Figure 4.8. Development of an image interpretation key designed to aid an interpreter in the identification of snowpack on small scale, synoptic view, U-2 imagery is a primary objective of our snow survey project. The purpose of the key is to provide actual U-2 images showing snowpack under a variety of conditions present in a forested wildland area. The terrain conditions include various combinations of vegetation type, slope, aspect and elevation. Furthermore, each combination will be presented as it appears on successive dates so that the interpreter can see how each condition appears in different parts of the year and with different snow loads. For example, the photos above show a dry site hardwood area on a north facing, 40 percent slope, at 3600 feet above sea level on October 15, December 20 and January 31, respectively. The October image shows no snow on the study area, whereas, the December and January images indicate complete snow coverage. Our objective is to prepare a large number of examples such as these, depicting a wide variety of conditions in the format of a selective image interpretation key. Then, as an interpreter maps snow conditions in an area where vegetation/terrain conditions are already known, he can (1) turn to the pages of the key which illustrate these conditions, (2) make direct comparisons between image characteristics seen in the area to be mapped and in the key, and (3) make a decision, based on this comparison, as to whether snow is present or absent.

to define exactly what is a "snow boundary" or "snow boundary condition"; however, both high altitude imagery and ground data must be studied even before this decision can be made. Furthermore, a close working relationship with members of the California Department of Water Resources and researchers within the U.S. Forest Service will continue to be maintained as we progress with this work.

Rangeland Vegetation Change Surveys

There is a need to improve techniques for monitoring changes in range conditions as a means for predicting the amount, availability, distribution, and condition of the forage resource. The objective of our research on this topic is to demonstrate the feasibility of using small scale, synoptic view imagery to monitor changing range conditions throughout the California annual grassland.

The annual grassland in California occupies approximately 20 million acres. During the growing season the forage resource produced on these lands provides feed for approximately 60-80% of the 4.7 million cattle and 1.1 million sheep in the state. The use of these rangelands is seasonal, the duration depending upon environmental factors which regulate the timing of plant development and plant production. In the southern part of the state the grazing season may last only 2 to 3 months, whereas in the northern portion of the state grazing may continue for 8 to 9 months. The amount of forage produced at any given site is governed by climatic variables, and will vary from year to year in accordance with how favorable the climatic conditions are for forage growth.

Because of the seasonal variations in plant production and the length of the growing season at different sites throughout the annual grassland, a rancher can not accurately predict how many cattle or livestock he should graze on his range, how much feed will be produced, how long it will provide an adequate feed source, and how soon before he must move his animals to other pastures, ranges or the feedlot. It is visualized that by monitoring the change in range condition during the growth cycle, using remote sensing data, the rancher will have access to timely information for making better management decisions.

During the period between March 31 and April 2, 1971, the NASA RB-57F aircraft acquired high quality, small scale (1:100,000) color and color infrared aerial photographs of about 40% of the State of California. This high resolution photography showed most of the annual grassland associated with the Coast Mountain Range, extending from Ukiah in the north, to the Tehachapi Mountains to the south. The photography provided an unequalled opportunity to (1) view a substantial geographical portion of California's annual grassland at essentially the same time of year, and (2) make observations regarding the gross phenology and development of the grassland in various climatic zones, on different topography, and at different elevations, exposures and soil types.

Certain correlations between the physical environment of an area, and the development of the forage crop were readily discerned. For example, the forage crop had already matured and dried in areas which had received only 4" to 6" of rainfall; in areas receiving 8" to 12" of rainfall the forage crop was mature and appeared green on all areas of deep soils and north east exposures, but the forage had dried on shallow soil sites and on southwest exposures. Furthermore, the forage crop had not yet reached peak production or maturity in areas which had received more than 12" of accumulated rainfall. It was very apparent from interpretation of the small scale photography that one could assess the plant development and condition of the forage within any given geographic area, and that the conditon of the vegetation could be explained in terms of the current climatic regime which had prevailed during the period of the growth cycle preceding the date of the photography. It was found that within the 5" rainfall zone, seasonal rainfall was only 70-80% of normal. So even though the forage had already dried at the date of the photography, one could conclude that forage production was below average. Similar conditions existed in the 10" rainfall zone in the Coastal Range. In the 20" rainfall zone around San Luis Obispo, part of the forage especially on shallow and south-facing slopes had dried and part had remained green, especially that on deep soils or on north-facing exposures. Here, seasonal rainfall to date of photography was about 67%. One can assume that the range was drier than it normally would be on an average year, and that the amount of forage produced would be correspondingly low. In the 20" rainfall zone near Berkeley, California the rainfall was slightly above normal and the range vegetation was still very green. Inflorescences had developed on grasses occupying shallow soils, but for the most part foliage development was still in progress. The interpretations regarding conditon and production of the forage in the southern Coast Range made from the aerial photographs were borne out by Range Condition Reports issued monthly by the California Crop and Livestock Reporting Service.

To the extent that interpretations of range condition, coupled with existing climatic (rainfall) data, can be made for different rangeland environments on any given date, one can generate a dynamic model for predicting range condition and associated forage production throughout large regional grazing land, provided that one can monitor the changing conditions throughout the duration of the growth period. (The premises for developing such a model appeared in the January, 1972 Progress Report.) To this end preliminary studies have been initiated to determine if monitoring changing range conditions can lead to improved predictions of forage availability and production.

In September, 1971, the NASA U-2 aircraft began obtaining very small scale aerial photography (1:450,000) at approximately 18-day intervals. This program has continued through April, 1972. The primary areas photographed are centered around the Bay Area, the Feather River Test Site in the Sierra Nevadas, and the Los Angeles area. In addition, a transect of photographs was taken along the west side of the San Joaquin Valley to show the intrastate canal system. The photographs from around the Bay Area and those taken along the canal provided an opportunity to observe changes in the appearance of the annual grassland as the forage plants developed. Rainfall and temperature data were obtained and studied in conjunction with the changing condition of the rangelands.

The photos in Figure 4.9 were taken from a U-2 aircraft at an altitude of approximately 65,000 feet and show the rangelands east of Berkeley, California in the San Pablo Reservoir test site (NASA Site #48). The first photo was taken on November 19, 1971 and shows the grassland as appearing very dry, as indicated by the straw-color of the rangeland. This means that the forage crop had not yet germinated. On a normal year the new annual grassland crop would have germinated and begun to grow by late October; thus, interpretation of the small scale photography tells us that the forage crop is off to an unseasonably late start. In fact, sufficient rainfall to cause germination did not occur until the third week in November. The new plants were just beginning to emerge through the soil during the first week of December.

Despite its unrepresentative color, interpreters were able to locate a few areas on the December 7th photos where they could state with assurance that germination had occurred by virtue of the pink blushes associated with healthy vegetation. For the most part the rangeland at this date still appeared quite dry, because most of the new growth was still obscured by the residual dry material from the previous year. Because the crop got off to a late start, forage production was well below normal for that date. And in fact, grazing animals required supplemental feeds to be sustained on the range.

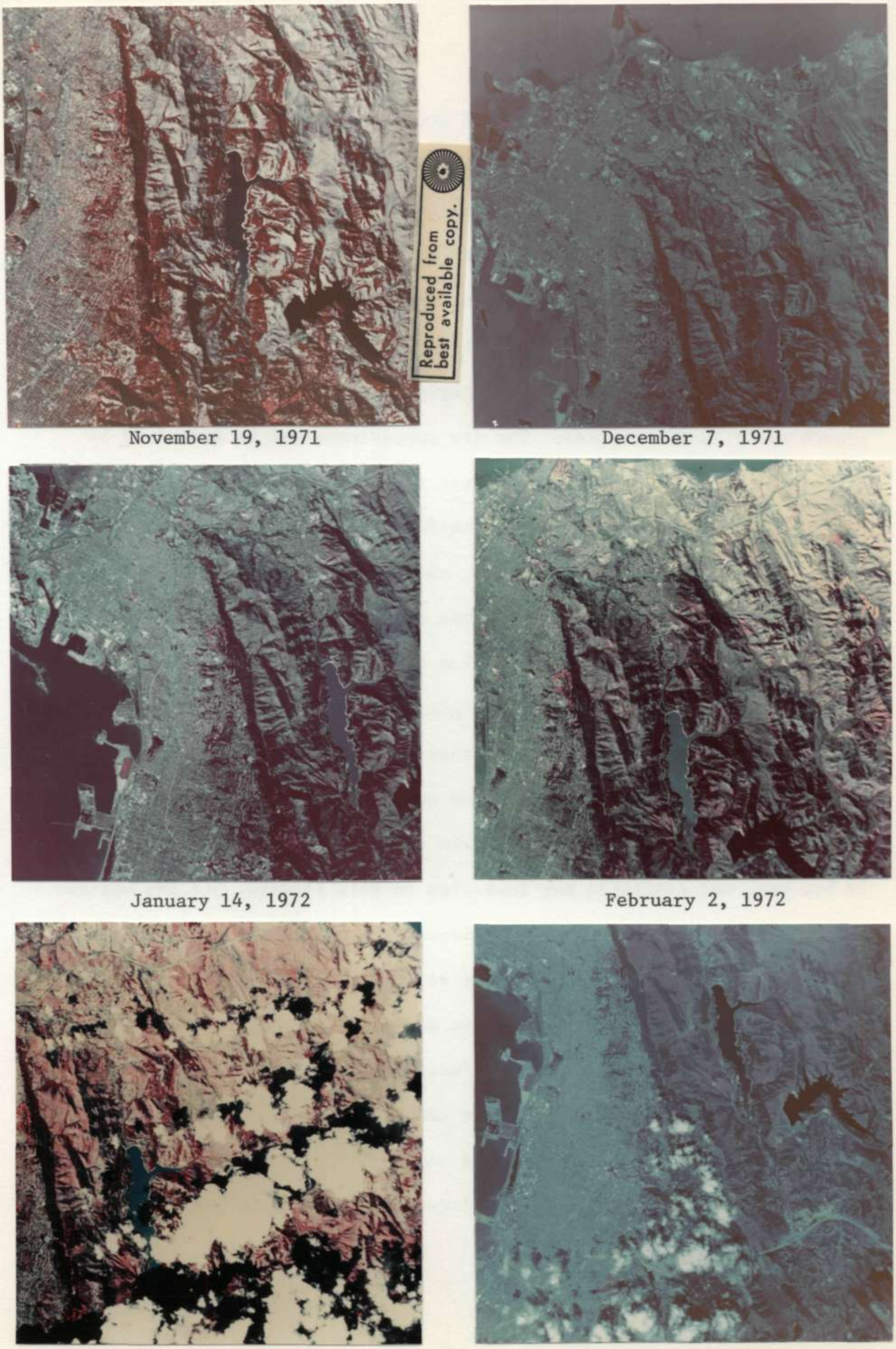


Figure 4.9. U-2 photographs taken of the San Pablo Reservoir test site near Berkeley, California.

The January 14 photo shows good ground coverage of annual vegetation on the better sites; however the absence of pink coloration on the upland sites suggests that growth has been slow and that complete ground cover has not been achieved. Furthermore, the heavy grazing pressure has prevented the annual plants from completely covering the ground. The fact that some upland areas still appear to be lacking in complete ground cover on the February photography indicates that a very poor growth cycle is in progress. The dry appearances can be explained by the late growth start, the cold winter temperatures retarding growth through December and January, the residual material from the previous year still obscuring new vegetation, and heavy grazing.

By February 22, it is seen on the high altitude infrared color photography that the annual vegetation has covered the ground on most all sites and the rangeland is beginning to look fairly homogeneously red, indicative of healthy green forage. These kinds of interpretations can be made despite the partial cloud cover in the area.

U-2 photographs of this same area were also taken on March 8 and 28 but were not available for inclusion in this report. Our own oblique photos taken from a light aircraft document the conditions in the rangeland environment on March 16, and April 7. They reveal that on the latter date the annual vegetation has matured on most of the upland sites having shallow soil. Annual forage on intermediate slopes has reached maturity while vegetation on the bottomland sites is just reaching maturity, but is still green and vigorous. This condition of plant maturity and development on the various sites within the same area we call "the photogenic stage", because this is the best time for distinguishing the various sites and making assessments regarding productive differences. Normally the "photogenic stage" for this rangeland does not occur until the first week of May. Thus it is apparent that the forage crop this year is maturing about 3 weeks earlier than normal. This, coupled with the late start of growth, spells a very poor forage production year. And in fact ranchers are claiming that the range is the driest it has been in thirty years. Animals in the southern ranges were leaving the range 30 to 60 days early and 100-150 pounds lighter than normal. These observations coincide accurately with rainfall conditions. During the month of March, which is one of the critical months for determining the condition of the range, the total rainfall was only .2 inch compared to an average monthly rainfall of 2.8 inches. Thus the information interpreted from the aerial photographs regarding the time of germination and the early occurrence of the photogenic stage, coupled with knowledge of the rainfall data, combined to produce two valid kinds of information which are important to the range managers and livestock owners: namely, (1) the length of the growing season of the forage crop is abnormally short, and the range is expected to be dry three weeks earlier than normal; and (2) forage production is also expected to be abnormally low resulting in lower weight gains by grazing animals and movement of animals from the ranges earlier in the season than normal.

Although such information may already be known by the individual rancher, there may be great benefit in knowing it on a regional basis so that timely and better decisions with respect to animal disposal and supplemental feed acquisition can be made. For example, ranchers who normally move their range animals to summer ranges may have to acquire extra supplemental feed for their animals while waiting for the summer ranges to be ready. The amount of feed needed will depend upon the amount of time anticipated between when available forage is inadequate and when the animals can be moved to summer range. Ranchers who normally move their animals to a feedlot may want to know what range conditions are being encountered by ranchers in other areas in order to time his movement of animals to obtain the best market price.

Moreover, the feedlot owner and the dairy man, two of the largest users of alfalfa hay for supplemental feed, want to know what other factors will affect the price of hay. An increased demand for alfalfa hay caused by a short growth period for native forage can cause an increase in demand for hay, thus pushing up the price of hay.

To the extent that observations and interpretations similar to those just made in the rangeland east of Berkeley, California, can be made in other rangeland environments throughout the annual grassland in California, a monitoring system can be established to determine the range conditions and the availability of forage in other portions of the state.

In order to explore the feasibility for monitoring range conditions within and between years, studies were undertaken to compare the range conditions in the Coast Mountains of California on April 1, 1971 (the date of existing high altitude photographs) with the range conditions this year. A field trip was taken on March 1 and 2, 1972, which transected more than 700 miles of rangeland in the Coast Range. At this time the existing range condition was observed and compared with those conditions interpreted from the high altitude photographs. Upon completion of the survey, it was concluded that most of the ranges were almost at the same stage of development as they were on April 1 a year earlier.

The first of two aircraft flights was made over the rangelands in the Coast Ranges on March 16, 1972. At this time the existing condition of the rangeland was again compared with the appearance of the respective ranges as seen on the high altitude photography. Upon completing this aerial transect it was concluded that the ranges were at the same stage of development (if not further developed) on March 16, 1972 as on April 1, 1971. A second aerial reconnaissance was made on April 7, 1972, at which time southern ranges were considerably drier than one year previously, as were those rangelands in the central and northern portion of the Coast Range. Based upon these comparative observations, we felt confident in stating on March 1, 1972 that range conditions in the southern portion of the Coast Range would be dry at least two weeks earlier this year than last year, and moreover we felt confident on March 16 that range conditions in the central portion of the Coast Range would be two to three weeks drier this year than last year. (These observations must be qualified by assuming that unusual changes in weather conditions do not occur.) Because rangelands in the different climatic zones develop at different rates and within different time periods, we were obliged to make a series of observations which extend over an indefinite time period. From year to year this period will be regulated by the weather conditions in the various climatic zones. Hence, a monitoring system such as that provided by the ERTS-A spacecraft is essential for observing the rate of plant development, and the time period during which these changes are occurring. Only under these conditions can one acquire the timely information for making predictions of range condition and forage availability. Such information will permit ranchers to make better decisions regarding movement of their cattle onto or off of annual grassland ranges, and also regarding acquisition of supplemental feeds to sustain their livestock during periods when the forage resource is inadequate.

4.3.2 Future Proposed Work

Forestland Vegetation/Terrain Surveys in the Feather River Watershed

Now that we are familiar with the hydrologically important vegetation/terrain resources for the entire Feather River Watershed area, and now that imagery has been acquired and prepared for analysis, and suitable interpretation training aids have been prepared, we can conclude activities relating to another component in the interpretation process, that of performing the photo interpretation tasks. Within the next few months, and well before our next reporting date in January 1973, we will have generated for the entire 2-1/4 million acres a series of map overlays (using simulated satellite imagery and ERTS-A imagery when it is distributed to us) showing major management units and a variety of vegetation/terrain categories. In addition, detailed map overlays will be made for each of several sub-watersheds using state-of-the-art high flight imagery. Since large amounts of ground data were collected during the last field season, personnel from both the II&E Unit and Operational Feasibility Unit will be able, immediately upon completion of the interpretation, to begin to correlate ground data with interpretation data. Thus, a thorough evaluation of the precision and accuracy associated with the interpretation results will be made. Each vegetation/terrain survey map will be thoroughly evaluated, with the aid of quantitative statistical methods, and definitive statements will be made concerning their accuracy and therefore, usefulness.

Snow Surveys

One additional U-2 high flight mission is scheduled this spring -- during the first part of May. It is anticipated that, because of the lack of precipitation and the unusual warm temperatures this spring, the melt season will be nearly completed by early May. However, ground data, principally in the form of low altitude oblique photographs of the few remaining snow boundary conditions will be procured.

Once imagery for all the U-2 missions has been processed and made available to us, we will complete the image interpretation key depicting the appearance of snow influenced by a wide variety of vegetation/ terrain, conditions. With the fully illustrated key in hand, interpreters will attempt to map areal extent of snow for the entire Feather River Watershed on at least one set of U-2 imagery taken on one date. The ground data collected by the FRSL crews (mainly low altitude oblique photographs) and by the California Cooperative Snow Surveyors will be used to analyze the accuracy of the snow boundary map. It is anticipated that the level of accuracy of the snow map will be high since an interpretation key will be employed indicating the relationships between appearance of snow and vegetation/terrain condition.

If it can be shown using quantitative methods that snow boundaries can be mapped on the U-2 imagery to an acceptable level of accuracy, an effort will be made, working with Professor Robert Burgy, Department of Water Science and Engineering, University of California at Davis, to experiment with existing and new runoff forecasting models using sequential data on areal extent of snow as additional input information.

Rangeland Vegetation Change Surveys

At the present time, we are awaiting U-2 photography taken during March and April over the San Pablo Reservoir test site. These photos, when added to those already presented in this report, will help to illustrate how the time of the growth season of annual grasslands can easily be monitored. We are continuing to interpret the photos taken in April, 1971 and those taken this year to seek recognizable conditions which permit a comparison of conditions from one year to another. In addition, we are analyzing the rainfall and temperature data for various climatic zones within the Coast Range to determine how amount and distribution of rainfall affect forage development. We also are seeking to determine the critical period (calendar dates) when monitoring is essential for making predictions of forthcoming forage condition.

4.4 REPORT OF THE AUTOMATIC IMAGE CLASSIFICATION AND DATA PROCESSING UNIT

The primary function of this unit, as part of the Laboratory's overall image analysis capability, is to study techniques which utilize data processing equipment as a means of extracting useful information from remote sensing imagery. The emphasis is upon information, not just data extraction, because often the ability to generate data from pictorial or taped records is not always a clear indication that successful information of use to, say, the vegetation resource manager will be forthcoming. Thus, our specific activities have stressed the derivation of "information" through automated and semi-automated digital processing techniques. The FRSL Terminal/Display system has been designed to facilitate the process of reducing data in a variety of formats to a digestible state for producing useful resource information. With the total efforts of the FRSL directed towards both manual and automatic feature identification and classification, it is easy to see that we are ideally suited to examine and define an effective interface between man and machine insofar as vegetation resource analysis is concerned.

In addition, the current status of the Terminal/Display system is such that utilization by other participants in the study is a factor which governs our approach towards software development. It is planned that non-FRSL personnel will have occasion to conduct studies with the aid of the Terminal/Display system. Much of the discussion of the current state of development of this facility is aimed primarily at describing its flexibility and versatility for feature classification. A glance at the components which make up this facility readily indicates its diverse input/output configuration which enables thorough digital processing from both a feature classification and a feature enhancement standpoint (since these two processing functions are clearly interrelated). However, some excellent examples of resources feature enhancement are present in the chapter by Dr. Algazi, a co-investigator in this study who has a complementary role in data processing from the standpoint of developing "enhancement" techniques rather than classification. Both techniques of image processing are herein reported upon, with chapter 8 covering the enhancement aspects, primarily, as a complementary effort to our classification work.

It seems appropriate for this second year's Progress Report to document in some detail the status of all aspects of our image classification and data processing activities as they relate to the primary objectives of this study. We have certainly reached a stage of development whereby the product of our "system" definition -- namely, the FRSL Terminal/Display facility -- enables us to conduct "R&D" applications studies which combine the best attributes of manual and automated data interpretation techniques. But our energies have not been directed solely towards "equipment development". As we reported in our first annual summary of activities, several potentially useful areas of future research are clearly evident. We have made significant progress toward the effective utilization of image processing techniques through the Terminal/Display system and have developed a computer-oriented storage and retrieval capability ("data bank") for use by the resource manager. The current status of these activities is described in the present progress report.

4.4.1 Work Performed During the Period Covered by This Report

A portion of our effort during this reporting period has directly involved systems development leading to the current status of our FRSL Terminal/Display facility which is next described.

FRSL Terminal/Display System Status

A review of last year's Annual Report indicates that the system contained the following components:

- a process control "mini-computer" with 8K words of memory
- a cassette tape recorder for special local applications
- a prototype scanning microdensitometer
- a keyboard and teletype with I/O capabilities
- a data link to nearby CDC6400 computer center facilities
- a 9-track industry-compatible magnetic tape drive
- a storage tube CRT device for display and graphics

As of this writing, we have added the following components as per our original ADP equipment proposal documentation for this study:

- components for 1/3 of our color display subsystem (these include a Hughes Model 639 Scan Conversion Memory device and a 19" color monitor)
- a small digital disc for high-speed data (pictorial) manipulation
- a graphics "joystick" controller
- a high-speed paper tape handling capability (read and punch)
- a hard copy unit for recording images derived from the CRT screen

Additionally, under separate funding sources, we have incorporated several components designed to facilitate the system's versatility. These include an updated scanning capability for our microdensitometer, an additional 9-track tape unit for tape-to-tape data manipulation, and a punched card reader. These additional components are described subsequently. Figure 4.10 contains a current schematic of the total FRSL Terminal/Display configuration. All of the components of the system that are presented in Figure 4.10 are briefly described next. Detailed schematics and interface logic for each component are available, but they contribute very little to this presentation, since the user of such a facility is primarily interested in what the peripherals can do for him and how reliably these functions can be performed. It is in this context that component descriptions are presented. In each case of component specification and selection, utmost care has been taken to obtain the best device for the money invested to insure that our overall data processing and image analysis objectives would be met.

A. Hardware

The components are described and referenced by number to those appearing in Figure 4.10.

1. Process control computer; this device is essentially as described previously, a 16-bit word length "mini-computer" possessing 8K words of core memory. All interfacing of peripheral devices which the computer controls is done "in-house" with the exception of the disc controller.

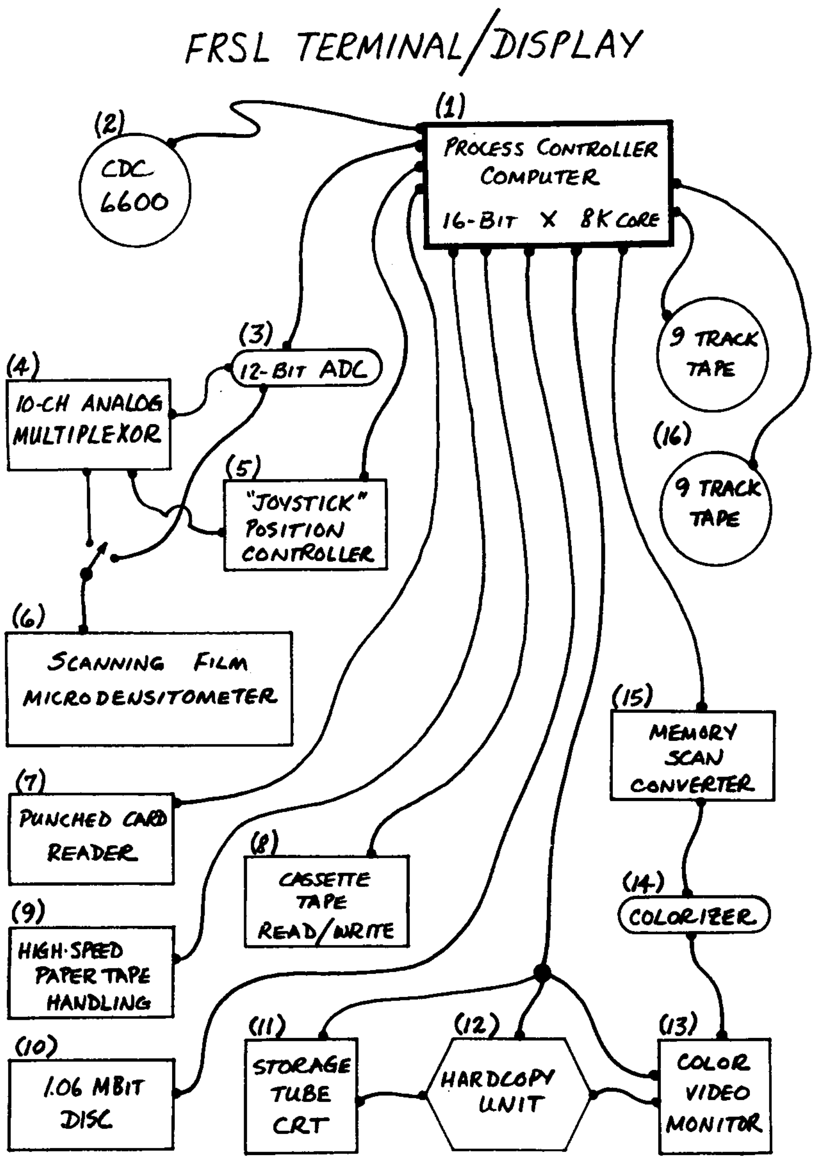


Figure 4.10. FRSL Terminal/Display System. The schematic at the left shows the interrelationships of the various system components. The heart of the system is the "Process Controller" computer. Each device is designated by a parenthetical reference number which corresponds to its description in the text.

2. Communication link to a large high-speed general purpose computer; our line-of-sight device for transmitting data between stations is currently suspended as a developmental activity in favor of the more conventional phone line hookup between stations. Our line-of-sight device is about 80% complete and will be fairly easy to return to in the future as time and funds permit. We have implemented a link-up at a facility possessing greatly reduced cost to our projects as well as adequate support services for our requirements. This line is to a very large high-speed CDC6600 computer. Our transmission rates are currently 4800 baud but with improved circuit analysis we expect to at least double this rate. This will enable us to fully utilize the power of the larger computer for some of our studies. This line is essential, of course, to our requirements for a large computational capability for multiband tone signature and texture analyses. We have a modified version of the LARS pattern recognition routines presently operating on the CDC6600. Since the closed-shop general purpose computer is unsuitable to an effective man-machine interaction for interim decision making, some sort of facility for gaining access to the processing operation is necessary. This is accomplished through a remote terminal facility whereby we can transmit partial operations to our FRSL station for CRT display and decision-making prior to continuing the classification programs, without requiring a dedicated project computer at prohibitive expense.

3. 12-bit analog-to-digital converter. This was part of the system last year but has not been described in any detail. It allows

us to digitize an analog signal, such as the one obtainable from the scanning microdensitometer, for subsequent processing.

4. 10-channel analog multiplexor. This also was a part of last year's system configuration but was not described in any detail. It allows us to "enable" up to ten analog signals from various devices which can then be singly selected via computer control, depending on the processing objective. For instance, it is used for the potentiometric decoding of the X and Y positions of the "joystick" device described next.

5. "Joystick" position controller. This console device has a computer-decodable position analysis and pushbutton function generator. The controller is used to locate or select data from some logical output device (usually one of the CRT devices). It will ultimately be used in general graphical applications. It also will be used for training sample selection of coded imagery for transmission of coordinates in connnection with our pattern recognition routines.

6. Scanning film microdensitometer. This is roughly the same device as was described in last year's report, but with the modifications proposed therein now implemented. A commercial movable stage was purchased to upgrade the positioning accuracy. Improved circuitry was also included in this new version such that sampling frequency for film densities could be as rapid as 2000/second, a ten-fold increase over the old system. We have also improved the light source to 1000 watts intensity giving us increased sensitivity at the darker densities and also yielding a more desirable color temperature for density analysis

work. Apertures are estimated to be about 20 microns.

7. Punched card reader. Our 400 card per minute reader is now an integral part of the system as an input device.

8. Cassette tape read-write device. This device is essentially as described in last year's report. An additional "read only" cassette device has been added for use in conjunction with our FRSL ground data collection system, described elsewhere in this report.

9. High-speed paper tape handling. Both paper tape reading (300 characters per second) and paper tape punching facilities have been implemented on the system during the past year. These facilitate principally the assembly and recording of programming routines for local station operation.

10. 1.06 Mbit disc. This device has just recently been added to the system and, as described previously, will function as a high-speed image storage device as well as "interim" data manipulation and storage facility during operation of the pattern recognition programs using the transmission links.

11. Storage tube CRT. This is unchanged from last year's description. Up to 800,000 addressable coordinates can be referenced on the screen, which makes it a high resolution device for pictorial and graphics applications.

12. Hardcopy unit. This device was added as a means of providing "hardcopy" printouts of the material contained on the storage tube screen. Several of the examples included in the illustration section of our present report are copies made from this device.

13. Color video monitor. An additional output device is our color monitor which works in conjunction with some of the other peripherals. This particular device was originally proposed to be used in a multi-iamge subsystem as the primary display unit. As of this printing we have only implemented a single channel configuration. We have, in previous progress reports, described the complete three-channel subsystem. The complete color display subsystem remains unchanged from our original proposal. The hardcopy unit will be modified in order to reproduce pictorial information from the face of the color monitor as well as it now performs this operation on the storage tube CRT.

14. Colorizer. This special unit is used in conjunction with the closed circuit video subsystem for adding colors to linearly sliced density information (greylevels) detected by a conventional video camera. Six levels are sliced with three or more slices being assigned a discrete color code for display purposes.

15. Memory scan converter. This is an additional special device that is used in conjunction with our originally prescribed color display subsystem. The unit serves as an interim read/write storage memory under computer control with subsequent readout to the color CRT monitor for display.

16. Two nine-track magnetic tape drives. During the past year an additional tape drive was added and both controllers implemented to be industry-compatible. Tape-to-tape and duplication routines are available for outside users possessing nine-track computing capability. Also, this configuration is very compatible with ERTS digital tape formats

and our own computer word length specifications.

B. Software

Along with our hardware development efforts, there logically must be software support to enable effective use of such equipment. Here, our activities have been structured in a way which would permit us to move ahead in several areas of application with the ultimate objective of bringing all aspects of our software in common register with the terminal transmission capability of the Terminal/Display facility. These application areas are: (a) pattern recognition (spectral response) analyses of multichannel sensor data, (b) texture (spatial frequency) analyses of various scales of sensor imagery, (c) optical density analyses, (d) analyses of computer-generated graphics for mapping and feature delineation, and (e) development of data storage and retrieval techniques. We have devoted considerable effort to each of these areas of application, as the illustrations section reveals, because they are critical factors in keeping pace with requirements for data processing and data manipulation as imposed by the potential users of such techniques. Also, these feature classification and enhancement topics are directly applicable to our progression from the analysis of sensor data obtained from high altitude aircraft to the analysis of ERTS-A satellite sensor data.

Briefly, the capabilities provided by our current software package in each of the areas mentioned are described next. We are working on a "User's Manual" which will describe the total capability of our system from the user's viewpoint. We will incorporate the ideas and suggestions of skilled image interpreters in the development of this manual in order to insure proper conceptual balance between natural science and engineering science. Our Laboratory structure places us in an ideal position to implement an effective interface between manual image processing techniques and automated techniques.

a. Multichannel pattern recognition routines. As mentioned in our first year's report, it is not the purpose of our activities to duplicate hardware or software developed at other institutions, since this is neither in the best inerests of NASA nor consistent with our overall study objectives under which we seek to use limited funds to best advantage in carrying out our various tasks. Rather, we have been successful in adapting certain software routines to our particular computer facilities instead of rewriting them completely. We have done this with the automatic pattern recognition programs developed at the Laboratory for Applications of Remote Sensing (Purdue). These routines enable man-machine interaction in the automatic recognition of spectral information recorded in as many as twelve channels of sensor data. These routines have been adapted to the CDC6600 computer at the Lawrence Berkeley Laboratory and some results of spectral analysis utilizing our version are described in a later section.

Ultimately, this technique will be upgraded to enable the interaction of the full capability of our Terminal/Display facility. Presently, we scan the optical densities in multichannel photography (or we may scan, as an alternative procedure, multi-date photography) and transmit these data successively to LBL for pre-processing of a greylevel map for the selection of training samples. From such samples we can define the spectral properties of features we wish to automatically recognize elsewhere in the imagery. Our plan is to complete our software to the extent that initial scan and display can occur at our local station. In this way we can implement the joystick device for the selection of train- samples to transmit to the LBL for final processing. Some examples of our local station scan and display are included in the illustrations section.

Not all pattern recognition and related data processing operations need be conducted through a linkage to the LBL computer facilities. One of the real strengths of the system we have implemented is its reliance upon large computer interaction <u>only when it is required</u>. Our local station data manipulation capability, while quite modest in comparison to the LBL facilities, easily accommodates single-image density slice and display routines for isolating particular features of interest in a scene. Figures 4.11 and 4.12 show digital density slicing for feature extraction purposes. Figure 4.17 illustrates similar techniques using the color monitor for display purposes.

b. Texture analysis routines. In addition to the information which can be extracted from a point-by-point classification of spectral responses recorded on sensor imagery, considerable use can be made of the textural, or spatial frequency, component of this same recorded signal. Thus, it is useful to consider not only the "spectral signature" analysis technique just mentioned but also the "textural signature" analysis which is to be

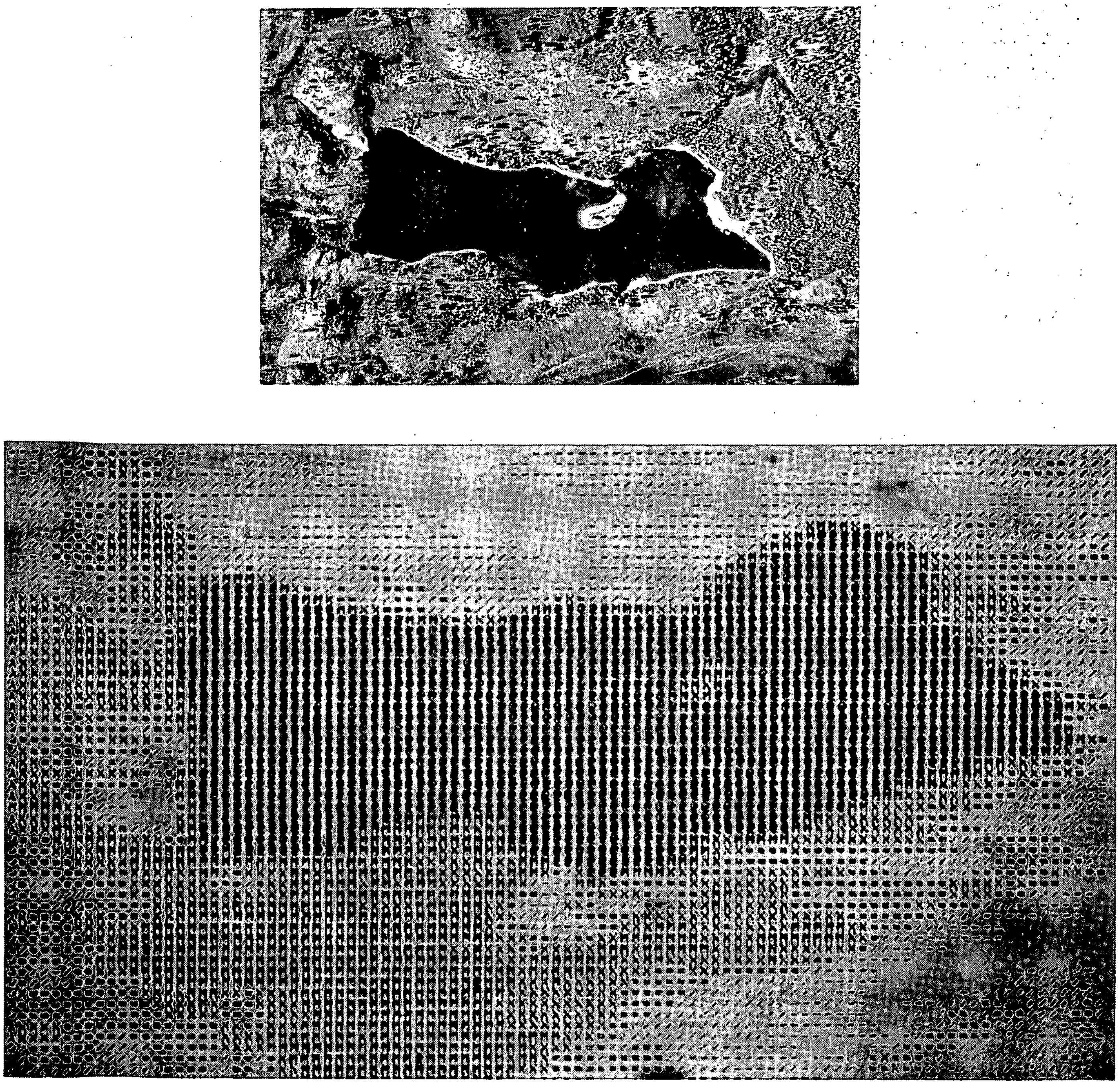


Figure 4.11. Digital density slicing and display capabilities are demonstrated above. The photo at the top is a print (enlarged 25x) of the negative scanned and displayed in eight density levels. Any number of "slices" can be viewed as a preprocessing procedure. Eight are shown here for illustration purposes. Areas represented by slices are readily available as a percent of total area sampled.

Figure 4.12. Part of the area shown in this figure is snow-covered. Snow vs. "everything else" is depicted in this illustration. A comparison with the original photograph from which this display was derived indicates excellent results for the detection of "SNOW" when it is not obscured by tree shadows. The light toned symbols above denote snow; some of the darker symbols appearing within the snow boundary are commission errors caused by scattered tree shadows (about 5%). Otherwise, as expected, the technique of using a microdensitometer to detect and subsequently enhance through digital processing a feature such as snow proved very successful.

described. The applications section describes specifics of some studies currently being conducted using texture as a correlative parameter in the information extraction process leading to improved image interpretation performance. Basically, the technique involves the scanning of various spatially distributed features (such as forest stands of different densities) with the use of a locally run transform routine based upon a one-dimensional Hadamard transform algorithm. The Hadamard transform was chosen because of its low computational cost (compared to other transform routines) and its ease of operation within our system components. The routine generates a series of "digital masks" of increasing periodicity and causes these masks to shift regularly and sequentially in relation to the scanned image, thus producing a series of energy coefficients. The minimum, maximum, and mean energy coefficients are computed for each scan line and averaged over several scan lines within data of "homogeneous" spatial frequency properties (as may be determined by an interpreter in conventional timber typing operations on aerial photography). Finally, these coefficients are correlated with other data derived from the areas of interest, as described in later examples. Preliminary results using this procedure with forest stand densities show high correlations with many of the parameters used in making cutting and forest management decisions.

c. Optical density feature extraction studies. These digital techniques have already been mentioned earlier. They involve use of the scanning microdensitometer in conjunction with the storage tube display and one of the data storage devices (magnetic tape or disk).

An image is scanned under direction of the user who places dimensional parameters defining his area of interest. Upon completion of the scan, a computer generated histogram is displayed on the storage tube for inspection by the user. This histogram consists of the frequency distribution of density values recorded through the a/d converter electronics. Often peaks and valleys appear in the historgram suggesting suitable "slices" which define homogeneous density levels. Up to eight slices can mechanically be selected by the user with the joystick as a pointer device. Following slicing, the computer generates a pictorial map with symbols assigned to each sliced level for viewing purposes. With some data (imagery), it is possible to isolate features directly with this procedure. Of course, once a useful slice has been made in the digital data, it is an easy process to derive the area represented by the slices. Thus, in a relatively few and easily understood processes, it is an easy process to derive the area represented by the slices. Thus, in relatively few and easily understood processes, it is possible to derive information from considerable amounts of data.

d. Graphics for mapping and feature delineation. A package of software routines has been developed for use with the storage tube display and the color CRT monitor. These routines enable the user to generate alphanumerics and vectors, and to plot in a point mode. All of these capabilities are useful attributes for a computer controlled graphics system. These routines utilize the joystick device and the CRTs. Examples of graphics were presented in last year's report and no further examples will be presented at this time. It should be fairly easy to see the potential application of the graphics capability to that which has already been herein discussed. Training sample selection, feature selection and display, mapping of information directly upon scanned data, automatic transfer of ground truth data to digital maps for coding purposes, mapping coordinate generator, and many more applications are possible with the addition of the graphics capability.

e. Data storage and retrieval techniques. Our data bank storage and retrieval system has evolved to its present status during the past year. The system is called MAPIT and is essentially operational from the user's viewpoint. As with all data bank systems, the most time consuming aspect of its development stems from time required for the assimilation and reduction of source material for digestion by the computer into what we call profiles or maps. The following is a brief discussion of MAPIT. Examples of applications are discussed in a subsequent section.

MAPIT consists of a package of FRSL computer subroutines providing for the efficient storage, retrieval and updating of one or more profiles of resource data. It is written in FORTRAN IV and COMPASS and was developed for use on the CDC6600 computer at the Lawrence Berkeley Laboratory. The routines are comprised of several mapping systems which are commonly used in practice today, with the best features of each being incorporated into our version in order to facilitate the handling of a more diverse set of input profiles. MAPIT relies heavily upon the usage of mass storage devices (i.e., disc, drum, magnetic tape, etc.).

A "profile" is the result of translating triplets of data into spatially oriented X-Y pairs through conventional coordinate reference and an associated "Z" value. For example, the topographic map conforms to this set of requirements by a translation of XYZ triplets (i.e., longitude, latitude and elevation) into XY pairs with the Z value coded as a contour interval. Many maps also have additional information superimposed upon these three elements, such that Z can be thought of as an open-ended population of subelements (Z_1, Z_2,...,Z_n), each of which denotes a different "attribute" or condition associated with its respec-XY pair. By virtue of this configuration, it is fairly easy to represent three dimensional data in two dimensions. And due to the manipulative characteristics inherently associated with MAPIT's subroutines, it is also fairly easy (and often desirable) to not only "take a look" at particular stored profiles in their original state, but also to create "new" data files through the combination and correlation of existing profiles.

MAPIT was conceived to operate with data whose X and Y coordinates serve to reference a particular point on the ground and whose Z represents a particular attribute or condition at that point. Thus, MAPIT is particularly well-suited for use with data from maps, photographs and related remote sensing imagery and true ground annotations. Conceptually, then, MAPIT consists of a box with particular width, length and height parameters, any element of which can be absolutely referenced by the appropriate XYZ triplet data point. Each Z profile is itself a map of the condition or attribute at that particular height within the box, as depicted in Figure 4.13.

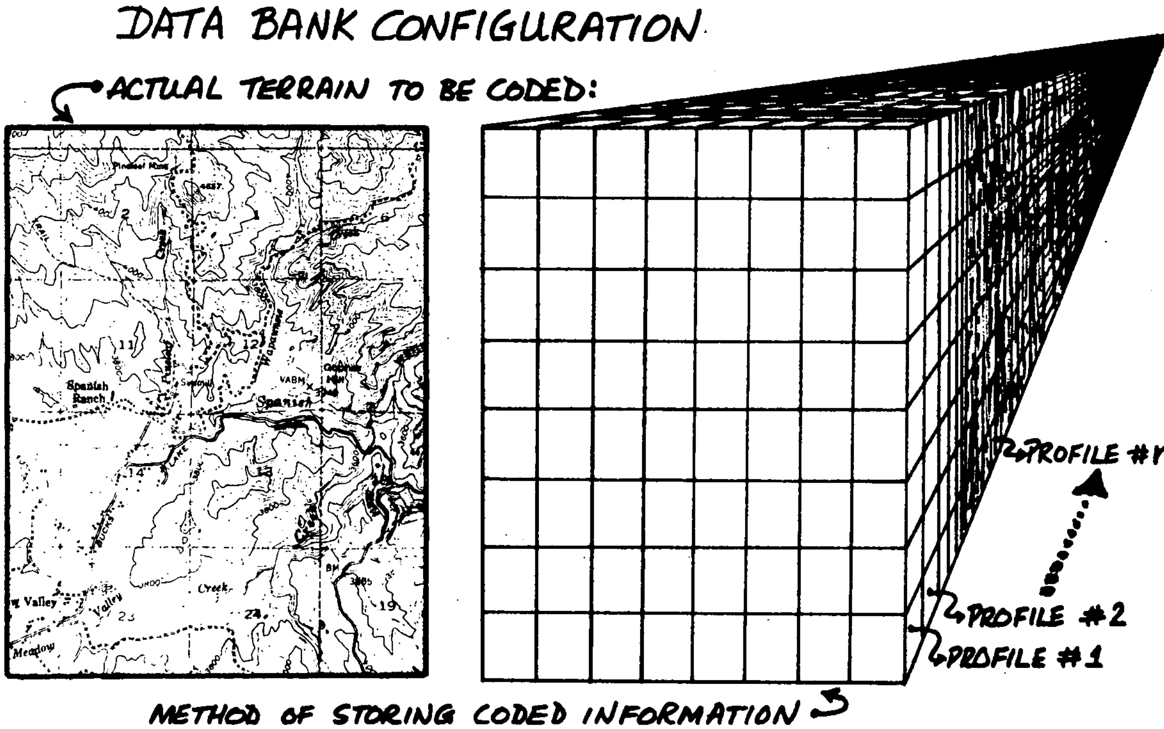


Figure 4.13. FRSL "data bank" configuration. Shown above, in a highly simplified schematic, is our conceptual approach to storing and retrieving information about an area of interest. In this case, a portion of the NASA Bucks Lake Forestry Test Site in Northern California is shown for illustrative purposes. The data bank is a three-dimensional array of data points with X and Y coordinates representing ground location points. The Z coordinates, which consist of "profiles" of discrete types of information currently residing in our FRSL data bank, are data about vegetation types, forest fire history, cutting history, land-use activity, zoning classifications, geologic types, etc. The amount of profile information which can be stacked on the X and Y scales is virtually unlimited; however, in terms of computer processing time for data extraction, it behooves the user to maintain useful profiles, calling out data which have become outdated or which might be better replaced by alternative data. Access to the data bank is by reference to the particular profile addresses. It is a fairly simple matter to extract information from the data bank which has been compiled from several discrete profiles.

MAPIT can accept data in two forms -- gridded or digitized. Gridded data are obtained by placing a grid on the input source map, dividing it into cells just as MAPIT would. Each cell is coded, and this can be done either manually or automatically. These codes are then transferred to MAPIT sequentially, one row after another. Only the codes (Z values) are needed because MAPIT generates the X and Y coordinates it needs. This option can be used quite well with scanned photographs. Digitized data consist of strings of one or more XY pairs, each string having an associated Z value. A string can represent single points, linear objects (roads, trails, boundaries, etc.) or patches on the source map. For single points, MAPIT codes only the cell into which the data point falls. MAPIT treats linear objects by first mapping the data points and then interpolating, linearly, coding the cells lying on the line segment between each successive pair of points. A patch is mapped by first mapping its string, which is actually its perimeter, producing a closed boundary; then all cells within this boundary are coded.

Display is a simple matter of associating a particular symbol on the display device with a particular code.

Since MAPIT is only a package of subroutines, it is necessary for the user to write a mainline program. This program need only dimension the variables used by MAPIT, but it can also do anything else the user wishes. It is this feature which allows MAPIT to have <u>no restrictions</u> on the maximum numbers of data points, maps, slices, etc.

Input and Output

MAPIT has two phases -- input and output. The input phase places a map in memory. The output phase produces a copy of this map. There are three modes to the input phase -- create, read and collate. Create, as one might expect, causes a new map to be produced "from scratch" and places it in memory. Read transposes a previously created map from a mass storage device and places it in memory. Collate is more complicated. It reads one or more maps, each from a separate mass storage device, 100 words at a time, combining the information on these maps through a subroutine which the user must write to fit his own needs. The resulting "new" map is then placed in memory.

The output phase has two modes -- storage and display. Storage takes a map, or any portion of it, and stores it in binary form on a mass storage device. Display copies any or all of a map and converts it to a form suitable for display. At no time does MAPIT have more than one map in memory.

Through proper manipulation of the options available, MAPIT can:

- Create a map from scratch
- Store "permanently" all or any portion of a map,
- Retrieve a previously stored map,
- Manipulate all or any portion of one or more maps using a filtering or combination subroutine written by the user,
- Update or correct a map, and
- Display any or all of a map.

The time required for any particular problem is, of course, machine-dependent and a function of the complexity of the problem. However, to get a general idea of the time involved in using MAPIT, the following times are presented. It should be kept in mind that these are only rough figures, based on our use of the program to date.

Compilation of the source	4-5 sec
Creation of a new map	1.5 sec/10000 cells
Sorting a map on magnetic tape . . .	0.006 sec/10000 cells
Collating 3 maps.	1.7 sec/10000 cells
Printing (Display)	1 sec/10000 cells/overprint

User Oriented and R & D Applications with the FRSL Terminal/Display

The current state of development of the Terminal/Display facility has enabled a number of interesting and relevant studies to be performed during the past year. Some of these studies are incomplete, but they are presented here as an indication of the level of interest and potential utility generated by our NASA sponsored efforts in developing such a facility. Several of the "outside" uses of our film emulsion digitizing facilities were made by graduate students doing experimental studies leading to doctoral degrees. One such study was conducted by a graduate student in Electrical Engineering whereby he was investigating the power spectra obtained from scanned aerial photographs of the spatial distribution of forest plantations. The study was terminated as the student was abruptly transferred from our Berkeley campus to work with the image processing staff at the University of Southern California. His efforts paralleled in some degree those in which we are currently engaged, as described in a subsequent section of this report. We are continuing our investigations of "signal variation" as an indicator of "texture" for the purpose of deriving statistics which can be correlated with known ground conditions. Some results of this work are reported upon later in this section.

A second study of this type was conducted (and completed) by a doctoral candidate in the Sanitary Engineering department of the Engineering School of our campus. Here the objective was to develop an improved technique for measuring the dispersion rates of dyes when injected into artificial channels analogous to those found in estuaries. The technique used was one which incorporated precision photography and film density extraction. Tides in the channel were simulated and dyes injected at various tidal states in order that sequential images could be taken of the state of the channel, and hence the rate of dye dispersion. The next step is that of relating the findings to actual estuaries in order to improve the methodology of monitoring pollution spills and spreads through the use of remote sensing data. This is planned as part of the laboratory's projected plans in the coming year and is included in our "Proposed Future Research" section.

Use of the system for research purposes consists of many varied applications, depending on the components specified. The system is configured such that image processing can be performed directly from either digital tape inputs or digitally reduced images, through scanning procedures. In the first case, for example, ERTS-A tapes are anticipated for analysis at our facility, employing various automatic and semi-automatic techniques. The pattern recognition routines from LARS (Purdue) are adapted to our CDC6600 computer facility through which a terminal link is established for greater interactive uses. Also, we are concentrating heavily on practical studies of the texture analysis technique as an improvement over conventional manual means of deriving subjective information from photographs. Initial tests of our color display components reveal them to be very useful in the image processing area -- especially where it is desirable to present results, in their most interpretable format, to the investigator. Examples of each of these activities are discussed next.

A. Spectral Frequency Data Classification Experiments

Two types of terrain have been studied and subjected to our version of a pattern recognition program: rangelands and agricultural lands. In both cases, our input data to be classified were derived from optical density values scanned with the FRSL scanning microdensitometer. In the case of agricultural fields, we have directed our attention to the Arizona area where extensive ground truth information exists. We have digitized high altitude, black-and-white photos obtained from the NASA aircraft in May 1970. Three bands were used: Pan-58, Pan-25, and Infrared-89B, to comprise a three-channel classification scheme. The area selected for training and testing is the "16-square mile" test area which we continue to monitor at the time of each successive overflight. Eight categories were chosen for recognition:

1. Alfalfa-1
2. Alfalfa-2
3. Barley
4. Cotton
5. Wheat
6. Alfalfa-cut
7. Bare Soil
8. Sugar Beets

The classification summary in Table 4.5 lists the preliminary results achieved to date. Much more work must be done with these routines to determine optimum dates, scanning parameters, and ground truth deficiencies (as exhibited by the difference in categories 1 and 2, which appeared to require separate labels for recognition). No illustrations of the automated categorization are presented in this report because of the difficulty of acquiring legible computer printouts of this size for photo reproduction.

In our rangelands investigations, we employed color infrared photography which had been acquired at extremely low altitude and used a "color separation" procedure to extract three channels of data corresponding to the emulsion layers of this film. Five features were selected for automatic recognition from the data: two different kinds of test panels, two brush species, and the background complex of bare soil and mixed grasses. Figure 4.14 contains an illustration of this imagery. Summary statistics for the classification are presented in Table 4.6.

B. Spatial Frequency Classification Experiments

Our texture analysis studies have concentrated upon the forest environment as a test case. The objective is to develop a procedure for taking aerial photos which have been manually "typed" as to homogeneous units (forest stands) and to digitally scan these types to derive statistics which can be used in the classification routine. Textural signatures are analogous to tone signatures in this respect. To date, we have worked towards the prediction of several forest stand

TABLE 4.5 AUTOMATIC CLASSIFICATION OF RANGELAND TYPES FROM SPECTRAL DATA PROVIDED BY LOW ALTITUDE INFRARED EKTACHROME PHOTOGRAPHY OF THE NASA HARVEY VALLEY TEST SITE

CLASSIFICATION SUMMARY BY TRAINING FIELDS

CLASS	NO. OF SAMPLES	% CORRECT	NUMBER OF SAMPLES CLASSIFIED INTO BRUSH 1	BRUSH 2	BACK	PANEL 1	PANEL 2
Brush 1	42	81.0	34	5	3	-	-
Brush 2	45	73.4	4	33	8	-	-
Background	66	95.5	2	1	63	-	-
Panel 1	49	97.9	-	-	1	48	-
Panel 2	42	100.0	-	-	-	-	42
TOTAL	244		40	39	75	48	42

OVERALL PERFORMANCE: 87.6%

TABLE 4.6 AUTOMATIC CLASSIFICATION OF CROP TYPES FROM SPECTRAL DATA IN THE 16-SQUARE MILE AGRICULTURAL TEST AREA OF MARICOPA COUNTY, ARIZONA

CLASSIFICATION SUMMARY BY TRAINING FIELDS

CLASS	NO OF SAMPS	PCT. CORCT	NO OF SAMPLES CLASSIFIED INTO ONE	TWO	THREE	FOUR	FIVE	SIX	SEVEN	EIGHT
Alf-1	35	82.9	29	6	0	0	0	0	0	0
Alf-2	156	46.2	80	72	0	0	0	1	2	1
Barl	168	100.0	0	0	168	0	0	0	0	0
Cot	77	100.0	0	0	0	77	0	0	0	0
Wht	171	81.3	0	0	0	2	139	0	28	2
Alf-cut	36	97.2	0	0	0	1	0	35	0	0
Bare	96	80.2	0	0	0	1	18	0	77	0
SB	121	98.3	0	0	0	0	1	1	0	119
TOTAL	860		109	78	168	81	158	37	107	122

OVERALL PERFORMANCE = 83.3%

parameters of interest to the forest land manager. Table 4.7 shows preliminary results of our ability to predict from photo-scanned statistics that which we have previously measured as ground truth.

TABLE 4.7. SUMMARY OF REGRESSION ANALYSIS ON FOREST SPATIAL FREQUENCY DATA

	MULTIPLE r^2	STANDARD ERROR OF EST.	MEAN	STANDARD DEVIATION	UNITS
Volume*	0.97	1921.0	13594.0	4339.0	Bd ft/Ac
Basal Area*	0.95	13.0	91.4	23.9	Ft^2/Ac
No. of Trees*	0.96	9.2	44.9	18.1	Trees/Ac
Avg. Stand Height*	0.93	9.6	76.9	13.3	Feet
% Crown Closure+	0.96	3.5	17.6	6.0	%
Avg. Crown Diam.+	0.98	2.2	20.8	5.6	Feet

* = on-site measurements

+ = photo estimated by conventional manual methods

Figures 4.15 and 4.16 show the results of generating predictions from 24 scans of photography obtained over the NASA Forestry Test Site. The areas were selected to fall within the boundaries of stratified vegetation types determined conventionally by photo interpretation methods. Scanning was performed on a single photo, oriented normal to the shadows to minimize textural changes due to illumination angle and photo scale. A multiple linear regression equation was generated for each of the variables measured by the ground data acquisition crews and photo interpreters. (See Table 4.7.)

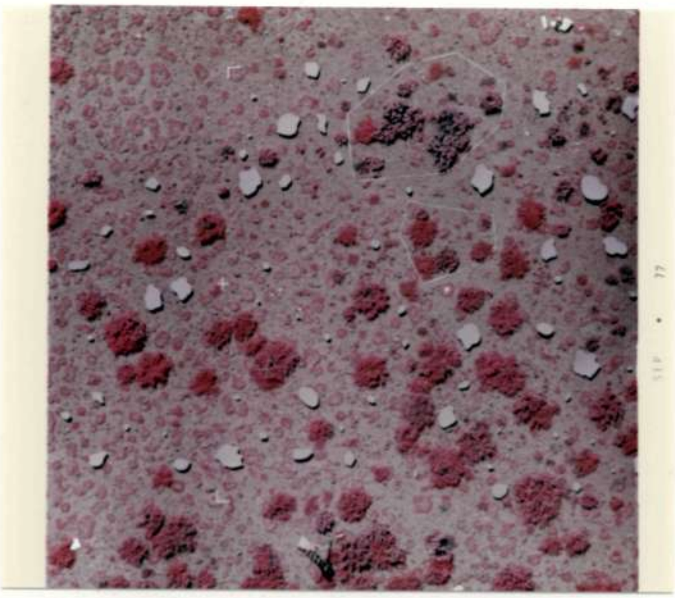


Figure 4.14. Photo illustration of the rangeland area which was studied for automatic classification of the categories annotated above. Results of the study are discussed in the text. No photo illustrations of the computer-generated classification results are included in this report because of the problem of obtaining good quality inputs for photographing. However, we are currently completing routines which will enable display of such results on our CRT devices.

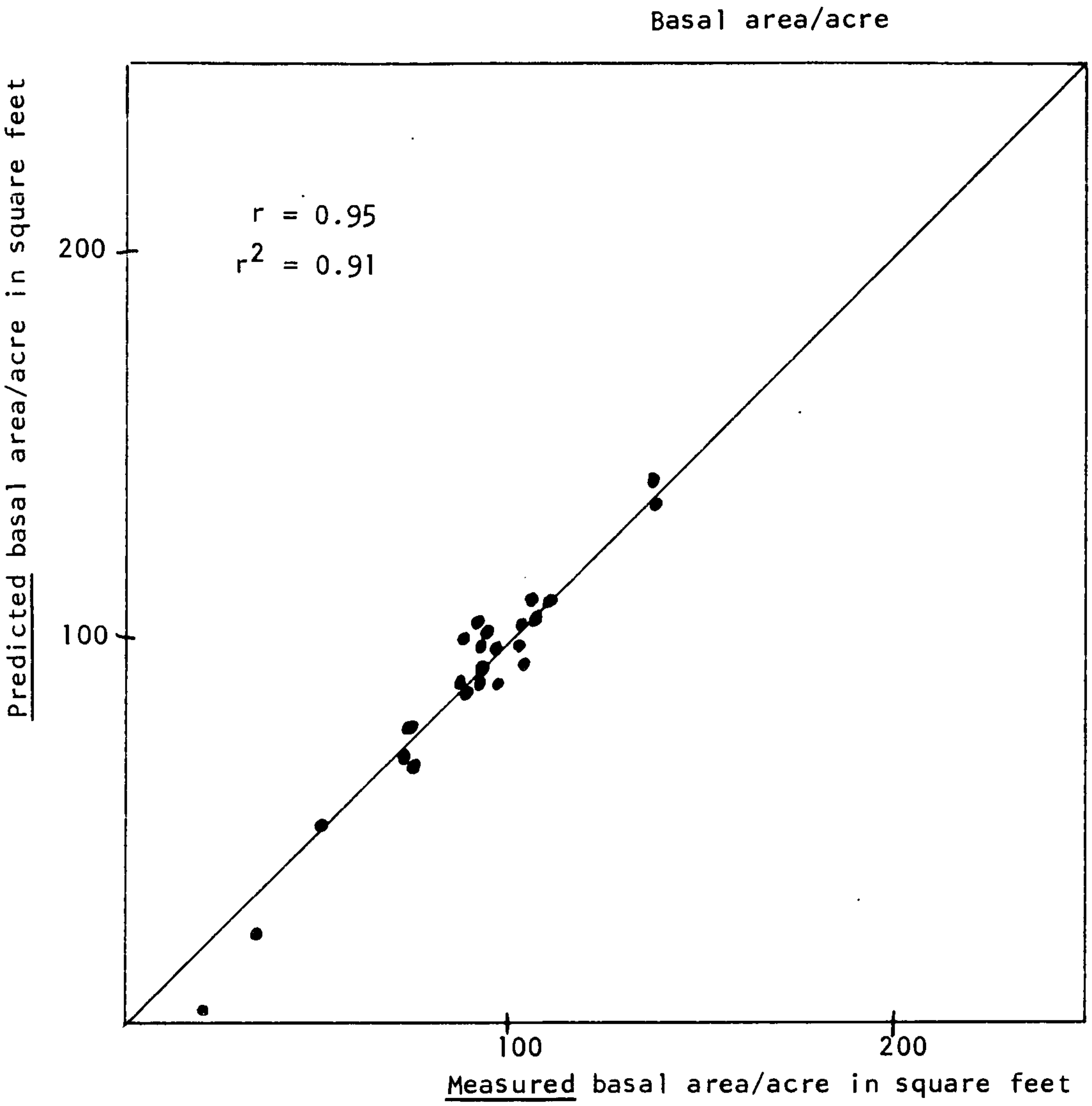


Figure 4.15. This plot shows, for representative timber stands, the relationship between measured basal area per acre (derived from ground truth records) and that which is predicted using textural energy coefficients of the same ground sites as imaged on aerial photos and optically scanned for spatial frequency data. The technique is described in the text.

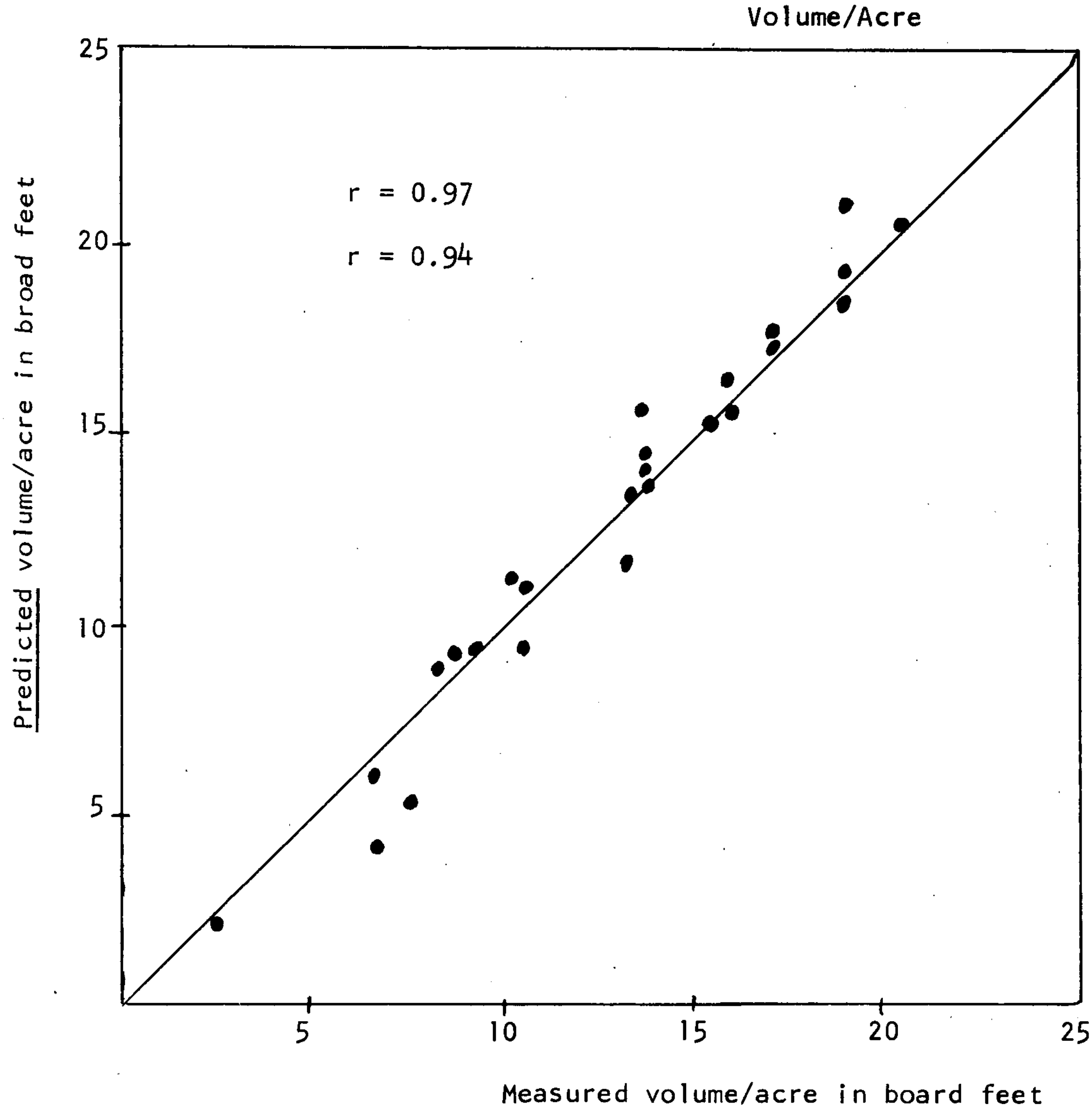


Figure 4.16. The ability to "predict" volume/acre for various timber stands by using textural energy coefficients is shown by the above relationship. Description of the procedure is presented in the text. A large number of relationships are being studied using this technique of relating information derived from actual ground measurements to that which is derived from scanned images of these ground measurement sites.

Figure 4.17. CRT color display for Hydrologic investigations. Shown on the preceding page are four varying color display presentations derived from the density data contained in the larger black-and-white photo example. This larger example is in fact photo data extracted from an airborne thermal infrared scanner device of a small stream emptying into the Pacific Ocean along the coast north of California. The airborne infrared scanner can be an important source of information regarding the thermal regimes of an area. It has a day-or-night sensing capability (this example was recorded at night) and the image densities (tones) are directly correlated with the emitted thermal properties of features in the scene. Since this example is the "negative" of what usually is presented to the image analyst, dark tones represent "warm" features and light tones represent "cold" features, thermally. The warmer stream is seen to empty and mix with the colder Pacific Ocean waters. The large square areas on the grey background consist of Douglas Fir stands which are "clear-cut."

The four color display examples illustrate the flexibility for presenting the data for subsequent interpretation. Different degrees of color mixing are shown using the Terminal/Display components as they presently operate. In the upper left color example, only a small portion of the grey tones are "enhanced" in blue and green; in the upper right, the warm stream flow is made to appear orange in contrast with the surrounding tones; in the lower left example, the "green" CRT phosphor is suppressed and the display is presented in color values of reds and blues; in the lower right example, the grey tones are all assigned a range of colors for enhanced display, ranging from the coldest features (in light green) through red, orange, violet and blue, to black, the latter representing the warmest features.

Figure 4.17. See caption on facing page.

C. Color Displays

More and more of our attention is being directed toward the color display aspects of automatic feature recognition applications. The illustrations contained in this report are presented as examples of the type of results which one can achieve using this format of presentation. The existing subsystem for color display is single-channel. This greatly restricts the discriminatory potential which the technique conceptually possesses. Figure 4.17 shows "typical" examples.

Data Bank Storage and Retrieval Capabilities for Resource Management Applications

Contained in the following pages are several figures indicating the possible application of the MAPIT routines in a "management oriented" situation. These illustrations (Figures 4.18 to 4.26) depict the output maps for a minimal set of resource profiles. The hypothetical problem used to demonstrate MAPIT was, using some of the profiles contained in a portion of the Bucks Lake Forestry Test Site, to select those areas deemed suitable for conversion of land use from brush species to commercially renewable pine forest stands. The constraints of the problem were:

- the maximum elevation of land which is to be converted must be less than or equal to 5000 feet
- the slope of the land must be no greater than 35% in order for bulldozers to operate effectively in the conversion
- all aspects of NORTHWEST, NORTH, or NORTHEAST must be rejected as unfavorable pine growing sites

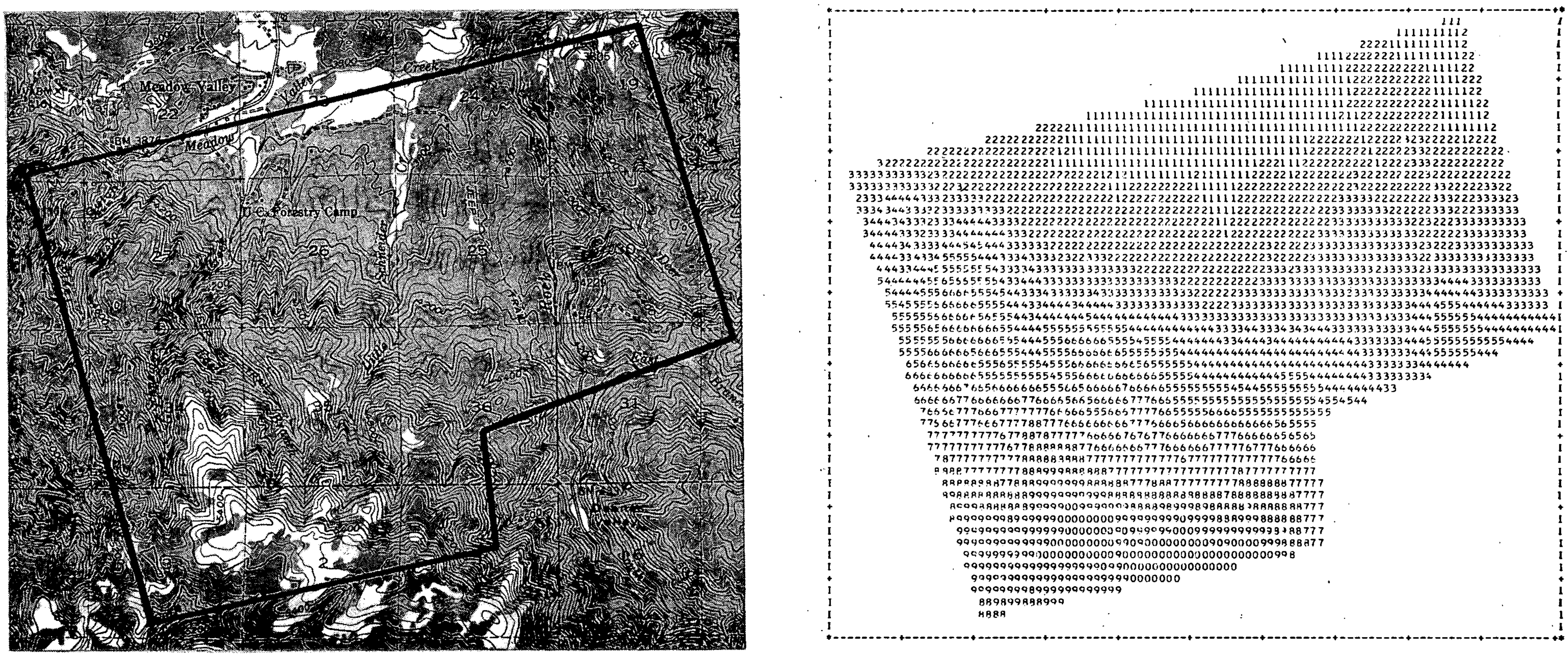
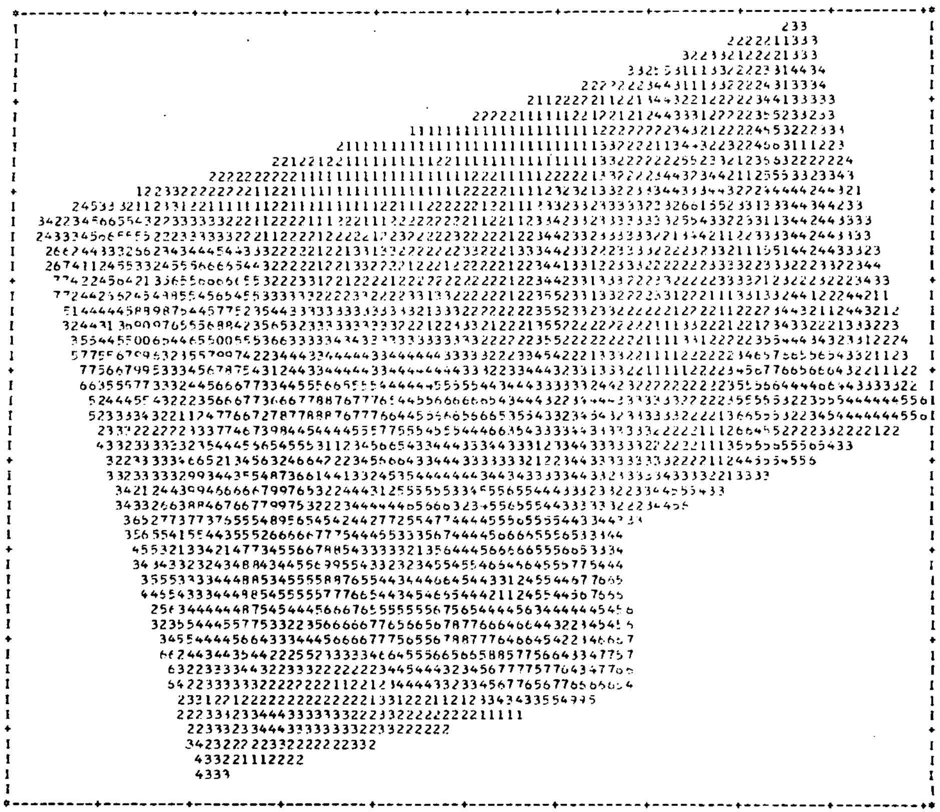


Figure 4.18. The illustration on the left shows a portion of the NASA Bucks Lake Forestry Test Site in Northern California with the boundary designating the region from which source inputs were encoded for storage and retrieval purposes using MAPIT. The computer printout on the right shows 10 slices of information about elevation for the area of study. Each cell represents approximately one hectare of ground-equivalent area. The slices represent 200' contour intervals for display purposes. The stored data contain elevational resolution that is sufficiently good to permit the drawing of contours at a 40-foot interval. Such a map, or profile, is considered to be a "raw base map" from which other information can be generated, as indicated by the remaining examples in this series.



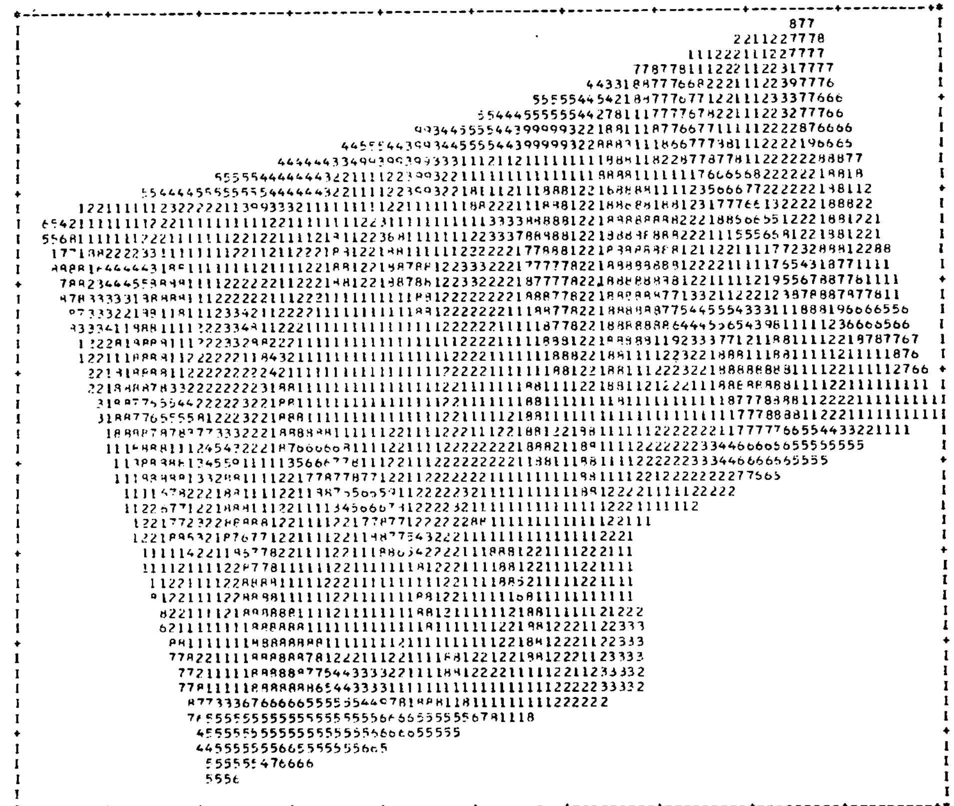
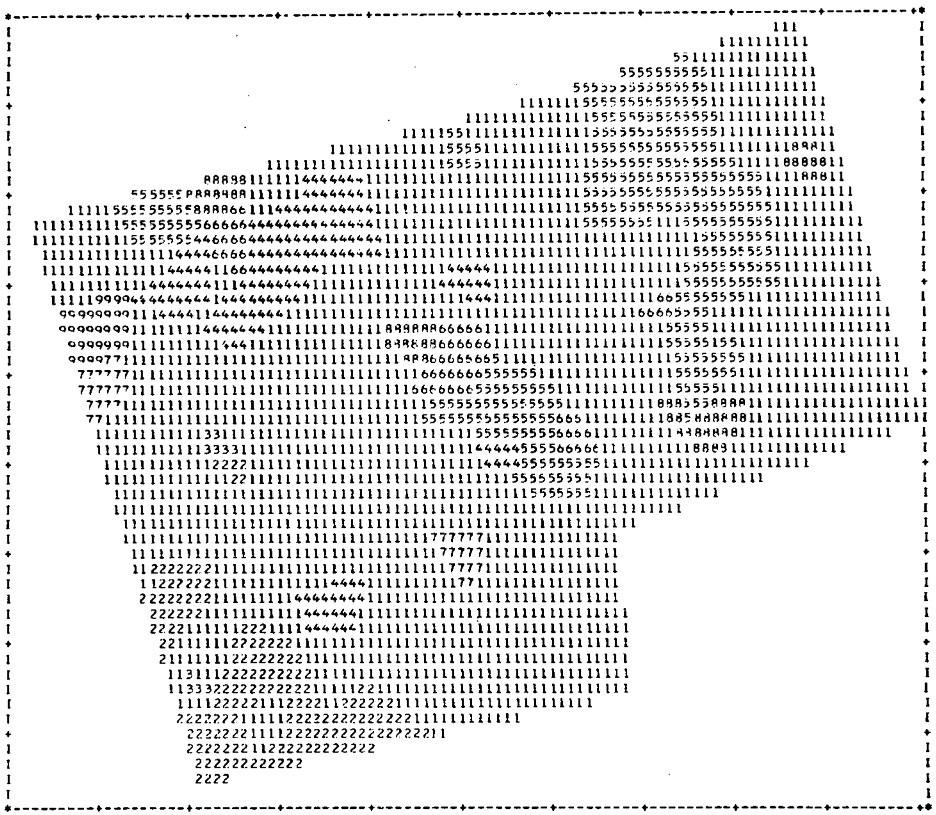


Figure 4.19. The raw base map on the left represents per cent slopes at five percent intervals (slices). The map on the right is another raw base map containing data on aspect, with resolution equal to 45°.



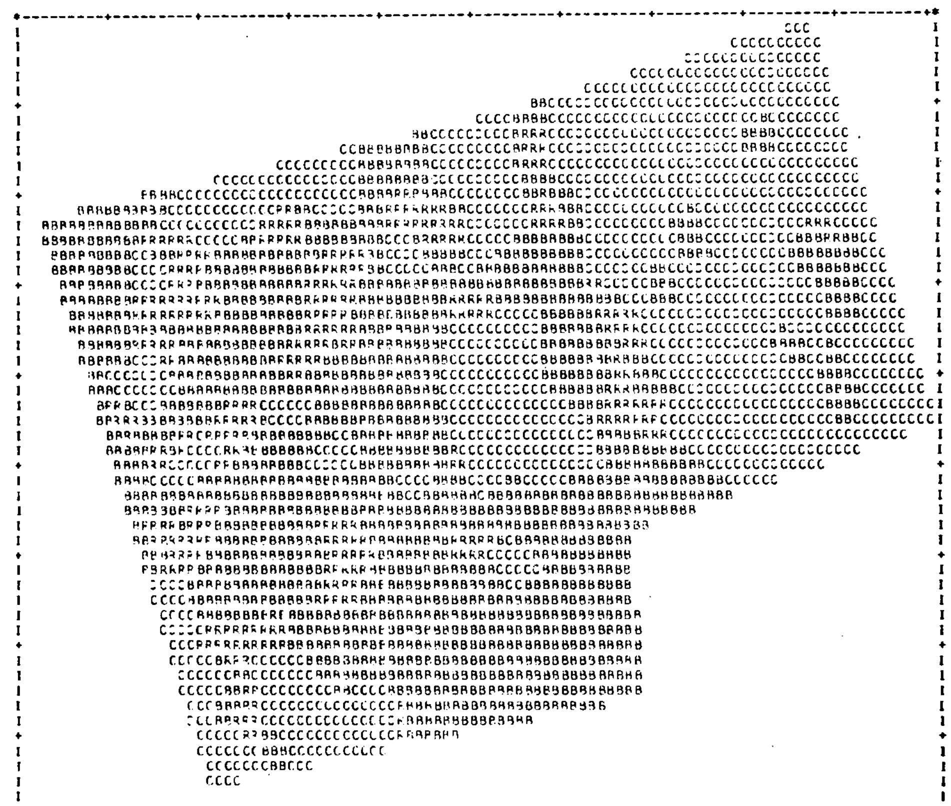


Figure 4.20. The raw base map on the left is encoded to represent nine soil types which exist in the area of study. The map on the right represents the raw base data for the broad vegetation types found in the area. "C" denotes commercial conifer, "B" denotes brush species, and "R" represents riparian vegetation types.

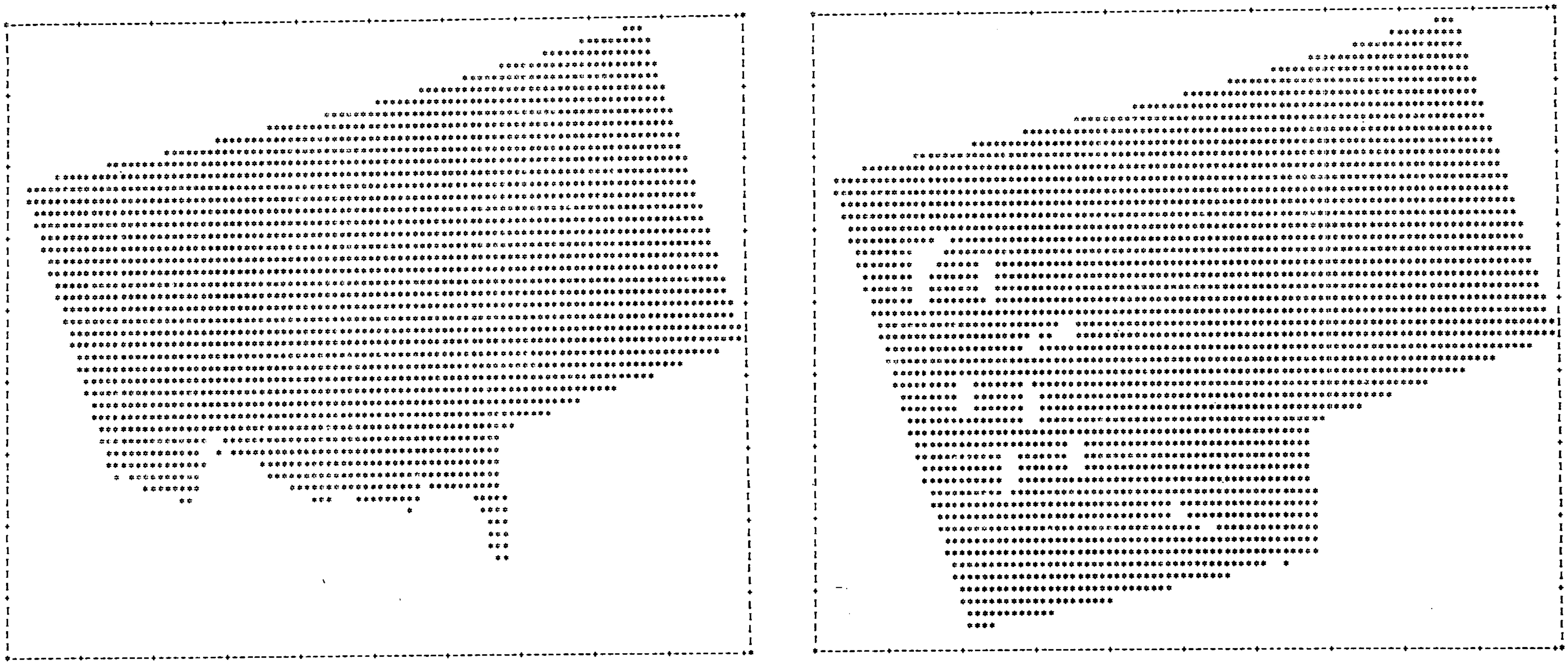


Figure 4.21. The printout on the left shows all cells which are less than or equal to 5000' altitude, as per the text problem constraint. The display on the right represents all cells which satisfy the requirement that favorable slopes are those which are less than or equal to 35 per cent.

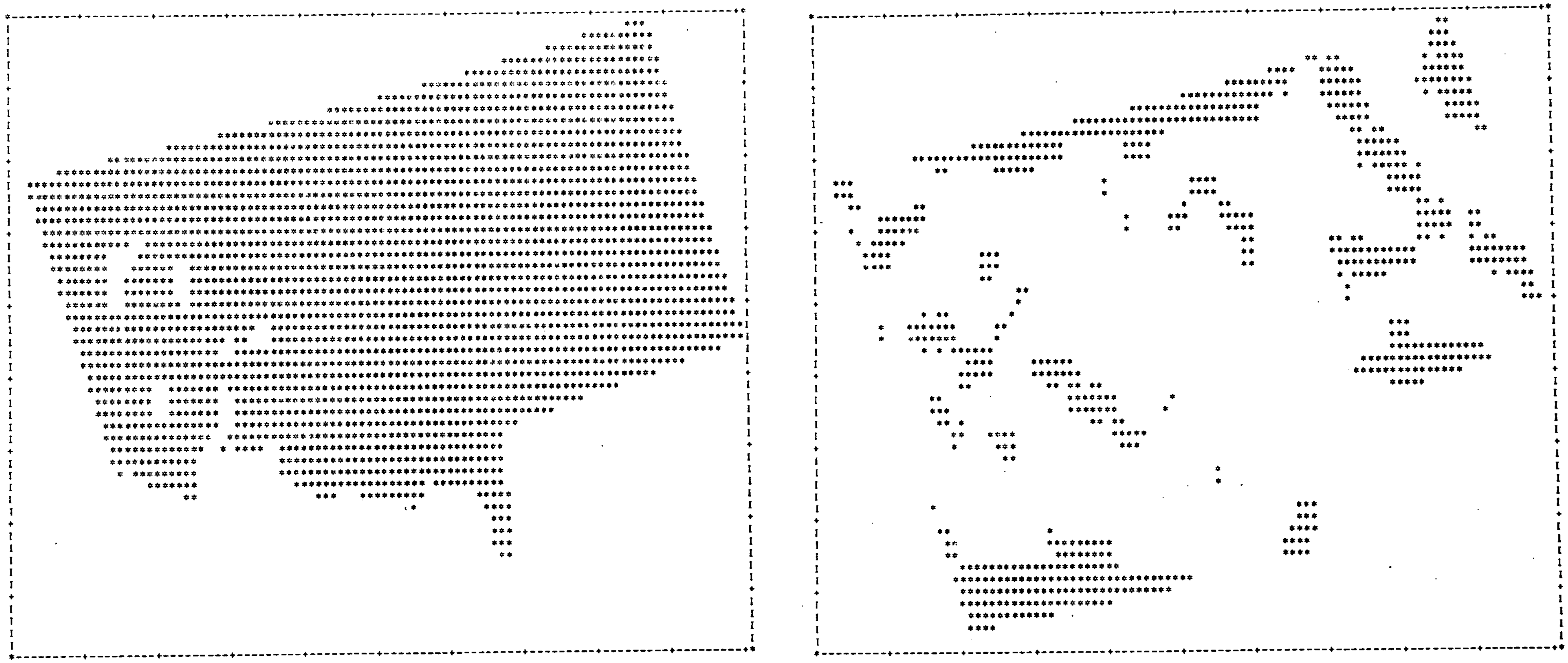


Figure 4.22. The display on the left represents all cells which satisfy the problem constraints of both elevation and slope, namely, a combination of favorable cells in both maps appearing in the previous figure. The display on the right represents those cells not residing on a NW, N, or NE aspect, since these are deemed as unfavorable conversion sites under the constraints of our problem.

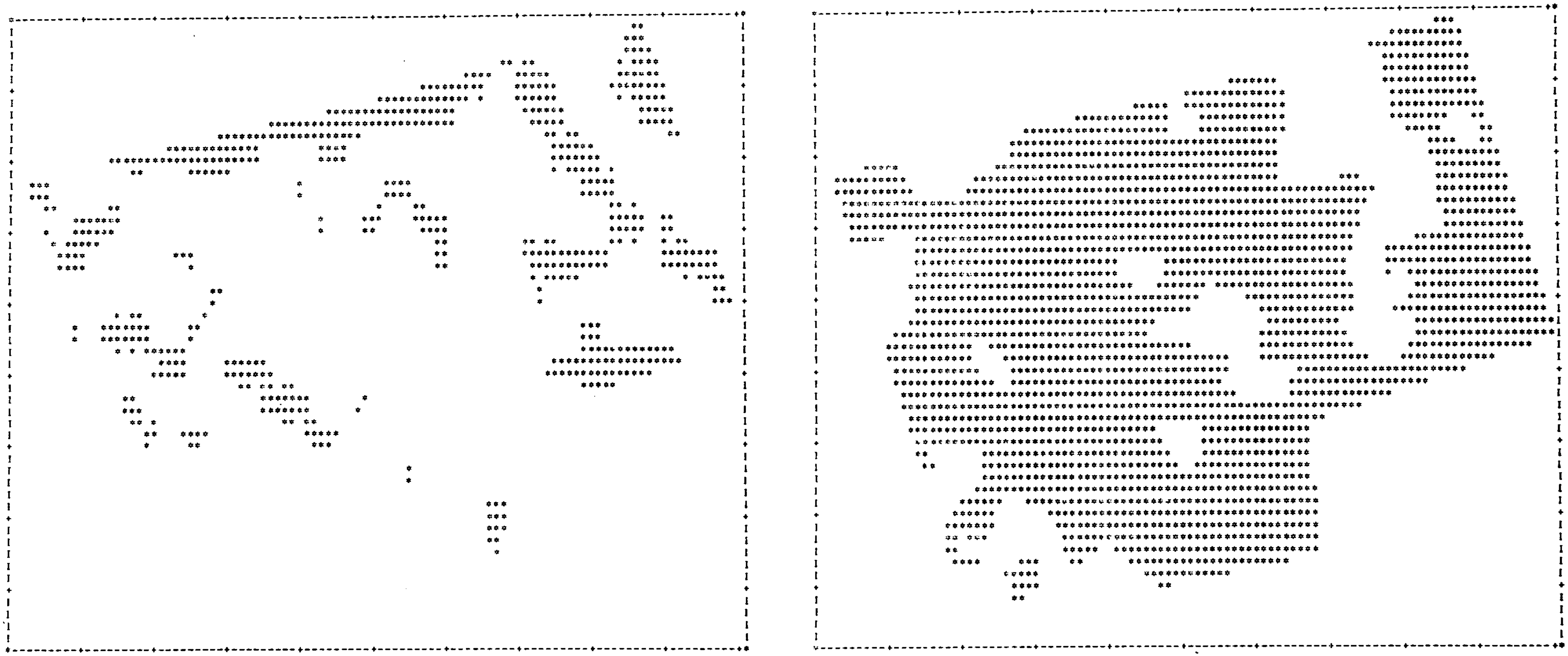


Figure 4.23. This display on the left shows those cells which comply with the problem constraints of (a) elevations less than or equal to 5000', (b) slope must be less than or equal to 35 percent, and (c) aspect must not be NW, N, or NE. The display on the right represents those cells with a soil type of either COHASSET, AIKEN, or CORNUTT, all deemed most favorable among those which exist in the study area.

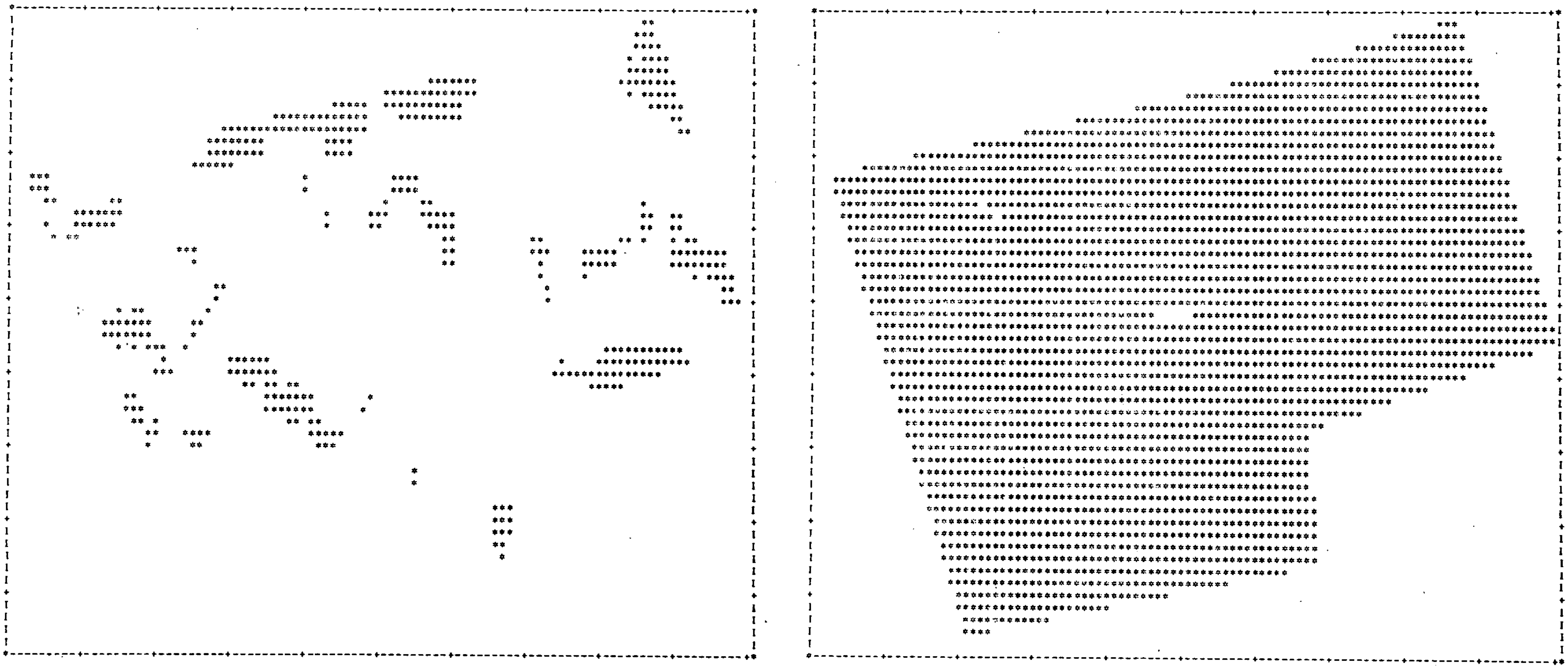


Figure 4.24. The display on the left represents the information contained in the left portion of the preceding figure, with the additional constraint of soil type represented by the right portion of the preceding figure. In other words, the two profiles of the previous figure are combined in the above left display. The display on the right, above, is an additional restriction that CORNUTT soil must be on a slope which is less than or equal to 20 percent, to minimize erosion potential from a conversion operation.

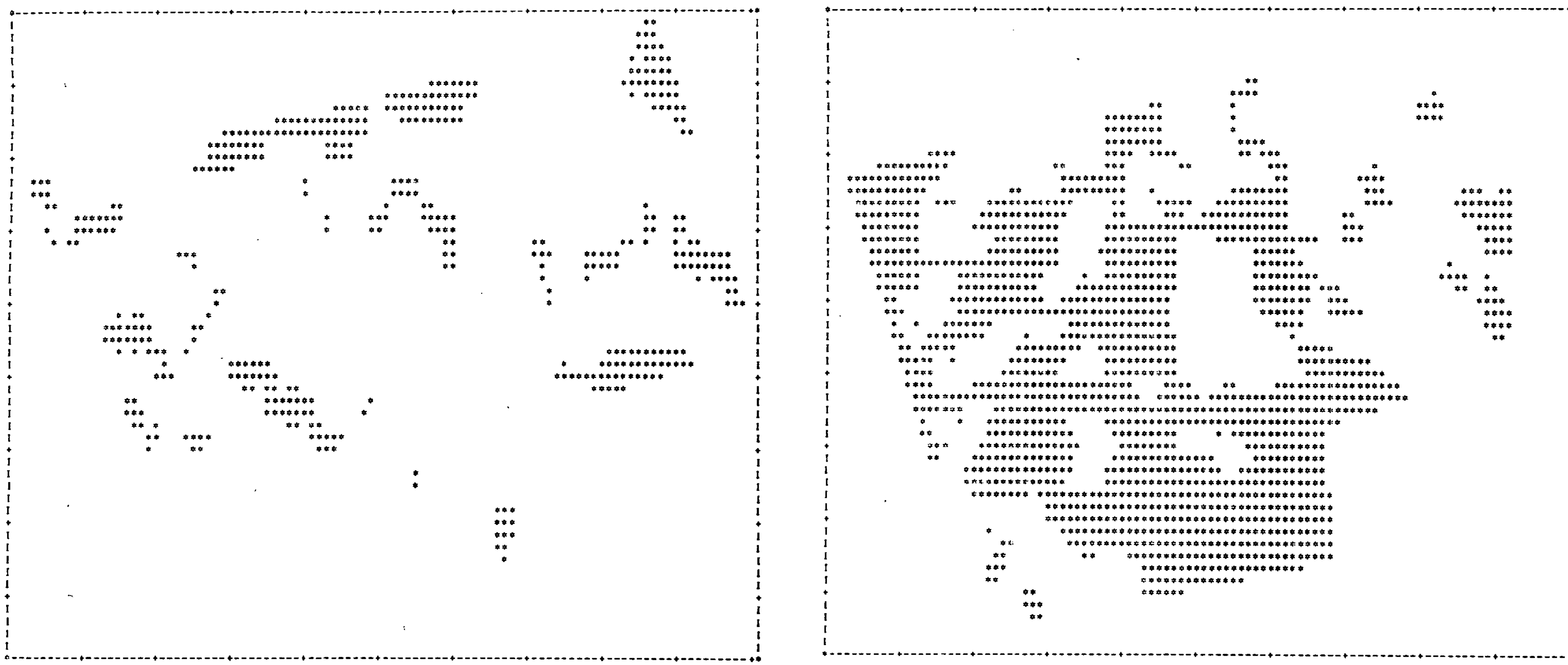


Figure 4.25. The left display represents the combined maps from the previous figure. The display on the right shows only the cells vegetated by BRUSH since these are the areas we wish to consider converting to forest plantations under the problem constraint.

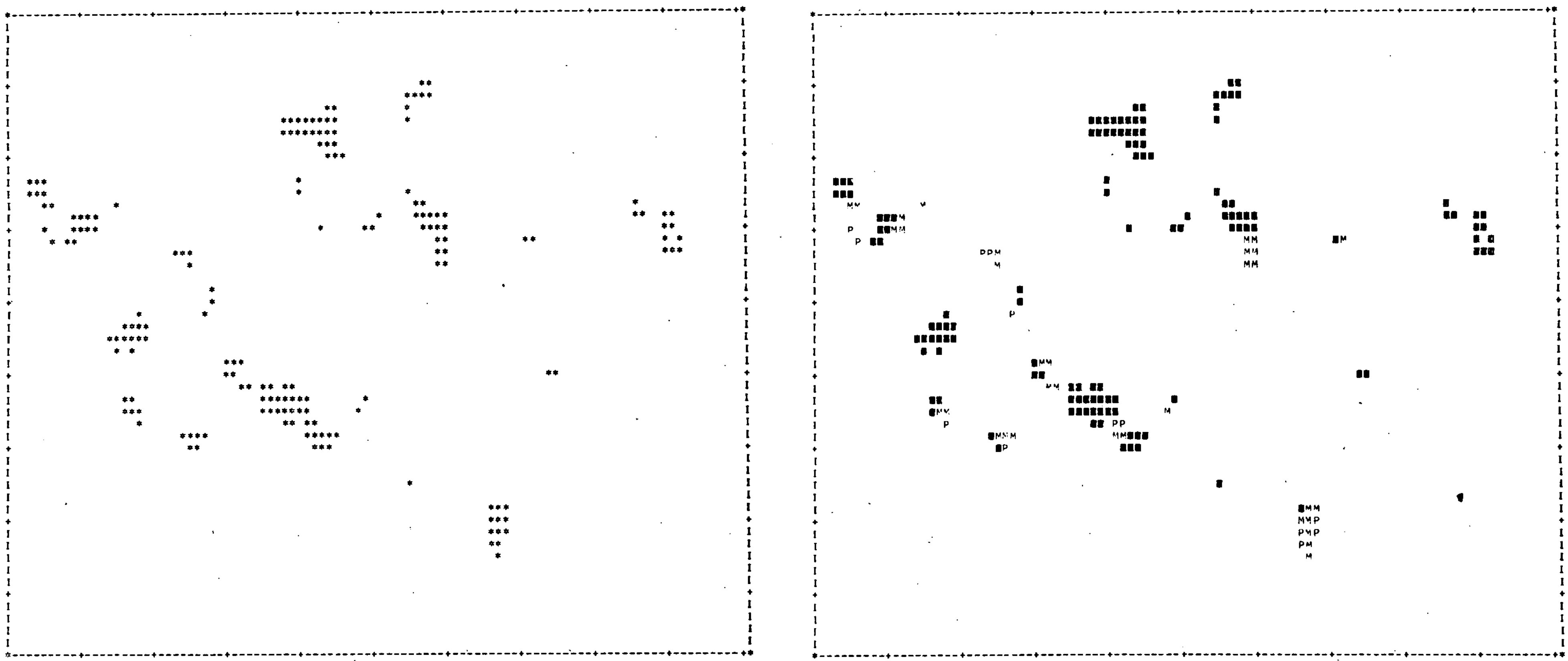


Figure 4.26. The display on the left shows those cells which satisfy the original list of constraints for the problem (see text). The display on the right is an additional breakdown of these "acceptable" cells into "GOOD", "MEDIUM", and "POOR" investment opportunity based on priorities determined by favorable slopes and soil types. It results in an additional piece of information for use by the land manager in making wise decisions in the face of a wealth of data.

- acceptable soils for the conversion to plantations are COHASSET, AIKEN, or CORNUTT; reject all others as undesirable
- the CORNUTT soil must be on less than or equal to 20% slopes in order to minimize its risk of erosion, and
- the vegetation, of course, must be presently a brush species.

The illustrations sequentially show the "raw" data maps from which the resource information is built up: (1) an elevation map of the area with 200 foot contour intervals shown, (2) a percent slope map of the area with 5% intervals, (3) an aspect map with 45 degree intervals, (4) a soil base map of the area under investigation, (5) a general vegetation base map of the area, and (6) a "profile" map generated from the raw data maps showing the acceptable portion of the area under constraint number (1) above.

The additional illustrations show the management information desired, namely (7) the areas which satisfy all of the six original constraints, and (8) an additional map which has been stratified into GOOD, MEDIUM and POOR relative investment opportunities, based on the soil type information. The parameters most affecting the relative investment opportunity of a site are the soil type and the slope of the land. Since COHASSET soil is a more productive soil than either AIKEN or CORNUTT, it should receive a higher priority for conversion than the others. Hence the final map shows, of the total "acceptable" cells within the area under examination, a priority ranking of them for conversion purposes.

4.4.2. Proposed Future Research Activities

It is fairly clear what direction our unit's research activities should take in the immediate future, based on our efforts of the past year. The only "new" aspect of our plans calls for the integration of our program with data which are to be derived from the ERTS-A satellite and from supporting high altitude aircraft. But this is a logical transition, since this is the direction we have been anticipating in our first year of study. Specificially, we propose to conduct research designed to develop applications of remote sensing for the inventory of vegetation resources in each of the following areas:

1. Continue work with the modified pattern recognition programs we now have, and for which we are completing an interactive data link with a computer facility, to optimize their use. This effort has a two-fold objective: to examine the point-cell classification efficiency in a variety of terrain land use applications; and to develop some experience in the mechanics of determining the best mix of man with machine for such resource surveys.

2. Continue work with the scanning of spatial frequency data for the purpose of using "textural signatures" in a classification scheme as well as spectral signatures. An effort will be made to combine both spectral and spatial analyses in the same "multichannel" program.

3. Develop routines to handle ERTS-A tapes (9-track digitally recorded) as partial input to a system of display and sampling for a multi-stage approach to resource survey application. It is anticipated, for instance, that manual feature typing may be done at the satellite

altitude stage with supplementary scanning done at subordinate levels in a sampling scheme to determine important resource information for the land manager. This approach will be attempted first with the forest resource to determine its efficiency over conventional manual methods, using the textural signature approach described earlier.

4. Upgrade our single channel input color display system to enable three channels of input. The additional components of the system required as originally proposed by us consist of 2 scan conversion memory units (Hughes Model 639) and 1 synchronization unit (for congruency).

In addition, some electronics equipment will be needed to interface with the existing system. We currently have the components necessary for a single channel color display system and have ordered the additional required components listed above. The multi-image capability will greatly enhance our ability to analyze multiband and multidate images in a multi-dimensional framework, rather than through single inputs. Our many years of research experience have indicated that many features -- especially vegetation features -- require multidimensional information in order to automatically recognize them.

5. Based upon the successes of scanning artificial stream channels with dispersive dyes injected into them, we propose to extend the technique to actual coastal waters for the purpose of locating effluent discharges and determining the rates of spread of these effluents. We propose to investigate the procedure with sensor data obtained at higher and higher altitudes to determine the limits for detecting effluents and measuring their dispersive characteristics.

4.5 REPORT OF THE SPECTRAL CHARACTERISTICS UNIT

The activities of the Spectral Characteristics Unit include the definition of (1) the spectral characteristics of earth resources and (2) the procedures for specifying and calibrating multispectral remote sensing data acquired of those resources. These activities are performed in order that the resources may be more effectively identified.

The parameters which define the spectral characteristics of a resource may include, but are not limited to (1) the relative intensity of reflected light as a function of wavelength for standard conditions; (2) the manner in which the intensity relative to wavelength changes as a function of the azimuth angle between the illuminant (principally the sun) and the receptor; (3) the manner in which the absolute intensities change as a function of the azimuth angle; and (4) the manner in which the relative and absolute intensities of reflected light change as a function of the vertical angle between the illuminant and the receptor.

Although the foregoing may define a resource at a particular point in time, it is important to recognize that the spectral characteristics of a resource may change with time. Natural resources in particular may be sensitive to environmental changes -- and may be indicative of these changes. Vegetation varies in response to seasonal changes, changes in available moisture, changes in the temperature regime, and for agricultural vegetation, changes brought about through various cultural practices. Soils may change spectral characteristics as a function of surface moisture content.

These changes of reflecting characteristics in response to environmental parameters or position of observation may be thought of as either disadvantages or advantages. The variability of spectral response as a function of environmental parameters may create problems of identification. However, if the response is known, then the manner in which the observed response varies as a function of known environmental changes may be used as an identifying characteristic. The pattern of response as a function of position of observation may also be used as an identifying characteristic.

In a similar manner the observed response of a known resource may serve either to identify the environmental parameters attendant at the time of observation, or to identify the recent historical pattern of those parameters, e.g., greater or lesser rainfall during the growing cycle compared to normal.

In keeping with the philosophy of the Laboratory that the most meaningful measurements of spectral reflectivity for remote sensing purposes are those that are made in the field, the Spectral Characteristics Unit continues in the development of the capability to obtain field data. Equipment development has been predicated upon the need for a low-cost research tool, versatile, amenable to modification, and useful for determining the spectral characteristics of natural surfaces and features which must be examined in their natural undisturbed environment, and which may be remotely located and difficult of access. To date, most of the equipment for data acquisition has utilized off-the-shelf components. Many of these components have been modified and interfaced with components fabricated at the Laboratory to form a versatile data gathering system. The resulting system can be used to measure irradiance as a function of wavelength for the energy that is incident upon, and reflected from, natural features.

4.5.1 Work Performed During the Period Covered by This Report

Field measurements of reflected radiation in the 375-1200 nanometer wavelength range were made for several brush species within the Feather River watershed during the past season. An analysis of the data from a brushfield representative of thousands of acres of the upper elevation watershed is presented. Four species of brush are included: manzanita (*Arctostaphylos patula*); huckleberry oak, (*Quercus vaccinifolia*); tobacco-brush, (*Ceanothus velutinus*); and chinquapin (*Castanopsis sempervirens*). The data collection and analysis methods are discussed and the types of hardware and software used in the project are detailed in the sections which follow.

Hardware for Reflected Spectral Irradiance Measurements

A. Spectroradiometers

Two spectroradiometers were used to cover the spectral range 350-1200 nanometers and acquire data about spectral radiation reflected from the features of interest. They are identical except for the detectors and monochromator gratings. These must be different in order to cover the required wavelength ranges. One spectroradiometer is effective in the spectral range 350-800 nm; the other in the range 700-1200 nm. The spectroradiometers are modular units consisting of (1) beam input optics, (2) a monochromator housing, (3) a detector unit and (4) an indicator unit. The first three units are physically mounted together into one optical unit by means of twist-lock bayonet attachments. The indicator unit is connected by an electrical cable.

The beam input optics along with a cone and filter holder restrict the field of view to 14°, diffuse the light and direct it to the entrance slits of the monochromator housing. Changeable optical filters reject the short wavelength harmonics which would be generated by the grating monochromator.

The monochromator housing utilizes a plane diffraction grating to angularly disperse the light according to wavelength. The grating can be rotated and, in conjunction with the necessary mirrors and lenses, it directs the selected wavelength bundle to the exit slit. The bandwidth about the central wavelength is from 5 to 20 nm in the visible range and from 10 to 40 nm in the near infrared range, depending on the width of the entrance and exit slits.

Light leaving the exit slit falls onto a photodiode in the detector head. The strength of the electric current through the photodiode circuit is proportional to the light incident on the detector.

The indicator unit provides a bias voltage across the photodiode and measures the current flow. Operation can be from external line voltage or from a self-contained battery power supply. The unit houses the necessary electronics for operating in various modes, selecting sensitivity ranges and other control functions. The indicator unit also has a 0-10 mv signal output available for connection to an external recorder.

B. Data Recording

The data recording unit houses a digital voltmeter, incremental digital tape recorder/reproducer, control switches, and necessary electronics and power supply for interfacing the units and formatting the data. The external recording output of the indicator unit is connected to the digital voltmeter which provides a visual display of the output and also function as an A/D converter with BCD output. The binary data output of this device is recorded on the tape unit by depressing a data entry thumbswitch. At the same time, a number indicating the position of the spectroradiometer sensitivity range switch is recorded. At the beginning of each set of data a number selected from eight thumbwheel switches and representing the data set identification number, the number of data entries, and the wavelength interval is entered on the tape by means of a code entry switch. This number identifies the data set for all subsequent operations.

C. Power Supply

Power for the operation of the equipment in the field is provided from an automotive type 12 volt battery. The digital voltmeter and the incremental tape recorder require a nominal 115 volt, 60 Hz power supply. Both units are non-critical about the voltage and frequency requirements and are adequately supplied by the output from an inexpensive current inverter powered by the 12 volt battery.

Hardware for Measurement of Incident Spectral Irradiance

Two systems are currently available for measuring and recording light incident on the area being studied. The first is an entirely separate spectroradiometer and recording system from that described above; the second utilizes most of the above system.

A. Separate System

1. Spectroradiometer

The spectroradiometer used to measure incident light operates through the spectral range 380-1300 nm. Sunlight and skylight are incident upon a horizontal cosine response diffuser screen. Light from the diffuser screen passes through a mechanical chopper, an optical entrance slit, and then a wedge interference filter monochromator. The wedge interference filter can be moved past the entrance slit by a drive motor thereby producing a continuous spectral scan. The monochromator transmits a bandwidth of 15 nm in the visible part of the spectrum and 30 nm in the near infrared part of the spectrum which is incident upon a photodiode detector. The signal output is read on the unit's indicating meter or is taken from the external signal output. Approximately a 0-10 mv signal range is available. The center wavelength being sensed at any time can be read from the monochromator dial for direct readings or as a function of time measured from an electrical timing spike if recording the signal externally.

2. Data Recording

In the FRSL system, the analog output of the spectroradiometer is input to an FM recording adapter which converts it to a frequency output. The frequency output varies through a range of 500-3000 Hz and is recorded on an audio tape recorder with a servo controlled capstan motor.

When the signals are to be retrieved they are input to a frequency discriminator which converts frequency to voltage. This analog voltage signal is input to the computer through an analog to digital converter.

B. The second system utilizes the equipment described under "Hardware for Reflected Spectral Irradiance Measurements", but replaces the 14° field of view cone with an adapter fabricated at the FRSL which provides a flat diffuser plate to intercept incoming light. Incident energy measurements are accomplished from the same setup used to measure reflected energy. With this arrangement measurements of incident light are easily interspersed with measurements of reflected light using the same spectroradiometer. In addition to simplifying the problems inherent in calibration between different types of instruments, the data from incident and reflected measurements are recorded on the same data tape and in the same format, making data retrieval possible with only slight modifications to the software used to retrieve data from reflected light.

Software

Current programming allows playback of field recorded data to the computer. The raw data can be displayed in the original bit mode on CRT, TTY or line printer outputs. Alternatively the raw data can be mathematically corrected for system sensitivity at each wavelength and output on these devices in absolute radiometric units, i.e., Watts/cm^2/nm. In addition, the data can be rewritten on an addressed magnetic tape for storage and efficient future retrieval. Data for incident light utilizing the system described in the immediately preceding section can also be processed and stored in the same manner.

Standardization, to account for differences between the illumination attendant at the time of making a measurement of reflected light and a selected standard illumination, can be made by calling for the incident and reflected measurements of interest from the addressed tape. The program compares, at each wavelength interval, the intensity of the standard and actual incident light, computes a ratio, applies this to the data from the reflected light measurement and computes a new standardized reflected light measurement. The resulting data can output on any of the same devices as the original data and can be stored on the addressed tape for future access.

In addition to being output in tabular form, the data can be output in graphical form on the CRT. Several graphs can be overlaid on the screen for visual comparison if desired.

Data Collection

Measurements of the spectral radiation reflected from the brush plants were made in the field under natural illumination using the equipment previously described. The spectroradiometers were set up on a tripod such that the instruments were approximately four feet above the top of the brush. All measurements were made at an azimuth of 90° to the sun and with the spectroradiometers at about 15° from the vertical. Three sets of measurements were made over each of the plant species.

At fifteen minute intervals measurements were made of the spectral irradiance incident upon the area in order to be able to standardize all the reflectance measurements to a single illumination condition.

The standardization of reflected energy to a common time was accomplished by obtaining, for each wavelength, a ratio of the irradiance incident at the time for which the data were being standardized to the irradiance incident at the time of the measurement of reflected energy. The measured energy reflected at each wavelength was multiplied by the ratio for that time and wavelength to obtain a standardized measurement. A graph of the standardized data is shown in Figure 4.28 where the means of reflected energy from three data sets for each species are plotted against wavelength.

Data Analysis

The data were analyzed using Duncan's multiple range test to determine if statistically significant differences exist among the ranked means of irradiance as reflected from the four brush species at each of twenty-four wavelengths. The summary sheets which follow show the results of this analysis.

As an example of the interpretation of the analysis, let us consider the data for wavelength 550 nm. The data are shown in terms of irradiance in Watts x $10^{-7}/cm^2/nm$. The mean of the energy reflected by any species is considered to be not significantly different from the mean of another species if the rankings of the two are preceded by the same vertical line. Any two means not preceded by the same line are considered to be different. This statistical analysis was made at the 95% protection level.

Manzanita is different from the other species and ranks as number one, i.e., reflects the least amount of light at 550 nm. Tobaccobrush

TABLE 4.8 IRRADIANCE MEASUREMENTS OF REFLECTED ENERGY 7/29/71

01580000 REFLECTED Chinquapin time: 1203

NM	WATTS/CM↑2/NM	NM	WATTS/CM↑2/NM
0375	+.5086057E-07	0700	+.4271135E-06
0400	+.6679135E-07	0750	+.1040467E-05
0425	+.8878695E-07	0800	+.1008476E-05
0450	+.1313130E-06	0850	+.8525824E-06
0475	+.1528610E-06	0900	+.6841796E-06
0500	+.1938034E-06	0950	+.4268544E-06
0525	+.3613568E-06	1000	+.5240272E-06
0550	+.4612669E-06	1050	+.5346378E-06
0550	+.4469174E-06	1100	+.5350296E-06
0575	+.3734828E-06	1150	+.4738467E-06
0600	+.3382607E-06	1200	+.1182983E-05
0625	+.2970201E-06		
0650	+.2503563E-06		
0675	+.2249581E-06		
0700	+.5667249E-06		
0700	+.5922760E-06		
0725	+.1257463E-05		
0750	+.1798868E-05		

01590000 REFLECTED Chinquapin time: 1207

NM	WATTS/CM↑2/NM	NM	WATTS/CM↑2/NM
0375	+.5303145E-07	0700	+.4358597E-06
0400	+.6812715E-07	0750	+.1011686E-05
0425	+.9116369E-07	0800	+.1020849E-05
0450	+.1335412E-06	0850	+.8624964E-06
0475	+.1545951E-06	0900	+.7010728E-06
0500	+.1925027E-06	0950	+.4309986E-06
0525	+.3613568E-06	1000	+.5272308E-06
0550	+.4679278E-06	1050	+.5398221E-06
0550	+.4539833E-06	1100	+.5363981E-06
0575	+.3781513E-06	1150	+.4848664E-06
0600	+.3401973E-06	1200	+.1095570E-05
0625	+.3003414E-06		
0650	+.2551100E-06		
0675	+.2279981E-06		
0700	+.5768449E-06		
0700	+.5992852E-06		
0725	+.1302695E-05		
0750	+.1850265E-05		

TABLE 4.8 IRRADIANCE MEASUREMENTS OF REFLECTED ENERGY 7/29/71 (continued)

Ø1600000 REFLECTED Chinquapin time: 1210

NM	WATTS/CM↑2/NM	NM	WATTS/CM↑2/NM
Ø375	+.5520233E-07	Ø700	+.4373176E-06
Ø400	+.7003551E-07	Ø750	+.1020407E-05
Ø425	+.9337061E-07	Ø800	+.1020849E-05
Ø450	+.1368092E-06	Ø850	+.8624964E-06
Ø475	+.1467254E-06	Ø900	+.7010728E-06
Ø500	+.1951041E-06	Ø950	+.4268544E-06
Ø525	+.3627255E-06	1000	+.5034324E-06
Ø550	+.4712583E-06	1050	+.5385260E-06
Ø550	+.4575162E-06	1100	+.5473451E-06
Ø575	+.3758171E-06	1150	+.4885396E-06
Ø600	+.3259957E-06	1200	+.1235430E-05
Ø625	+.3098310E-06		
Ø650	+.2551100E-06		
Ø675	+.2340781E-06		
Ø700	+.5802183E-06		
Ø700	+.5957806E-06		
Ø725	+.1320788E-05		
Ø750	+.1881103E-05		

Ø1610000 REFLECTED Manzanita time: 1223

NM	WATTS/CM↑2/NM	NM	WATTS/CM↑2/NM
Ø375	+.7443010E-07	Ø700	+.3571426E-06
Ø400	+.7824128E-07	Ø750	+.6994593E-06
Ø425	+.1033867E-06	Ø800	+.6657177E-06
Ø450	+.1577540E-06	Ø850	+.5204718E-06
Ø475	+.1680672E-06	Ø900	+.4265562E-06
Ø500	+.1977055E-06	Ø950	+.2880230E-06
Ø525	+.2888117E-06	1000	+.3304346E-06
Ø550	+.3347100E-06	1050	+.3538330E-06
Ø550	+.3214979E-06	1100	+.3872466E-06
Ø575	+.3011204E-06	1150	+.4114018E-06
Ø600	+.3082432E-06	1200	+.1171328E-05
Ø625	+.2908520E-06		
Ø650	+.2551100E-06		
Ø675	+.2279981E-06		
Ø700	+.4351637E-06		
Ø700	+.4591015E-06		
Ø725	+.8766061E-06		
Ø750	+.1137570E-05		

TABLE 4.8 IRRADIANCE MEASUREMENTS OF REFLECTED ENERGY 7/29/71 (continued)

01620000 REFLECTED Manzanita time: 1228

NM	WATTS/CM↑2/NM	NM	WATTS/CM↑2/NM
0375	+.6698709E-07	0700	+.3760931E-06
0400	+.8205789E-07	0750	+.6767833E-06
0425	+.1091587E-06	0800	+.6731426E-06
0450	+.1680034E-06	0850	+.5254287E-06
0475	+.1720688E-06	0900	+.4307795E-06
0500	+.2042090E-06	0950	+.2934105E-06
0525	+.3052369E-06	1000	+.3345535E-06
0550	+.3447013E-06	1050	+.3525369E-06
0550	+.3320968E-06	1100	+.3913515E-06
0575	+.3034547E-06	1150	+.4224215E-06
0600	+.3166353E-06	1200	+.1199300E-05
0625	+.2998669E-06		
0650	+.2669939E-06		
0675	+.2340781E-06		
0700	+.4655240E-06		
0700	+.4661107E-06		
0725	+.9109824E-06		
0750	+.1171835E-05		

40630000 REFLECTED Manzanita time: 1232

NM	WATTS/CM↑2/NM	NM	WATTS/CM↑2/NM
0375	+.7567054E-07	0700	+.3731777E-06
0400	+.8377540E-07	0750	+.6872493E-06
0425	+.1101773E-06	0800	+.6681925E-06
0450	+.1663694E-06	0850	+.5303856E-06
0475	+.1734027E-06	0900	+.4265562E-06
0500	+.2068104E-06	0950	+.2938249E-06
0525	+.3093433E-06	1000	+.3368418E-06
0550	+.3530274E-06	1050	+.3583692E-06
0550	+.3391626E-06	1100	+.3790363E-06
0575	+.3034547E-06	1150	+.4187482E-06
0600	+.3163124E-06	1200	+.1205127E-05
0625	+.3027138E-06		
0650	+.2582789E-06		
0675	+.2371180E-06		
0700	+.4554039E-06		
0700	+.4766245E-06		
0725	+.9001266E-06		
0750	+.1161555E-05		

TABLE 4.8 IRRADIANCE MEASUREMENTS OF REFLECTED ENERGY 7/29/71 (continued)

01660000 REFLECTED Huckleberry Oak time: 1245

NM	WATTS/CM↑2/NM	NM	WATTS/CM↑2/NM
0375	+.4341756E-07	0700	+.4183670E-06
0400	+.6106631E-07	0750	+.8608055E-06
0425	+.9116369E-07	0800	+.7671844E-06
0450	+.1397801E-06	0850	+.6543076E-06
0475	+.1480592E-06	0900	+.5321395E-06
0500	+.1977055E-06	0950	+.3663487E-06
0525	+.3764133E-06	1000	+.4302057E-06
0550	+.4679278E-06	1050	+.4335425E-06
0550	+.4522169E-06	1100	+.4720851E-06
0575	+.3828198E-06	1150	+.4665002E-06
0600	+.3227680E-06	1200	+.1177155E-05
0625	+.3202694E-06		
0650	+.2677863E-06		
0675	+.2188782E-06		
0700	+.5599781E-06		
0700	+.5712484E-06		
0725	+.1094626E-05		
0750	+.1541888E-05		

01670000 REFLECTED Huckleberry Oak time: 1249

NM	WATTS/CM↑2/NM	NM	WATTS/CM↑2/NM
0375	+.5613270E-07	0700	+.3556848E-06
0400	+.6889045E-07	0750	+.8110934E-06
0425	+.9303110E-07	0800	+.7238757E-06
0450	+.1341354E-06	0850	+.6047388E-06
0475	+.1293851E-06	0900	+.4941295E-06
0500	+.1664889E-06	0950	+.3406546E-06
0525	+.3134496E-06	1000	+.4022881E-06
0550	+.3846667E-06	1050	+.4082688E-06
0550	+.3709591E-06	1100	+.4365075E-06
0575	+.2917835E-06	1150	+.4554805E-06
0600	+.2720933E-06	1200	+.1165500E-05
0625	+.2324917E-06		
0650	+.1925209E-06		
0675	+.1671986E-06		
0700	+.4317904E-06		
0700	+.4485878E-06		
0725	+.1022254E-05		
0750	+.1565873E-05		

TABLE 4.8 IRRADIANCE MEASUREMENTS OF REFLECTED ENERGY 7/29/71 (continued)

01640000 REFLECTED Huckleberry Oak time: 1252

NM	WATTS/CM↑2/NM	NM	WATTS/CM↑2/NM
0375	+.4279731E-07	0700	+.4096205E-06
0400	+.5953968E-07	0750	+.8625501E-06
0425	+.9065443E-07	0800	+.7795584E-06
0450	+.1420083E-06	0850	+.6592643E-06
0475	+.1533946E-06	0900	+.5363628E-06
0500	+.2055097E-06	0950	+.3642766E-06
0525	+.3805196E-06	1000	+.4311210E-06
0550	+.4745888E-06	1050	+.4361348E-06
0550	+.4575162E-06	1100	+.4652433E-06
0575	+.3874884E-06	1150	+.4775199E-06
0600	+.3292233E-06	1200	+.1177155E-05
0625	+.3183714E-06		
0650	+.2622403E-06		
0675	+.2279981E-06		
0700	+.5667249E-06		
0700	+.5852668E-06		
0725	+.1094626E-05		
0750	+.1658385E-05		

40650000 REFLECTED Tobaccobrush time: 1303

NM	WATTS/CM↑2/NM	NM	WATTS/CM↑2/NM
0375	+.4372769E-07	0700	+.3994165E-06
0400	+.6182966E-07	0750	+.8398741E-06
0425	+.9184271E-07	0800	+.7671844E-06
0450	+.1428995E-06	0850	+.6543076E-06
0475	+.1520608E-06	0900	+.5363628E-06
0500	+.2042090E-06	0950	+.3663487E-06
0525	+.3764133E-06	1000	+.4292904E-06
0550	+.4712583E-06	1050	+.4413192E-06
0550	+.4504504E-06	1100	+.4611381E-06
0575	+.3758171E-06	1150	+.4738467E-06
0600	+.3195403E-06	1200	+.1153845E-05
0625	+.3159991E-06		
0650	+.2551100E-06		
0675	+.2234382E-06		
0700	+.5566048E-06		
0700	+.5677439E-06		
0725	+.1121765E-05		
0750	+.1634401E-05		

TABLE 4.8 IRRADIANCE MEASUREMENTS OF REFLECTED ENERGY 7/29/71 (continued)

01680000 REFLECTED Tobaccobrush time: 1305

NM	WATTS/CM↑2/NM	NM	WATTS/CM↑2/NM
0375	+.5241121E-07	0700	+.3265305E-06
0400	+.6984460E-07	0750	+.8015000E-06
0425	+.9218227E-07	0800	+.7176887E-06
0450	+.1316101E-06	0850	+.5997819E-06
0475	+.1280512E-06	0900	+.4899062E-06
0500	+.1625868E-06	0950	+.3402401E-06
0525	+.3107120E-06	1000	+.3981691E-06
0550	+.3863319E-06	1050	+.4043805E-06
0550	+.3727256E-06	1100	+.4228239E-06
0575	+.2964520E-06	1150	+.4481341E-06
0600	+.2772576E-06	1200	+.1308857E-05
0625	+.2358132E-06		
0650	+.2004435E-06		
0675	+.1611186E-06		
0700	+.4317904E-06		
0700	+.4450832E-06		
0725	+.1031299E-05		
0750	+.1511050E-05		

01690000 REFLECTED Tobaccobrush time: 1308

NM	WATTS/CM↑2/NM	NM	WATTS/CM↑2/NM
0375	+.5272133E-07	0700	+.3338191E-07
0400	+.6908130E-07	0750	+.8067327E-06
0425	+.9320092E-07	0800	+.6991279E-06
0450	+.1338383E-06	0850	+.5997819E-06
0475	+.1460583E-06	0900	+.4899062E-06
0500	+.1651882E-06	0950	+.3356815E-06
0525	+.3093433E-06	1000	+.3972538E-06
0550	+.3813362E-06	1050	+.4017883E-06
0550	+.3727256E-06	1100	+.4200872E-06
0575	+.2894492E-06	1150	+.4407876E-06
0600	+.2714478E-06	1200	+.1303029E-05
0625	+.2329663E-06		
0650	+.1972744E-06		
0675	+.1641586E-06		
0700	+.4284170E-06		
0700	+.4520924E-06		
0725	+.9951138E-06		
0750	+.1535035E-05		

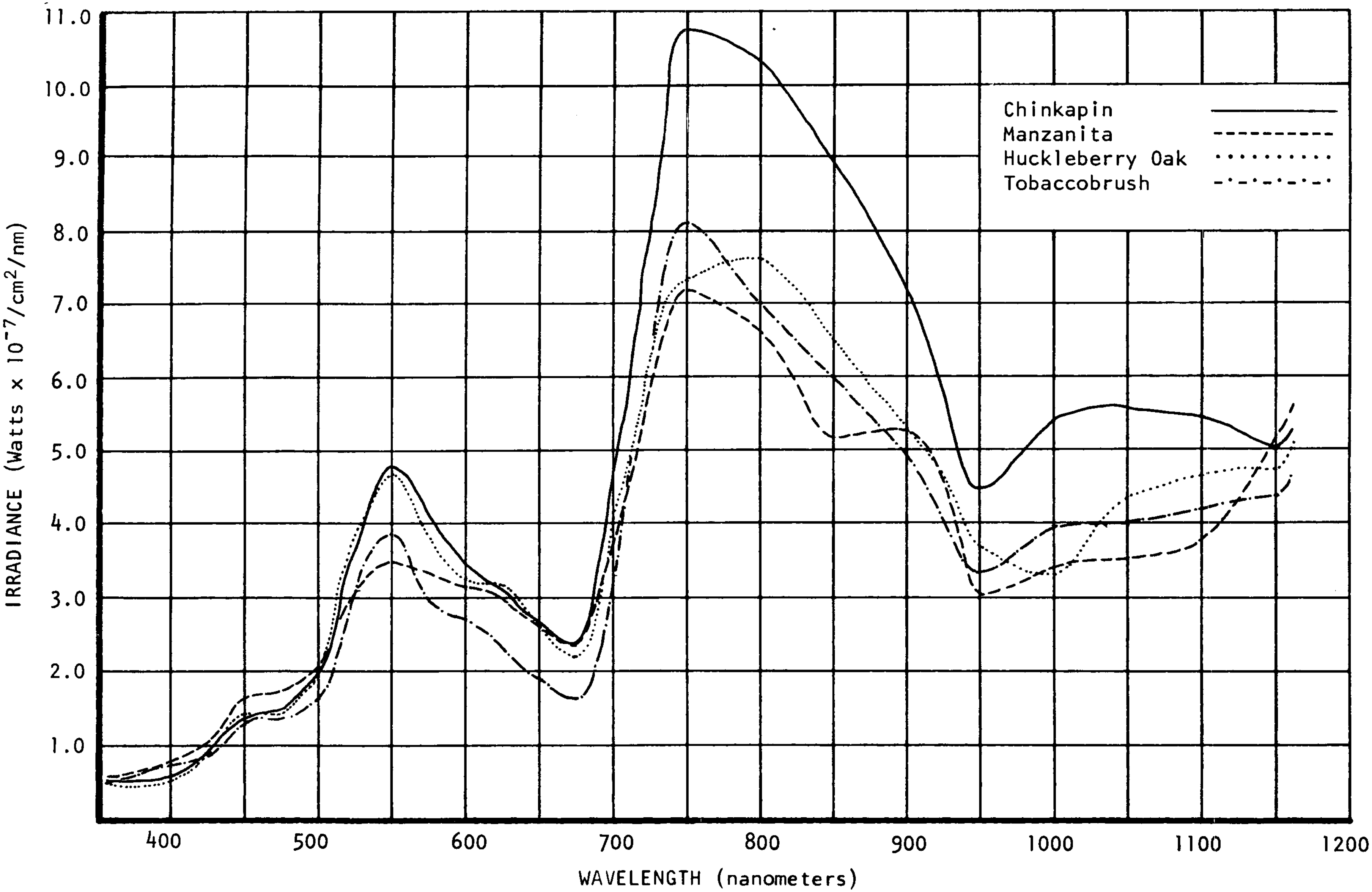


Figure 4.28 Energy reflected from four plant species in the Spanish Peak brushfields.

is also different from the other species and ranks number two; it reflects more light at 550 nm than manzanita, but less than huckleberry oak and chinquapin which are statistically inseparable in the amount of light they reflect at 550 nm. Huckleberry oak and chinquapin as a subset, however, reflect significantly more light at 550 nm than either manzanita or tobaccobrush.

Wavelength--550nm

TREATMENT MEANS IN RANKED ORDER

RANK	LABEL	MEAN	NUMBER OF REPLICATIONS	STANDARD DEVIATION
1	MANZAN	3.4800	3	.0954
2	TOBACC	3.8400	3	.0990
3	HUCKLE	4.7633	3	.0382
4	CHINKA	4.8850	2	.0212

From examination of standardized data such as are presented here it is possible to predict what parts of the spectrum are most useful for discriminating between the plant species. The information would be useful for planning film-filter combinations for aircraft photographic missions where knowledge of species composition within a vegetative type is desired.

San Pablo Range Test Site

A project has been initiated to follow the changes in the spectral characteristics of several California annual range types as they progress through their growth cycle. The study is being conducted in cooperation with another FRSL project investigating techniques for statewide monitoring of California's annual grassland. The objectives of defining the spectral characteristics at various stages of maturity are to determine the spectral regions which will give the greatest differences (1) between maturing and matured range grasses, emerging grasses and the bare soil-remaining litter complex, and (2) between range and non-range areas. The data from this study will be important for understanding and interpreting the data from fixed spectral regions returned from ERTS. Measurements are being made from plots established on deep and shallow soil sites and will continue through the season as differential drying occurs.

4.5.2 Future Proposed Research

The projects for defining the spectral characteristics of rangeland vegetation, both shrubs and grasses, will continue as the vegetation progresses through its seasonal cycle. More emphasis will be placed on vegetation in the north coastal region as the season progresses.

A study is being initiated to determine whether aerial photography, using spectral regions selected from analysis of spectroradiometric measurements made in the field, will provide better discrimination between two agricultural field crops than conventional broadband, i.e., blue, green, red and infrared multiband photography. The photography will be interpreted by humans and by machines to arrive at a determination.

Efforts will continue in the collection and analysis of spectral data for vegetation types in the Feather River watershed.

Time dimensional calibration of aerial photography can be accomplished by having targets of known reflectance in the scene and then measuring the energy reflected from them at the time of image acquisition. Man-made targets of adequate size are not practical for high altitude photography of wildland areas. Natural features of sufficient areal extent to be used for calibration references will be studied by spectral measurements to determine their usefulness for this purpose. Comparison between spectroradiometer measurements and multiband 35 mm ground photography of natural features and a grey-scale target will be made.

4.6 REPORT OF THE TRAINING UNIT

When our Forestry Remote Sensing Laboratory was restructured into "functional units", it was recognized that possibly its strongest contribution would be through training programs which would serve to disseminate information about our research findings to the potential users of modern remote sensing techniques. Not only is a University atmosphere conducive to such activities, but also several members of the Laboratory staff are professional educators experienced at giving lectures, seminars, workshops and short courses. Consequently, a fifth functional unit, the Training Unit, was created and immediately became active.

It is very apparent that the rate of remote sensing technique development is increasing at a much faster pace than is the rate at which these same techniques are being put to practical use. On the one hand, research scientists and engineers are actively engaged in sensor development and applications research, while on the other hand, earth resource managers and inventory specialists struggle to keep pace with new technology and to relate it to informational requirements within their own disciplines. Unfortunately, those burdened with the responsibility of managing earth resources often are unable to comprehend rapid advances in the field of remote sensing. This is particularly true for advances which employ high altitude aircraft and spacecraft sensor systems and automatic image classification and data processing techniques. Yet it is they who must ultimately decide whether the end product of this sophistication is meaningful.

Considering that ERTS-A will be launched within the year and that the high flight U-2 aircraft project already has been implemented, it becomes increasingly important to bridge this widening communication gap between remote sensing specialists and potential "users", especially resource managers. Thus the Training Unit within the Forestry Remote Sensing Laboratory has engaged in a number of activities which draw on the teaching experience and knowledge of members of the Laboratory staff. These training activities entail a consideration of virtually all phases of remote sensing data acquisition and analysis. Such activities have been designed to (1) provide a means of interchange between our research staff and "user" groups and (2) impart to resource specialists information on state-of-the-art remote sensing.

4.6.1 Current Activities

The diagram presented in Figure 4.29 lists five specific tasks which Training Unit personnel are currently performing. These include maintaining library facilities, disseminating research findings and training remote sensing specialists in adequate numbers for staffing various future earth resources survey programs.

The documents and film libraries at the FRSL are being maintained and updated for use by our staff, students and Laboratory visitors. The remote sensing documents library is, to our knowledge, the only one of its kind located in the far-western U.S. and now contains over 3400 items. Computerized search techniques (author and/or key word) can be employed to quickly and efficiently locate documents, and a loan file is maintained whereby anyone interested in any particular item, including a fully illustrated copy of any FRSL report, may obtain it.

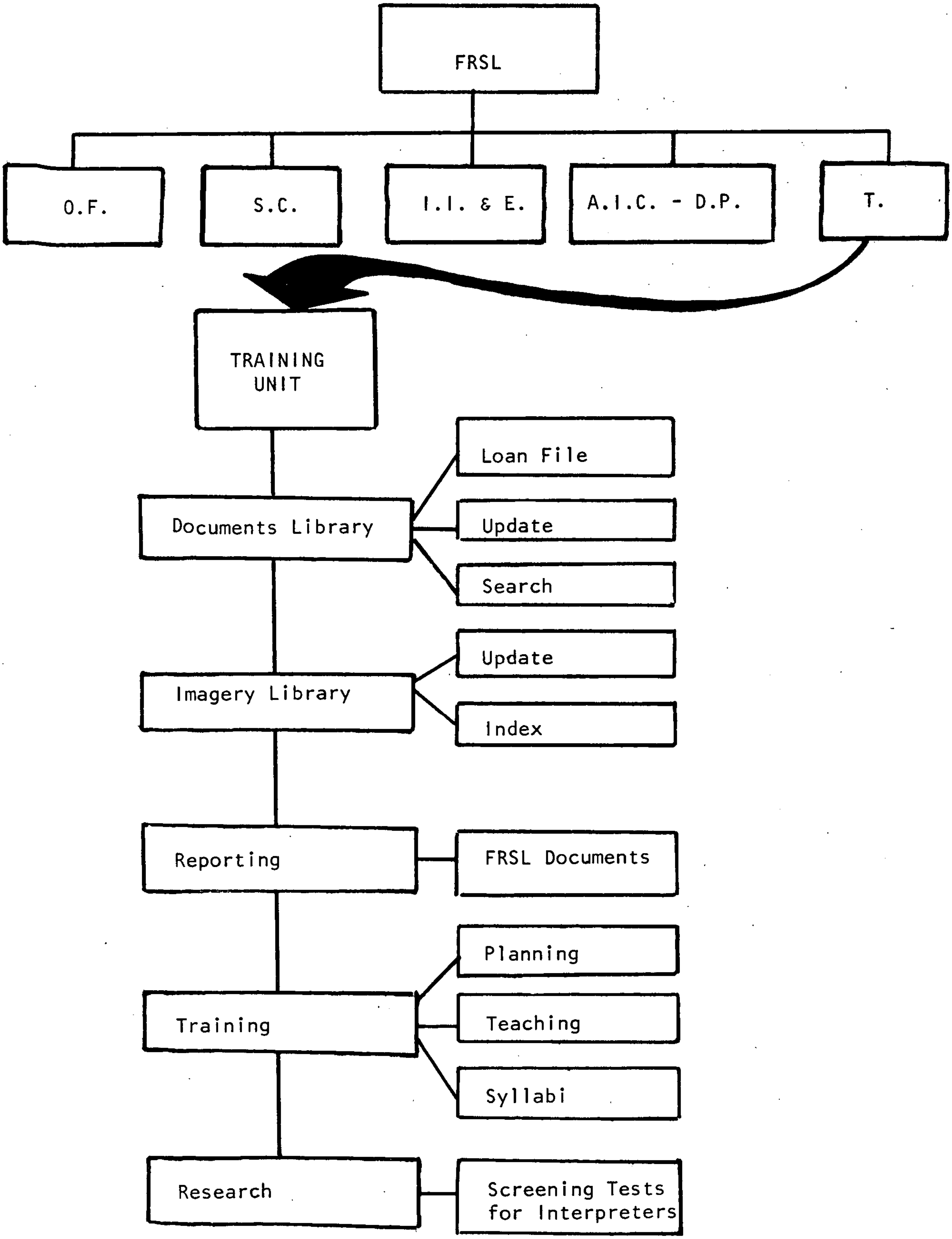


Figure 4.29. The diagram above depicts the functional tasks performed by the Training Unit within the Forestry Remote Sensing Laboratory.

Likewise, the remote sensing imagery at the FRSL, which is indexed in a manner similar to that used for all NASA imagery at NASA/MSC (U.S. Army Map Service UTM grid system) is available for analysis at the Laboratory. We have found that the imagery library, which contains data obtained from earth orbiting satellites (Tiros, Nimbus, Gemini, and Apollo), NASA Earth Resources Program aircraft (Convair 240, Lockheed P3A, Lockheed C130 and RB57), government agencies (Agricultural Stabiliation and Conservation Service, Geological Survey, Forest Service, etc.), and private contractors, can provide a means for review of imagery by scientists prior to requesting reproductions from NASA or other agencies. In addition, we are prepared to index, and thus incorporate into this library facility, the simulated ERTS data currently being procured over the various western U.S. regional test sites by the U-2 aircraft stationed at NASA-Ames.

In addition, a major responsibility of the Training Unit is to disseminate the research findings derived by the FRSL staff. Fully illustrated copies of all NASA funded forestry reports, special reports, training syllabi and field tour guides prepared by the FRSL staff are available in the documents library loan file. Furthermore, in the case of most FRSL reports, more than 200 copies are distributed to both national and international library facilities, research groups and user agencies.

In reference to training, we are pursuing a vigorous program involving lectures, short courses, workshops, guided field tours of NASA test sites and formal training courses. We feel that virtually all remote sensing training programs currently being offered are merely "appreciation

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courses", i.e., those designed to convey to the attendee the fact that remote sensing techniques offer a powerful means of making accurate, timely, economical inventories of earth resources. While there may be a continuing need for these courses to be presented to various top-level "decision-makers", the major need is to train the actual "doers". Mere appreciation courses definitely will not prepare them to accomplish the all-important task of making operational inventories. Instead, they need to receive rigorous training in how to produce, through an analysis of remote sensing data, a survey of earth resources of the type that will meet the specific informational needs of the resource manager.

As in other Forestry Remote Sensing Laboratory training exercises conducted thus far, all future programs will make maximum use of the concept of "learning by doing". Consistent with this concept, actual rather than hypothetical problems are emphasized. These problems are centered around the inventory of earth resources at NASA test sites, one of which (the San Pablo Reservoir Test Site) is only eight miles from our classroom facilities at the University of California. Training films, field tour manuals, and display boards based on this and other NASA test sites which our group has studied during the past seven years have been successfully used for training in the past and are available for future programs. These training materials illustrate various data acquisition and analysis techniques with emphasis on both the gathering of "ground truth" data and the extraction of information from remote sensing imagery. More specifically, during these training programs we attempt to disseminate information on the following subjects: (1)

specific user requirements for earth resource information; (2) basic matter and energy relationships; (3) remote sensing capabilities in various parts of the electromagnetic spectrum; (4) sampling techniques, including techniques for the acquisition of ground truth; (5) photo interpretation equipment and techniques; (6) image enhancement techniques; (7) automatic data processing techniques; and (8) techniques for optimizing the interaction between those who provide earth resource inventories and those who use such inventories in the management of earth resources.

It should be noted that the FRSL staff presented a comprehensive 5-week training course last fall. The purpose of the course was to train approximately 30 resource managers and inventory specialists affiliated with the U.S. Department of Interior to inventory earth resources (i.e., land, water, mineral, vegetation, and cultural) with the aid of remote sensing. Maximum emphasis was placed on the use of current state-of-the-art remote sensing capabilities from aircraft and spacecraft, including those soon to be tested in the ERTS-A and Skylab programs. More recently, the FRSL group presented a one-week training program to representatives from various resources agencies in the State of California. Furthermore, two shorter briefings on applications of remote sensing were recently given -- one to visiting remote sensing teams from the Philippines and Thailand, and the other to personnel representing different bureaus within the USDI.

In addition, members of the Training Unit are engaged in several research efforts which relate directly to training people to become proficient in applying remote sensing techniques to resource inventory problems. For example, the testing of a person's level of experience, degree of motivation, and mental and visual acuity constitutes an important first step leading to the wise selection of trainees and to the developing in them of proficiency in performing resource surveys using manual interpretation techniques. Such testing often leads to adequate screening of candidate personnel and, thus, to the elimination of poor prospects prior to initiating an operational project. We are currently in the process of reviewing the literature relative to this subject, collecting examples of screening tests previously prepared by other investigators and making a series of our own tests. These tests relate directly to the FRSL projects involving applications of high flight, multiband-multidate imagery to agricultural and forestry environmental problems. Once the screening tests are perfected and proven to be effective, they will be valuable instructional material for any forthcoming training course given by the FRSL staff.

4.6.2 Future Activities

Training Unit personnel will continue to disseminate to interested parties pertinent information relating to remote sensing techniques and applications. For example, we will continue to (a) publish our research findings, (b) update our documents library, (c) maintain our film file, and (d) participate in lectures, short courses, seminars, workshops and training courses.

In addition to carrying on those activities mentioned above, the

Training Unit at the FRSL will act as a focal point for non-grant cooperators (e.g., California Agricultural Extension Service, Bureau of Land Management) during the U-2 and ERTS-A experiments. We will provide copies of imagery in our files to the various investigators and make available to them data analysis equipment and technical assistance.

Chapter 5

N73-14366

RIVER MEANDER STUDIES

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Contributor: Gerald Schubert

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As discussed in detail in our earlier progress reports, we are undertaking a basic study of river meander patterns, the results of which, we believe, would be of benefit to hydrologic development in two specific areas. First, the study which we have outlined should result in new criteria by which the stability of a meander pattern at arbitrary discharge may be examined. Such an examination would then be used as part of the evidence in the decision as to whether existing river control systems -- levees, check dams, and diversion areas -- are adequate at some assumed flood stage, or whether additional control facilities must be built. It is already clear that at some flood stage, rivers produce rapid, often disastrous, alterations in their meander patterns, and it is an objective of our study to see if such alterations can be anticipated. The Feather and Colorado Rivers are appropriate for attempted application of this technique, although part of the basic study which we are undertaking will require data from an undeveloped river to avoid the additional complication which river development adds to the problem. A second anticipated benefit of our study will be in the area of preliminary regional planning.

One of the new apparent shortcomings of many previous development programs is the limited regional scale to which the preliminary studies have been applied. The trend in recent years has been toward more extensive alterations in natural river flow patterns over large areas, which may involve more than one important drainage basin. As important and expensive as the Feather River Water Project in California has become, it is dwarfed by proposals already being advanced to divert large volumes of water from the Columbia River basin to the Southwest.

It is the intent of our research to develop a relatively simple and inexpensive technique to assess the water resources of large, relatively undeveloped geographical areas in order that comprehensive water development plans may be prepared with less expenditure of money and time for the collection of data on the earth's surface. We are seeking to determine whether it will be possible to extract data on the total discharge of a river, both past and present, from satellite television photography of river meander patterns. We expect also that this technique will yield indirect information on the average rainfall over large drainage basins, calculated by relating the flow measurements to the geographical areas involved.

Since most river drainage basins in the U.S. have already undergone substantial development, and since river discharge and rainfall data are reasonably reliable in this region, we expect the proposed technique to be of value largely in underdeveloped and poorly surveyed areas of the world. Data available in such areas as the United States will serve for the validation of the technique, which is our principal research task.

If the technique can be validated by our research, hydrologic data can be acquired for large regions at low cost, and a data base established to support a water management program for large, presently underdeveloped geographical areas.

5.1 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

During recent months we made substantial progress in our geomorphological investigation of a possible correlation between the stream meander power spectrum and the stream discharge frequency distribution. As we noted previously this investigation involves the following steps:

1. Selection of appropriate rivers.
2. Collection of suitable photographic coverage.
3. Collection of historical streamflow data.
4. Digitization of streamflow data.
5. Digitization of stream meander patterns.
6. Matching of individually digitized portions of meander patterns to obtain a continuous record.
7. Construction of stream discharge frequency distribution from discharge data.
8. Construction of power spectra of local river meander directions and radii of curvature.
9. Determination of relationship of meander power spectra to discharge frequency distribution.

We have now completed the first eight of these steps for the Feather River and have thus established the procedures for generating the stream discharge probability density functions and meander power spectra for other rivers.

Before we can proceed to the final step of studying the relationship between discharge spectrum and the meander spectrum, we must generate these quantities for a large number of rivers. We are presently engaged in this endeavor.

5.1.1 Digitization

The digitization of river meander patterns from aerial photography is most accurately and economically accomplished through photoelectric optical scanning. The Programmable Film Reader/Recorder (PFR-3) developed by Information International Inc., Los Angeles, employs this technique and we have constructed a program for digitizing river meanders on this machine. An important condition on the digitization procedure is that we locate points at equal increments of distance along the meander curve. This condition follows from the fact that local meander direction and radius of curvature are functions of distance along the meander and the algorithms used for constructing their power spectra require that we know these quantities at equal increments of distance.

The essence of the digitization procedure is as follows (see also Figure 5.1): The initial point on the meander pattern is found by scanning along a horizontal or vertical line and measuring the density profile along the scan (line AB in Figure 5.1). The river bank, i.e., the point digitized, is defined as the location of the point of maximum gradient in the density profile (point 1). The second point is determined by an iterative process starting with a scan (line CD) parallel to the initial scan but displaced by a distance, s, from point 1. The first estimate of this point (2') is determined in the same manner as above. The distance between points 1 and 2' is then calculated and if it is not equal to the required spacing, s, plus or minus some small Δ, another scan (line EF) is made along a line perpendicular to that line connecting points 1 and 2' at a distance s from point 1. Point 2" is then determined along this scan. If the distance between it and point 1

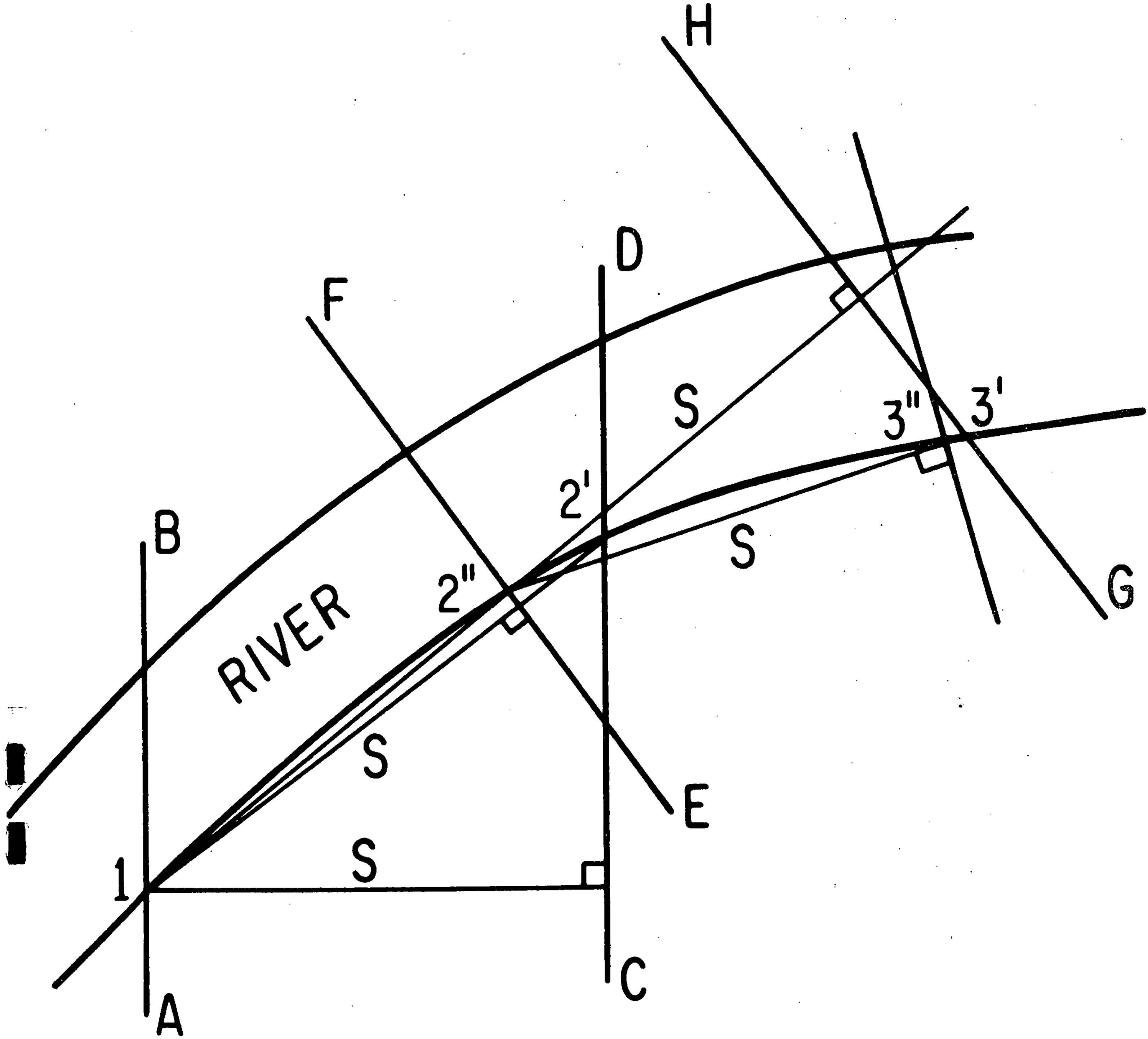


Figure 5.1. Digitization procedure.

is still not within s ± Δ, the iterative process is repeated until convergence is obtained. Once point 2 is located, the search for point 3 begins along a scan line (GH) perpendicular to the line connecting points 1 and 2 at a distance s from point 2.

In this manner the machine proceeds along the meander curve digitizing points at equal distance increments along the curve. The process is then repeated for the other bank of the river. A computer generated plot of the digitized meander pattern of a section of the Feather River is shown as the overlay in Figure 5.2 together with the infrared photograph from which the pattern was derived. As can be seen this technique provides an accurate reproduction of the meander pattern.

As is generally the case, the photographic coverage of the river consists of a number of overlapping frames, thus this digitization procedure is repeated for each frame. The data for adjacent frames must then be matched to give a continuous digitized record of the meander pattern for each bank. Because of the large overlap between frames (roughly one-third of the data on the end of each frame overlaps with the data on the beginning of the next frame) the data sets can be uniquely matched for congruency in the overlap region. We have developed a computer program which finds the appropriate coordinate transformation, i.e., includes both translation and rotation of one frame with respect to the other. This is accomplished by considering a length of river roughly half the length of the overlap region on one frame and effectively sliding this portion of the data along the overlap portion of the adjacent frame, finding that transformation within the overlap region which minimizes the sum of the squares of the distances between matched points.

Figure 5.2. Infrared aerial photography of section of Feather River with overlay of digitized meander pattern.

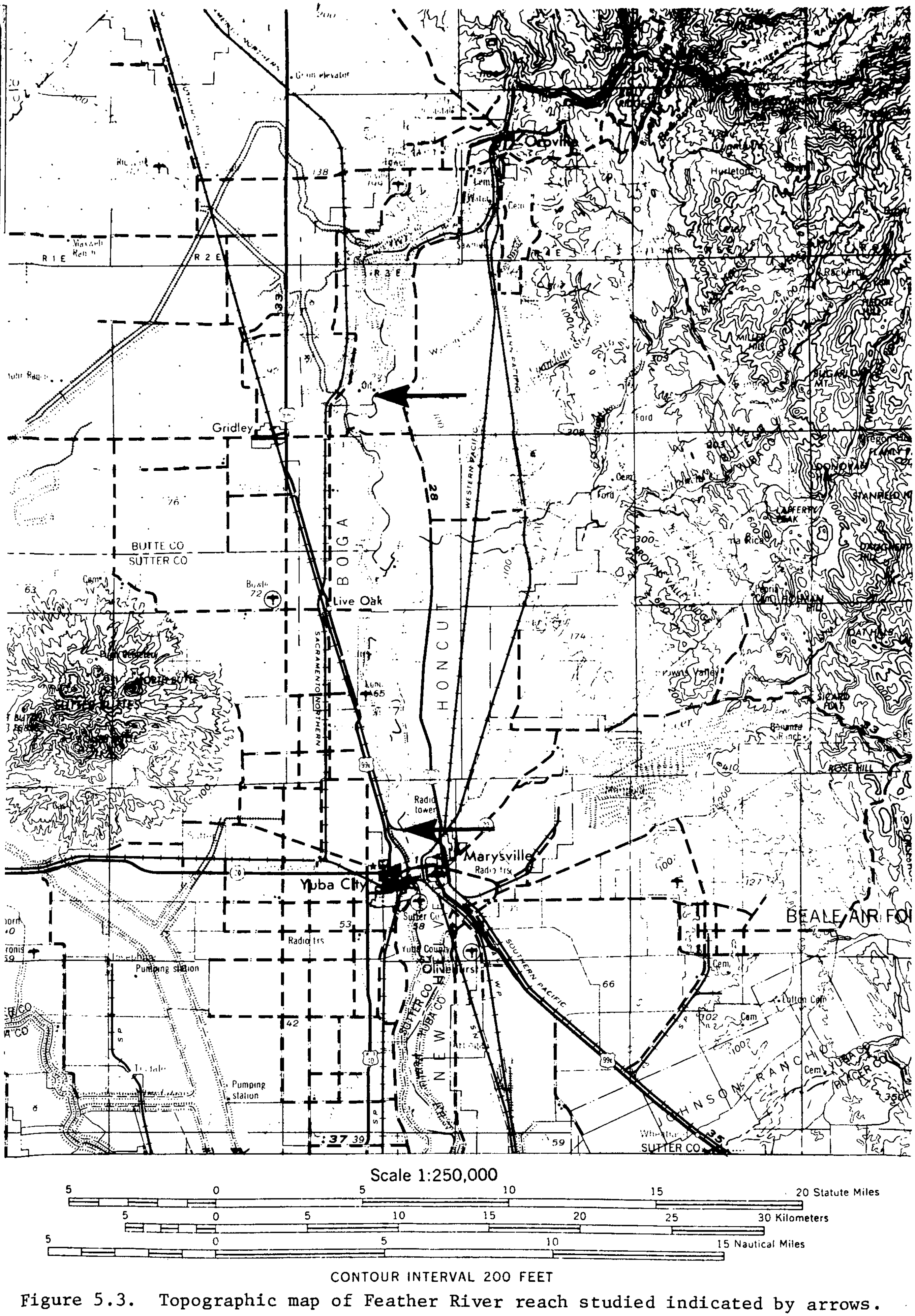
Once the appropriate coordinate transformation is determined, all of the data points on the second frame are transformed to the coordinate system of the first frame. The process is then repeated to match successive frames until the entire record is transformed into a single coordinate system.

The digitization and matching procedure described above has been applied to a 23 mile reach of the Feather River below the dredge tailings at Oroville to the Southern Pacific Railroad bridge north of Yuba City (Figure 5.3). A mosaic of aerial infrared photography covering this reach of the river is shown in Figure 5.4 and a Calcomp plot of the final data sets is shown in Figure 5.5 for two cases where the banks have been defined either by passage inside or outside islands and bars.

5.1.2 River Meander Power Spectra

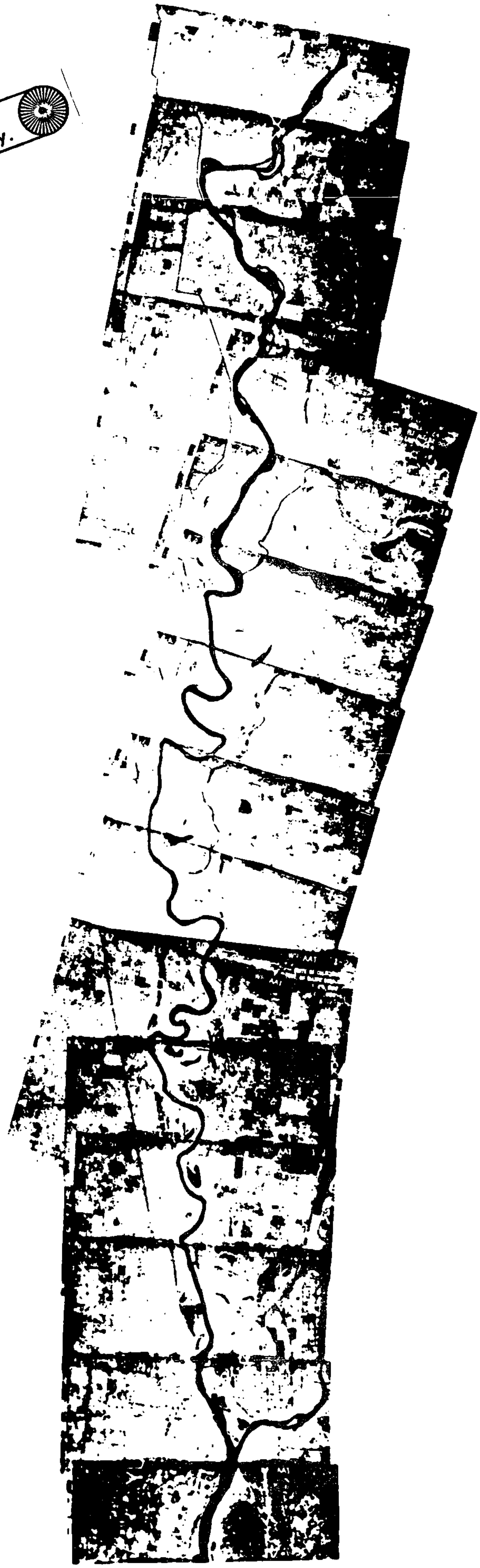
The digitization and matching procedures described above produce a set of data points (X, Y coordinates) which are equally spaced along the course of the river. A power spectral analysis of the river cannot be made directly from the X versus Y data since the river may double back upon itself making X a double valued function of Y. An equivalent representation of the river, which is single valued and thus amenable to power spectral analysis is its local direction, θ, as a function of the distance, s, along the river's course.

The power spectral density (deg^2/cycle per foot) for the direction θ is computed using standard techniques for determining the autocorrelation function, smoothing, and taking the Fourier transform (e.g., J. S. Bendat and A. G. Piersol, Measurement and Analysis of Random Data, John Wiley, 1966). The spectrum is analyzed for 6 degrees of freedom



CONTOUR INTERVAL 200 FEET

Figure 5.3. Topographic map of Feather River reach studied indicated by arrows.



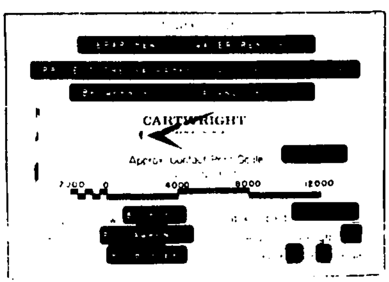


Figure 5.4. Mosaic of aerial photographs of Feather River reach from which meander pattern was digitized.

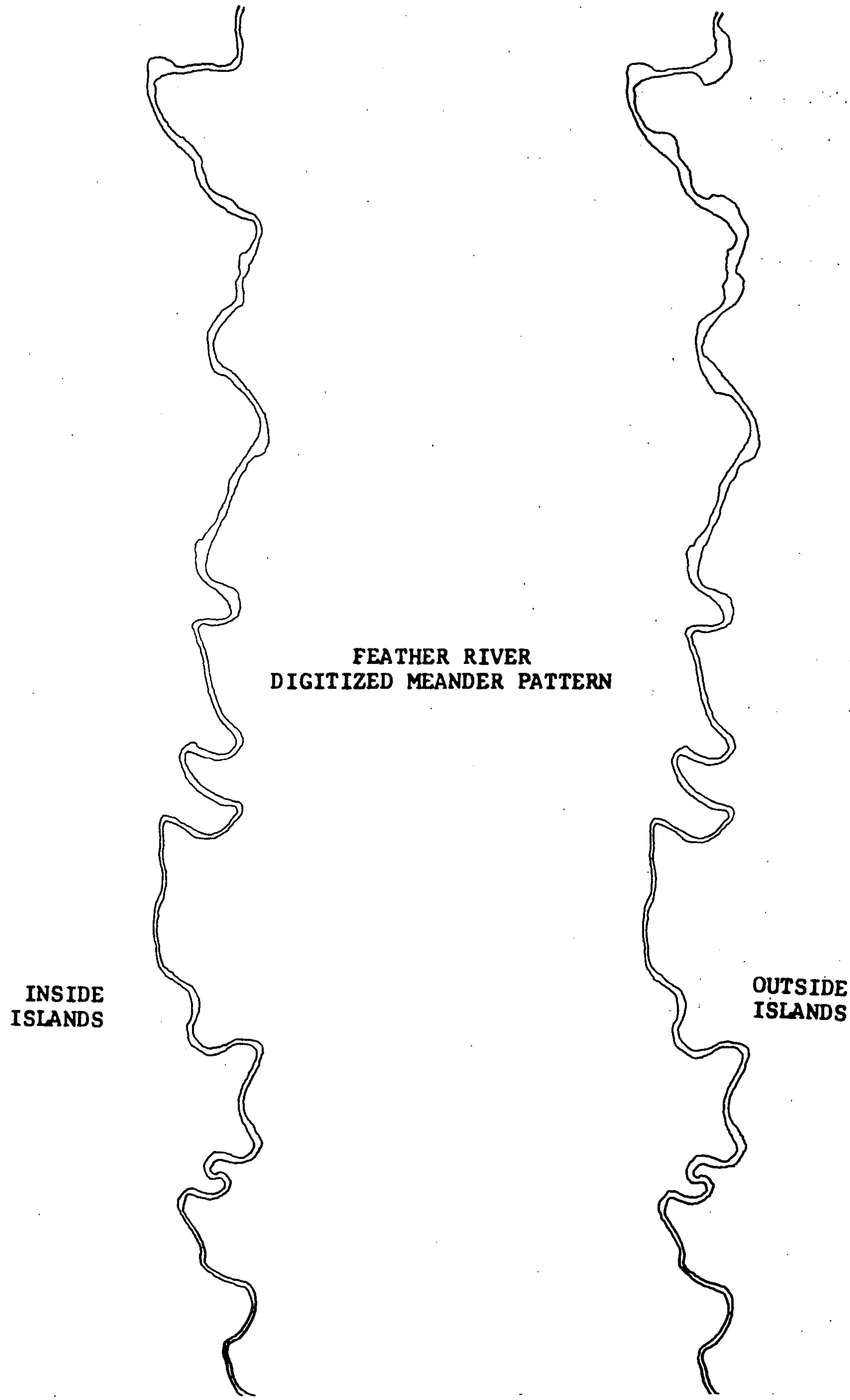


Figure 5.5. Calcomp plot of digitized meander pattern of Feather River reach with banks defined by passage inside (left) and outside (right) islands and bars.

which gives us 80% confidence that the spectral value lies within 2.8 and 0.5 times the computed estimate.

We have applied these techniques to the reach of the Feather River described above, and the power spectral density for each bank is shown in Figure 5.6 as a function of wavelength, λ, measured along s. As can be seen, the meander pattern results from a broad spectral peak at wavelengths between about 5,000 and 100,000 feet. Spectral information is limited at wavelengths greater than 100,000 feet by the total length of the reach of river being analyzed. At wavelengths less than about 5,000 feet there is no coherent contribution of power to the meander pattern. From this figure and Figure 5.7 we see that there is no significant difference in the power spectra of the right and left banks or of the banks defined by passing inside or outside islands and bars.

There is a suggestion of fine structure (i.e., multiple peaks) within this broad spectral peak. Furthermore, each of these multiple peaks may be predominantly associated with separate subreaches of the river as is evident from the positions of the spectral peaks for each of the subreaches shown in Figure 5.8.

The power spectra of portions of the Feather River presented here and spectra we have obtained of reaches of other rivers proves the practicality of our procedure and demonstrates that such spectra contain significant quantitative information on meander patterns, such as the wavelength of spectral peaks, which may ultimately be correlated with the discharge at peaks in the discharge probability density function.

5.1.3 Discharge Probability Density Function

Historical, daily streamflow data, in machine readable format,

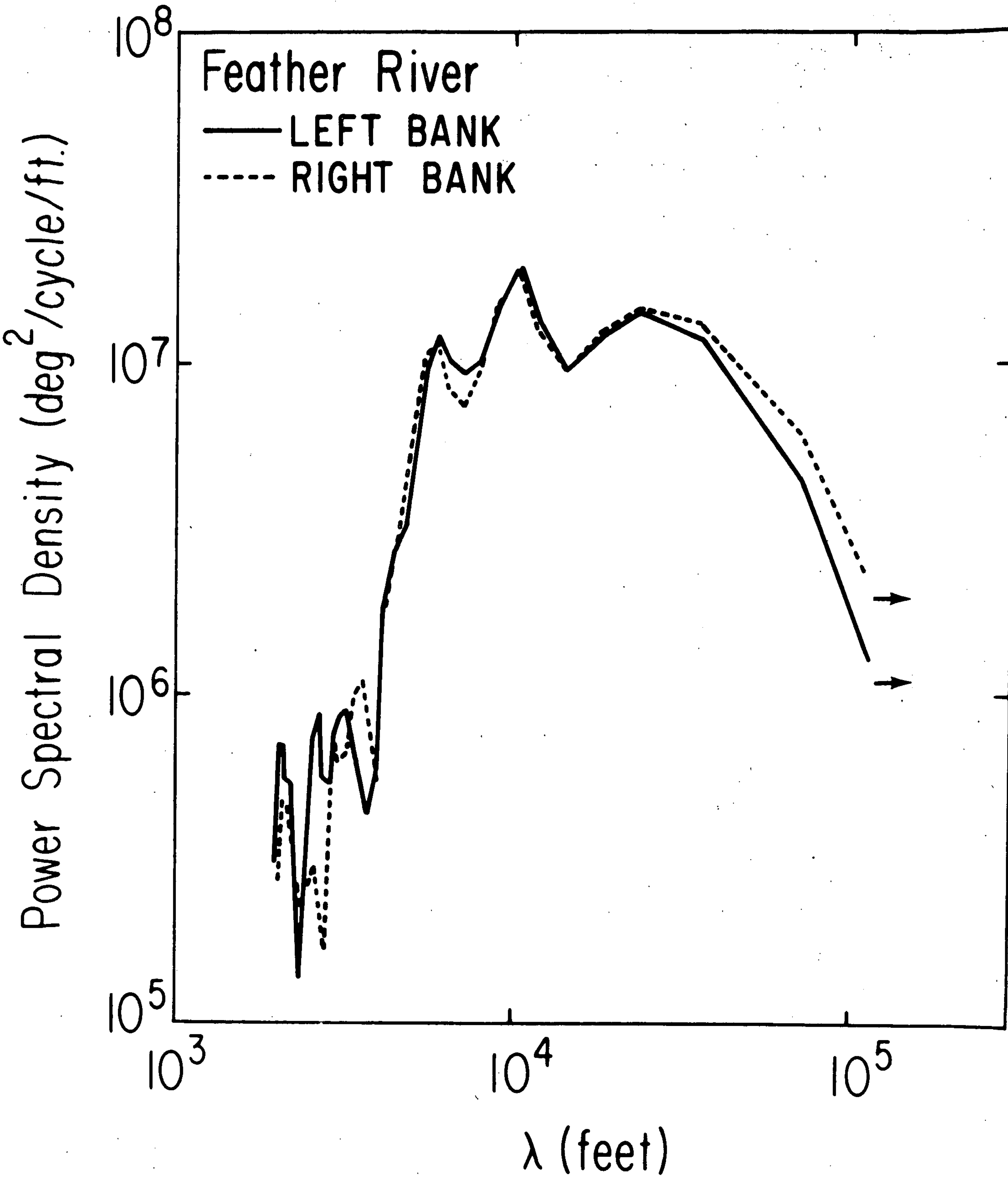


Figure 5.6. Power spectral density for each bank of Feather River reach as a function of meander wavelength, λ, measured along s.

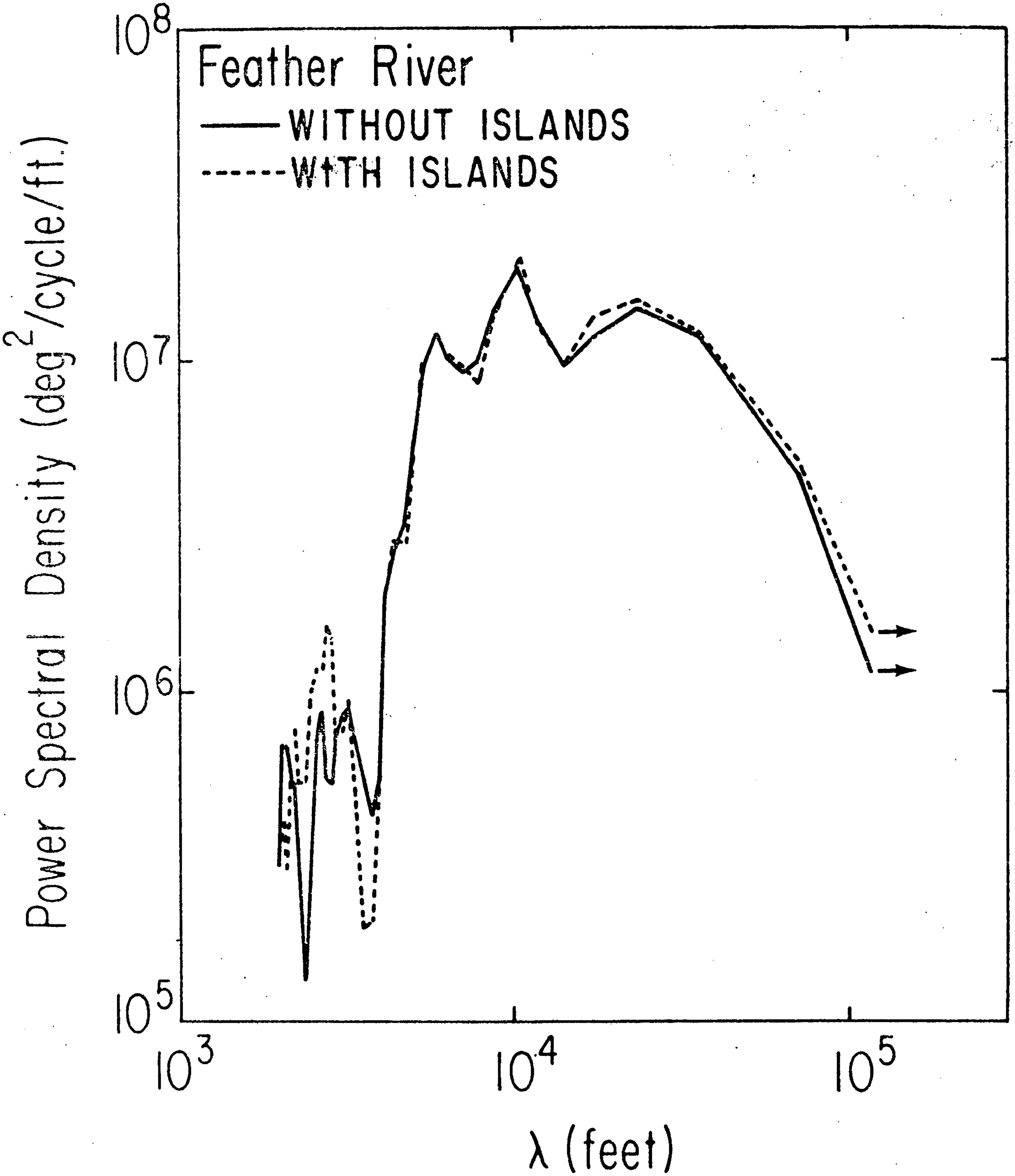


Figure 5.7. Power spectral density of Feather River reach for banks defined by passage inside (without) and outside (within) islands and bars.

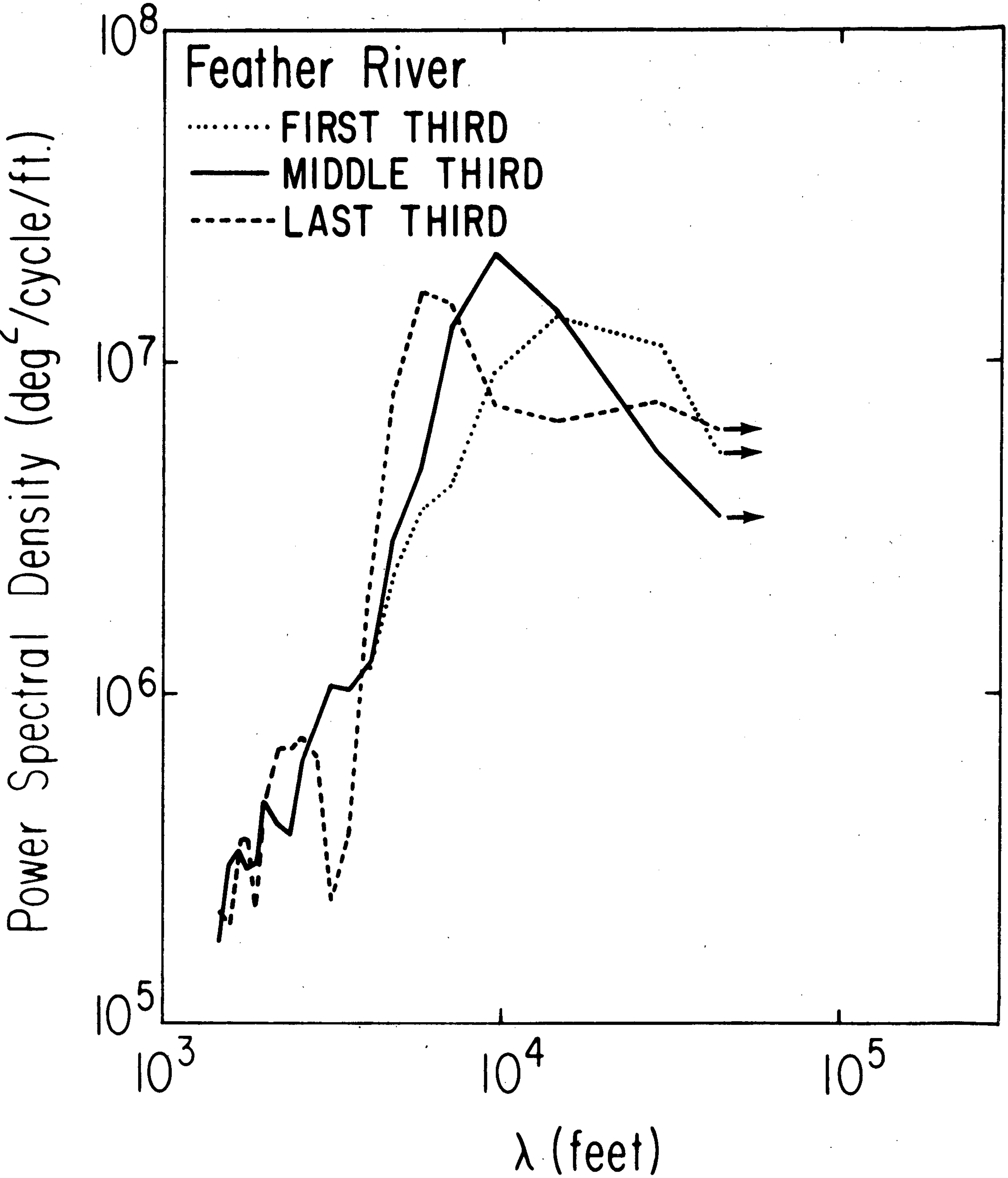


Figure 5.8. Power spectral density of three subreaches of Feather River.

have been obtained from the Water Resources Division of the U.S. Department of the Interior. We have developed an algorithm to compute the probability density function of the discharge, Q, from these data. This function is the probability that the discharge lies within the interval ΔQ at Q. The probability is determined by the fraction of the time that the discharge lies within this interval. We have also calculated the cumulative probability distribution function, which is the probability that the discharge is less than or equal to some value Q.

These functions computed from the daily discharge data for the Feather River near Oroville are shown in Figure 5.9 for the periods 1901-1933 and 1934-1967. As can be seen, there is little difference in the probability density functions for these two periods which are prior to regulation of the flow by the Oroville Dam. Starting at the end of 1967 the discharge has been regulated at $\sim$400 cu. ft./sec., as is evident in the probability density function for the period 1901-1968 shown in Figure 5.10. Since this controlled discharge is outside the range of the previous discharge spectrum, we will investigate whether significant changes in the meander pattern occur.

5.2 FUTURE PROPOSED WORK

Having developed the procedures for generating the meander power spectra and the discharge probability density functions for rivers, we are now in a position to begin studying whether a correlation can be established between these two functions. Thus we have selected for study several dozen river reaches, based primarily on uniformity of geology and availability of infrared photographic coverage or radar imagery and historical hydrologic data.

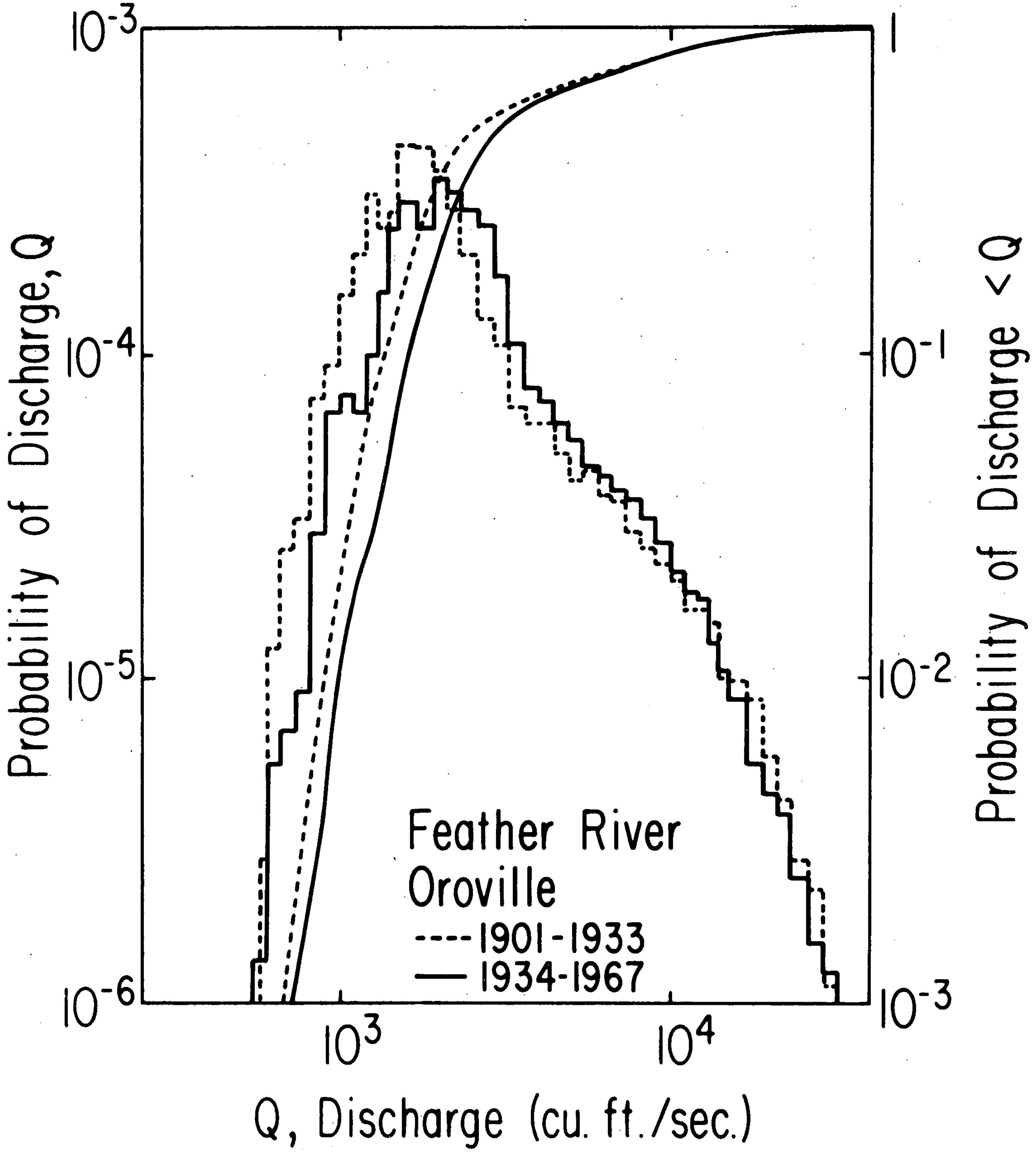


Figure 5.9. Discharge probability density functions and cumulative probability distribution functions for Feather River near Oroville for periods 1901-1933 and 1934-1967.

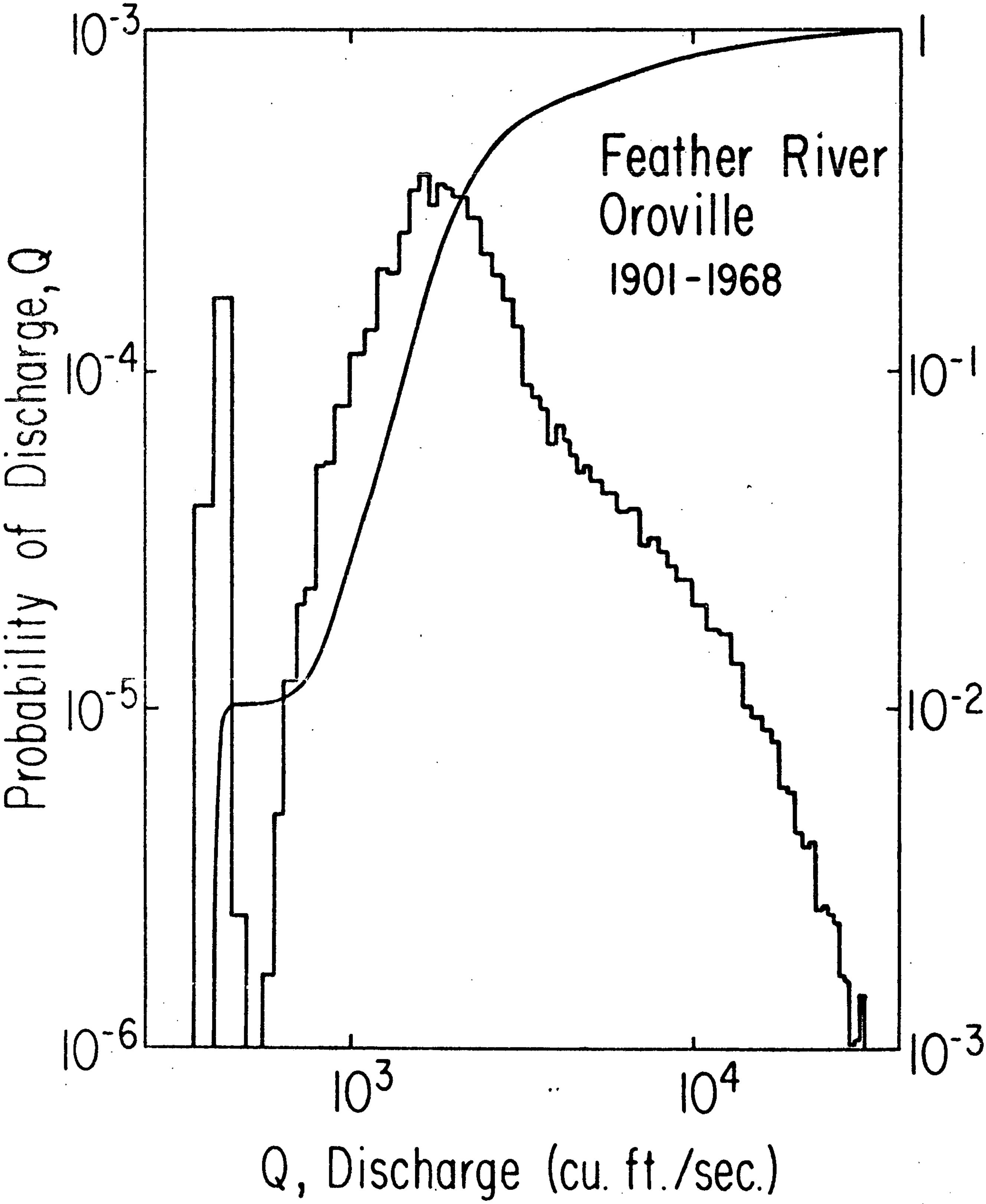
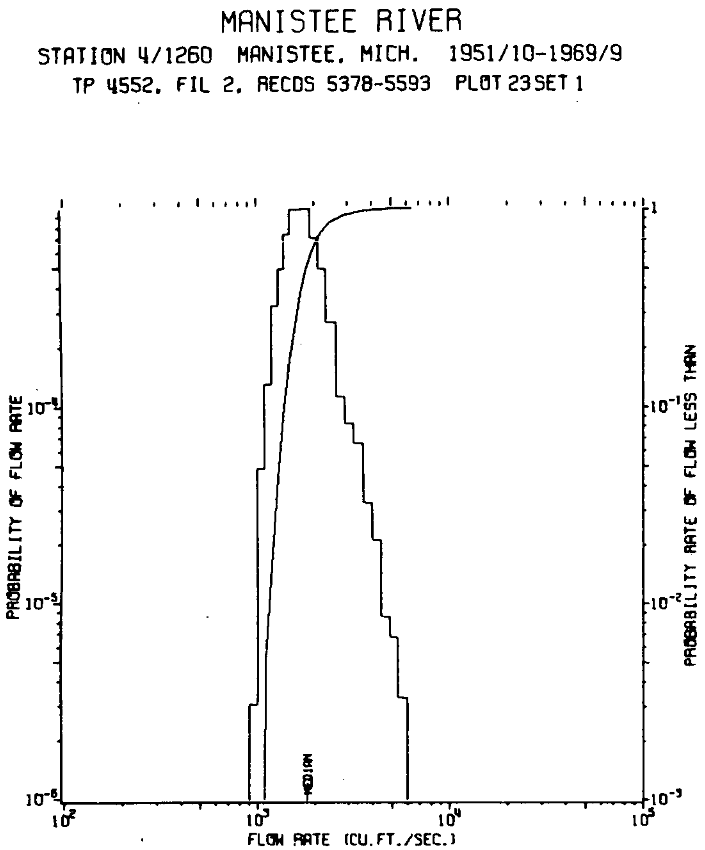
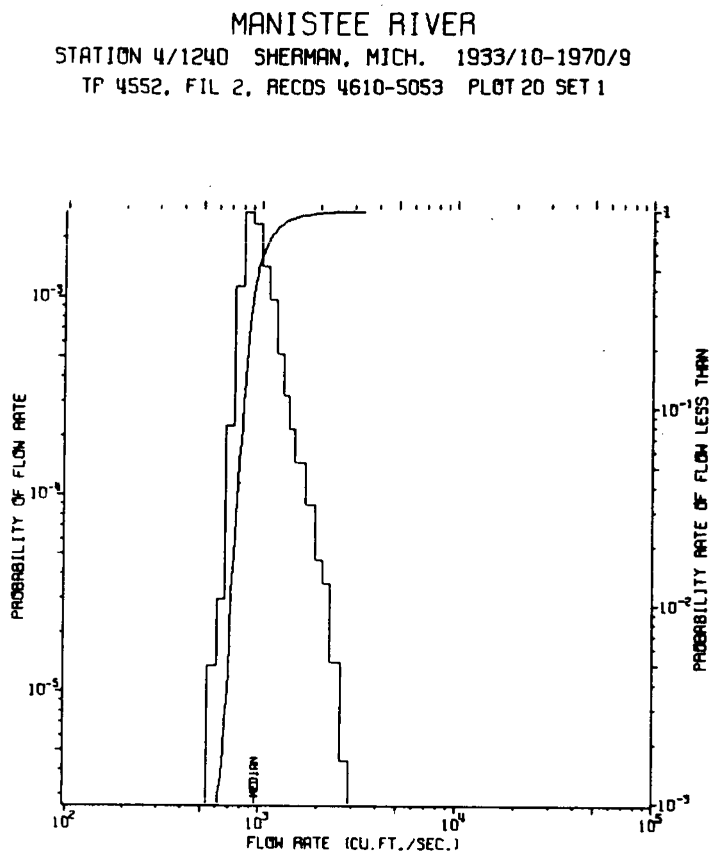


Figure 5.10. Discharge probability density function and cumulative probability distribution function for Feather River near Oroville for 1901-1968. Note separate peak in discharge at 400 cu. ft/sec resulting from Oroville Dam control in 1968.

We have obtained the hydrologic data on the first 30 river reaches from the Water Resources Division of the U.S. Department of the Interior. Figures 5.11 through 5.16 show the variety of discharge probability functions included in the data. We will attempt a first order correlation between power spectral density and the discharge probability function, using data for rivers whose discharge is very sharply peaked. In such cases only a clearly defined narrow range of discharge can be effective in producing the meander pattern. Examples of such discharge functions can be seen in Figure 5.11, showing data for three stations on the Manistee River with median discharge ranging over an order of magnitude. Such functions are not unique as can be seen in Figures 5.12 and 5.13 showing similar data for six other rivers. We will then investigate the relative importance of the high discharge end of the probability density function using data from rivers, such as the Homochitto and others, shown in Figures 5.14 and 5.15, which have much broader discharge probability functions. Finally, if we can find a satisfactory correlation between the meander power spectra and the discharge probability functions for these rivers, we can then investigate rivers with much more complex variations in flow rate, such as those shown in Figure 5.16.

We also have obtained infrared aerial photographs from the Forest Service and the Agricultural Stabilization and Conservation Service of the U.S. Department of Agriculture, and the Department of Water Resources of the California State Resources Agency. In addition, radar imagery has been obtained from the Earth Resources Research Data Facility at the NASA Manned Spacecraft Center.





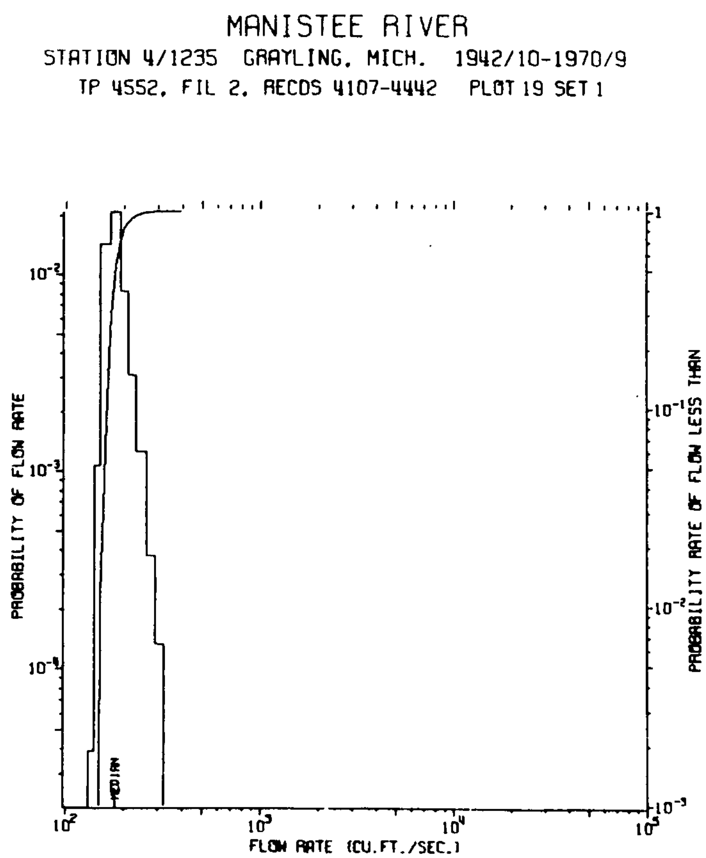


Figure 5.11. Water discharge rates at three stations on the Manistee River in Michigan, with median discharge values ranging over an order of magnitude.

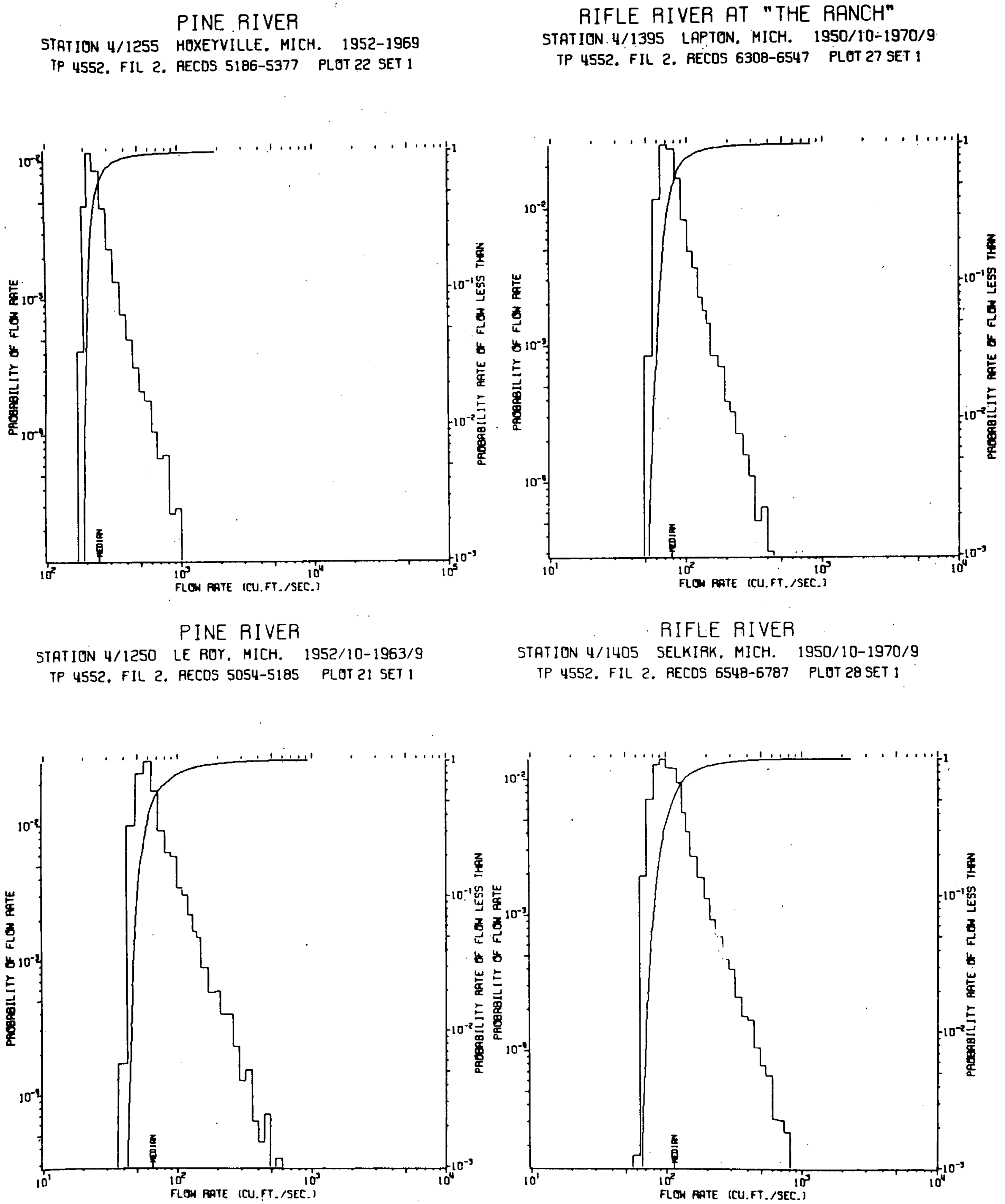


Figure 5.12. Water discharge rates at two stations in Pine River (left column) and also at two stations in Rifle River (right column). Note similarity to Figure 5.11.

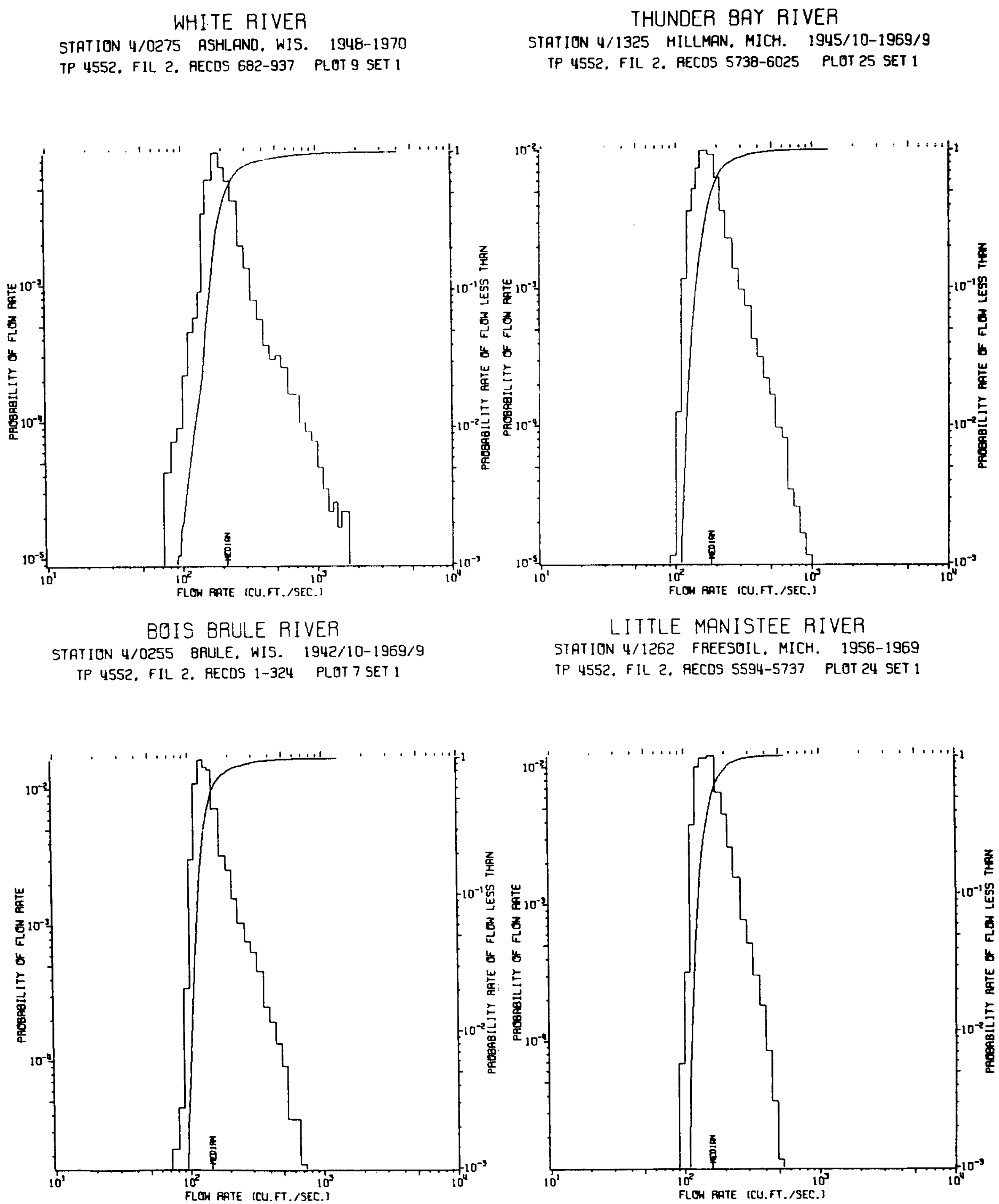


Figure 5.13. Water discharge rates from these four rivers in Wisconsin and Michigan are seen to be quite similar to those diagrammed in Figures 5.11 and 5.12.

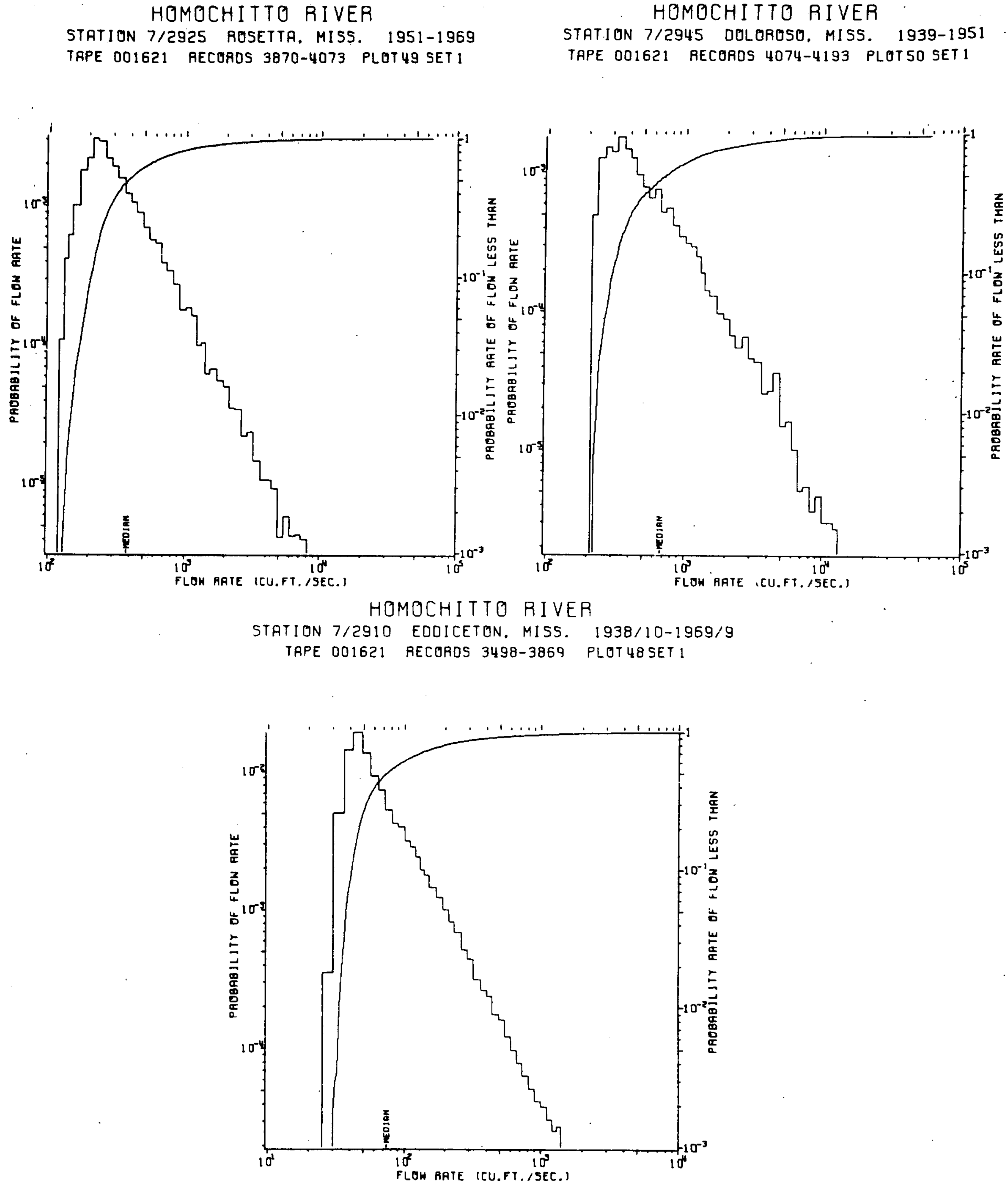
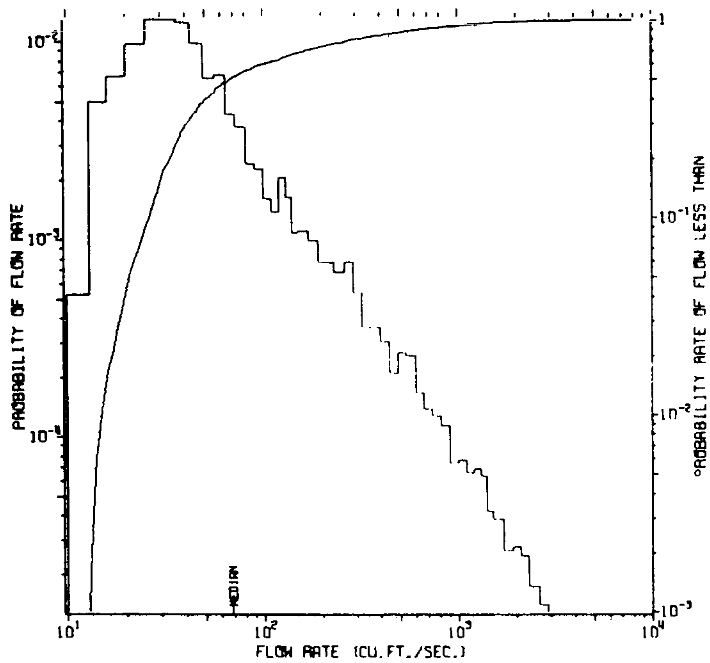
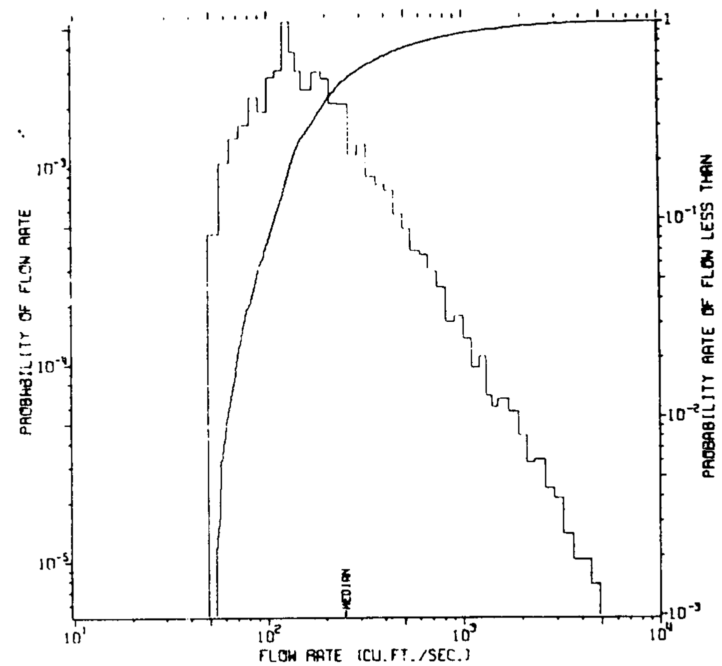


Figure 5.14. The water discharge rates at three stations on the Homochitto River in Mississippi are seen in the above diagrams to have much broader probability functions than those shown on the preceding figures.

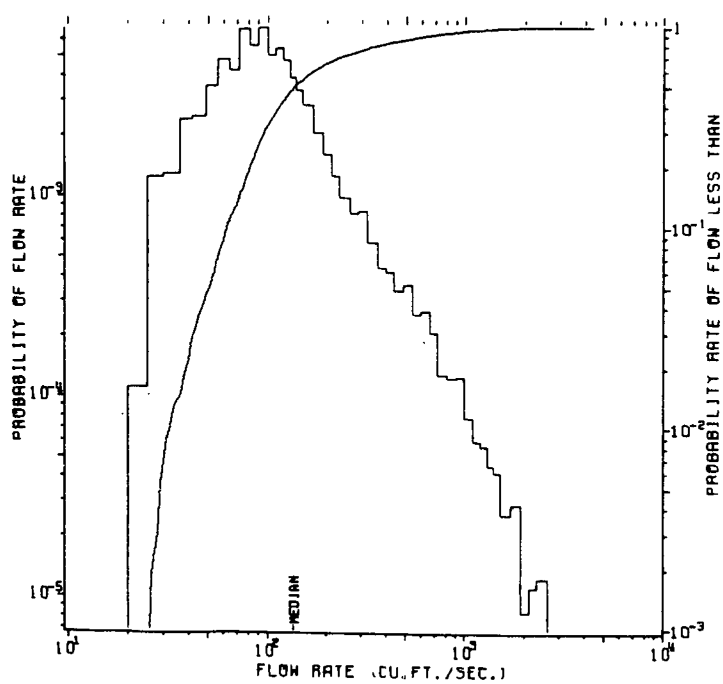
SOUTH FORK JUMP RIVER
STATION 5/3615 OGEMA, WIS. 1944/5-1954/9
TP 4552, FIL 2, RECDS 7377-7501 PLOT 32 SET 1



BAD RIVER
STATION 4/0270 ODANAH, WIS. 1948-1970
TP 4552, FIL 2, RECDS 426-681 PLOT 8 SET 1



PRESQUE ISLE RIVER
STATION 4/0320 TULA, MICH. 1945-1969
TAPE 001621 RECORDS 1-293 PLOT 37 SET 1



SHENANDOAH RIVER
STATION 1/6310 1930/10-1969/9
TAPE G40531 RECDS 217-684 PLOT 36 SET 1

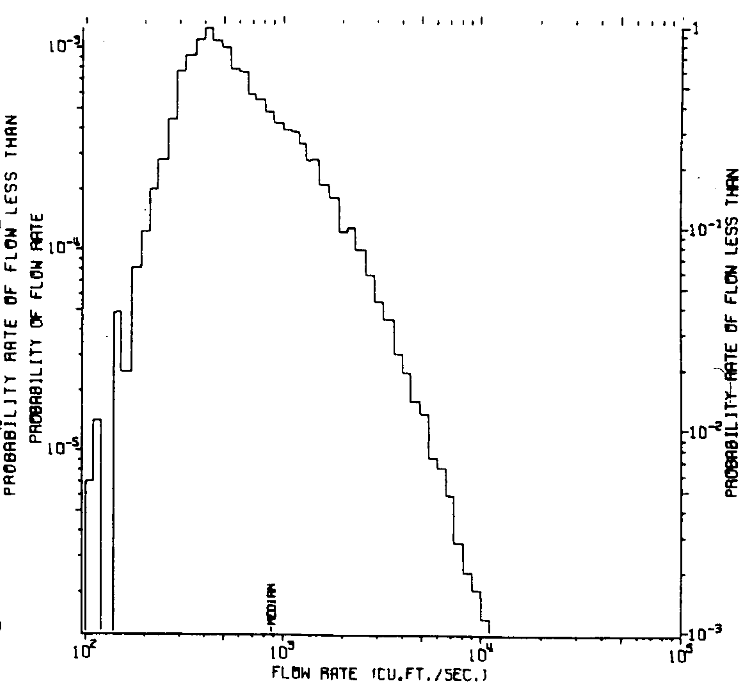


Figure 5.15. The discharge rates from these four rivers likewise exhibit broad probability functions as discussed in the text.

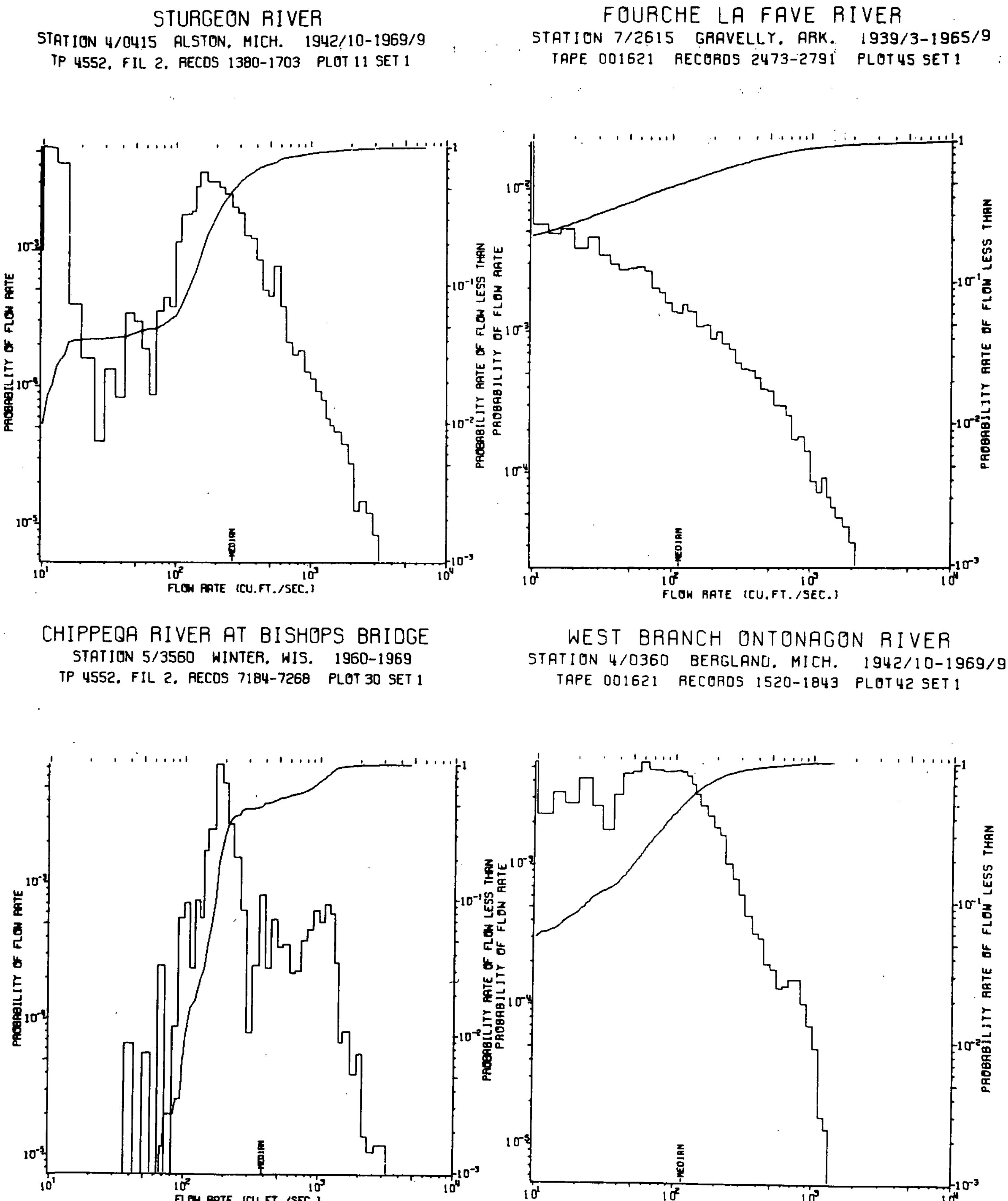


Figure 5.16. The discharge rates from these four rivers are seen to exhibit unusually broad probability functions.

We are currently engaged in processing the data for these reaches in order to demonstrate quantitatively both the potential uses and limitations of our correlation study.

Chapter 6

ASSESSMENT OF THE IMPACT OF THE CALIFORNIA WATER PROJECT ON THE WEST SIDE OF THE SAN JOAQUIN VALLEY

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Contributors: Leslie W. Senger, Michael W. Kuhn,
Lyndon Wester, Konai Thaman, Bruce Davis,
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6.1 INTRODUCTION

The research focus of our group is an investigation of remote sensing applications that contribute to an understanding of the impact of the California State Water Project on the West Side of the San Joaquin Valley. Specifically, studies are being conducted of various regional scale parameters that can be used to characterize the nature of the area transformation that is taking place. Information is currently being extracted from Mission 164 and ERTS-simulation high flight remote sensing imagery relative to: (1) land use, both general and urban-oriented; (2) vegetation, both general and problem-oriented (e.g. problems associated with boron and salinity affected areas); (3) irrigation systems; and, (4) identification of crops.

The photographic coverage of the area from Mission 164 (April, 1971) is complete with the exception of the 1:60,000 scale imagery. The lack of side-lap on parts of the imagery results in our having incomplete coverage of portions of the area at the 1:60,000 scale, but this does not seriously impair the research effort. The resolution of the imagery is quite good, but there were some exposure problems with the film (particularly with the color infrared). Camera exposures were pre-set causing those portions of the study area which are desert and highly reflective to be over-exposed. Despite these difficulties, the quality of the imagery appears to be compatible with our present information requirements.

The color infrared photography from the ERTS-simulation high flights covered only a very narrow portion of the area along the western boundary. The quality of the photography was generally good, but it would appear that November is a poor month for imaging purposes because of cloud cover. The photography is being used to analyze crop patterns, but it is clear that a larger area needs to be imaged for the most effective use of the photography.

The West Side of the San Joaquin Valley is a large area, and the studies being conducted are regional in scope. Considerable time is required simply to interpret these various kinds of imagery in order to obtain information suitable for analysis and evaluation. In the case of land use mapping, sufficient information has been generated to indicate that good quality maps with general categories can be produced. Furthermore, the photography is of sufficiently high quality that a more detailed expansion of the initial general land use categories is anticipated as a future part of the research effort. It would be premature at this stage to attempt to make similar comments for the other studies. It can be stated, however, that as the present studies are completed, other projects will be initiated that will encompass more of the regional parameters necessary to understand the transformation process that is occurring on the West Side.

The following sections are provided to indicate the nature of specific studies and progress which has been made in conducting them.

6.2 LAND USE CLASSIFICATION

In an area undergoing a process of regional transformation, a significant indicator of the nature and degree of change is general land use. The major objectives of land use investigations on the West Side are: (1) the compilation of sequential land use maps to determine gross land use changes; (2) detailed examination of particular land use categories to detect specific patterns of development that may be emerging; and (3) the interface of West Side land use data with classifications generated in other areas in order to develop a workable system for automated mapping.

The approach employed in this study to achieve the above objectives is the construction and analysis of a series of land use maps from aerial photo mosaics and the previously described NASA-supplied-imagery. General land use categories are being mapped to simplify identification, reduce interpretation errors, and provide a format amenable to slight modification in order to make it compatible with other land use classification systems being tested. The categories include transportation networks, settlements, oil extraction, cropland, grazing, and non-productive. Maps have been compiled for the dates of 1957 and 1971. The 1957 period represents a relatively stable period of West Side land use, and, therefore, serves as a good base from which to start monitoring change. The 1971 date is three years after water from the California Water Project first became available for use in the area and permits an analysis of Aqueduct-induced changes in land use patterns.

The status of land use in both 1957 and 1971 is illustrated graphically by the two maps in Figure 6.1. The two maps were overlain by a

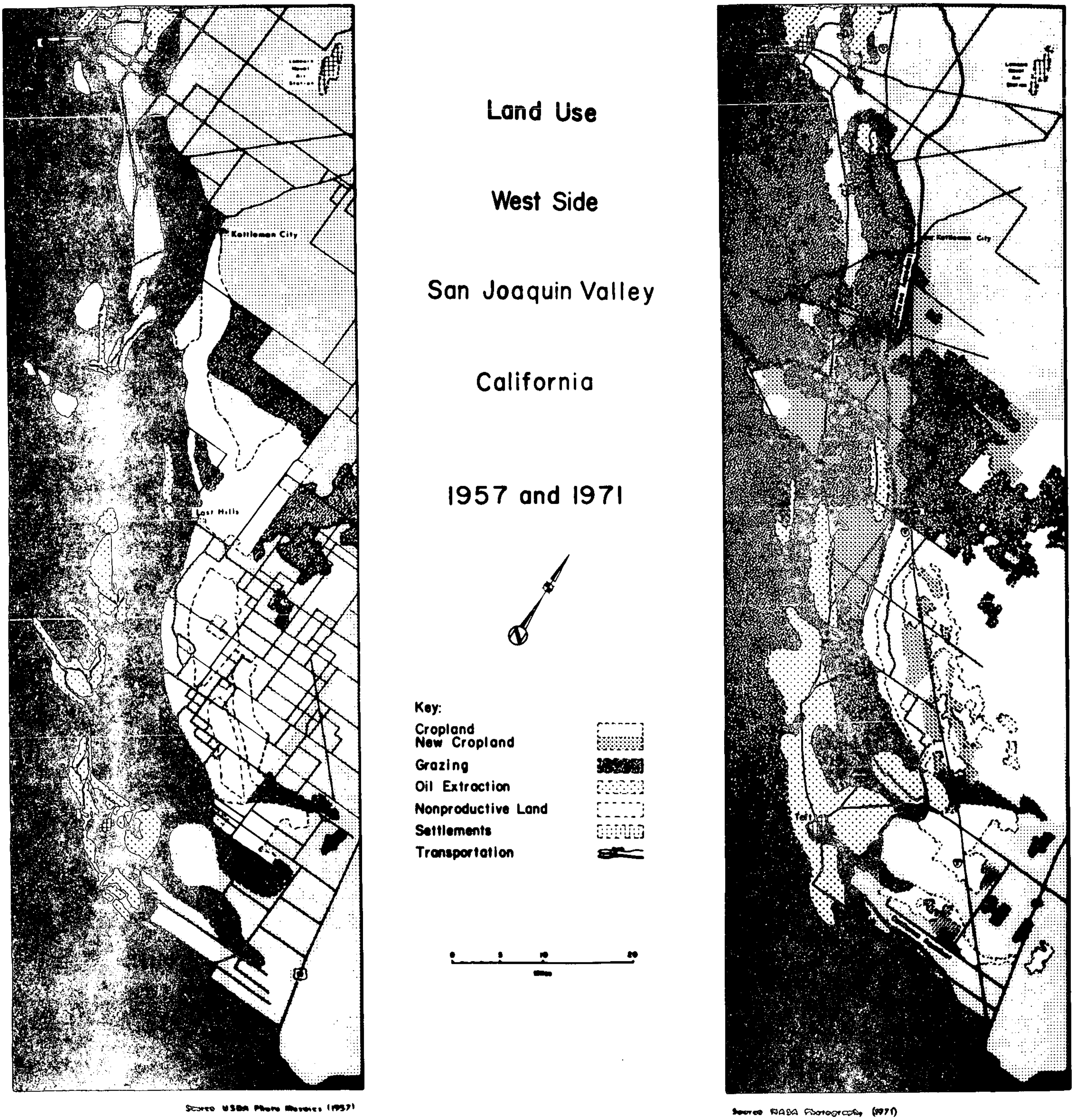

Figure 6.1. Land use maps of the West Side for 1957 and 1971.

square grid in order to derive a quantitative estimate of land acreages in the non-urban land use categories. The results of this estimation procedure are displayed in Table 6.1. The 1957 period is characterized by grazing and cropland, with grazing (51%) clearly dominating cropland (38%) in areal extent. Oil extraction (4%) and non-productive land (7%) occupy significantly less area. By 1971 the pattern has shown definite indications of change, with cropland (43%) almost on a parity with grazing (47%) in areal extent. Oil extraction (6%) has grown significantly, while non-productive land (4%) is clearly on the decline. Over the 14-year period, cropland has increased in area by almost 13%, while grazing has decreaed by 7%. Oil extraction has expanded by a dramatic 51%, while non-productive land has declined in area by 47%. In total, about 19% of the area underwent a change from one land use category to another.

A more detailed breakdown of the nature of the change can be seen in Figure 6.2. The two maps portray the various categories that changed and the distributional pattern of the changes. Table 6.2 is a quantitative estimation of the magnitude of the changes. More than twice as much grazing land was converted into cropland than vice versa, while non-productive land was changed into both categories in about equal amounts. Oil extraction increased substantially at the expense of cropland and grazing land, while non-productive land absorbed minor acreages from the other three land use categories. Of the more than one-half million acres of land that changed, the majority of land went into cropland (46%) or grazing (30%) and negligible amounts to the other categories.

TABLE 6.1 NON-URBAN LAND USE IN 1957 AND 1971 WITHIN THE WEST SIDE OF THE SAN JOAQUIN VALLEY

LAND USE CATEGORY	1957 (ACRES)	1971 (ACRES)	NET CHANGE (ACRES)
Cropland	1,094,926.3	1,233.063.9	+138,137.6
Grazing	1,439,843.3	1,339,388.9	-100,454.4
Oil Extraction	115,575.0	174,352.6	+ 58,777.6
Non-productive	205,080.6	108,619.8	- 96,460.8
Total	2,855,425.2	2,855,425.2	

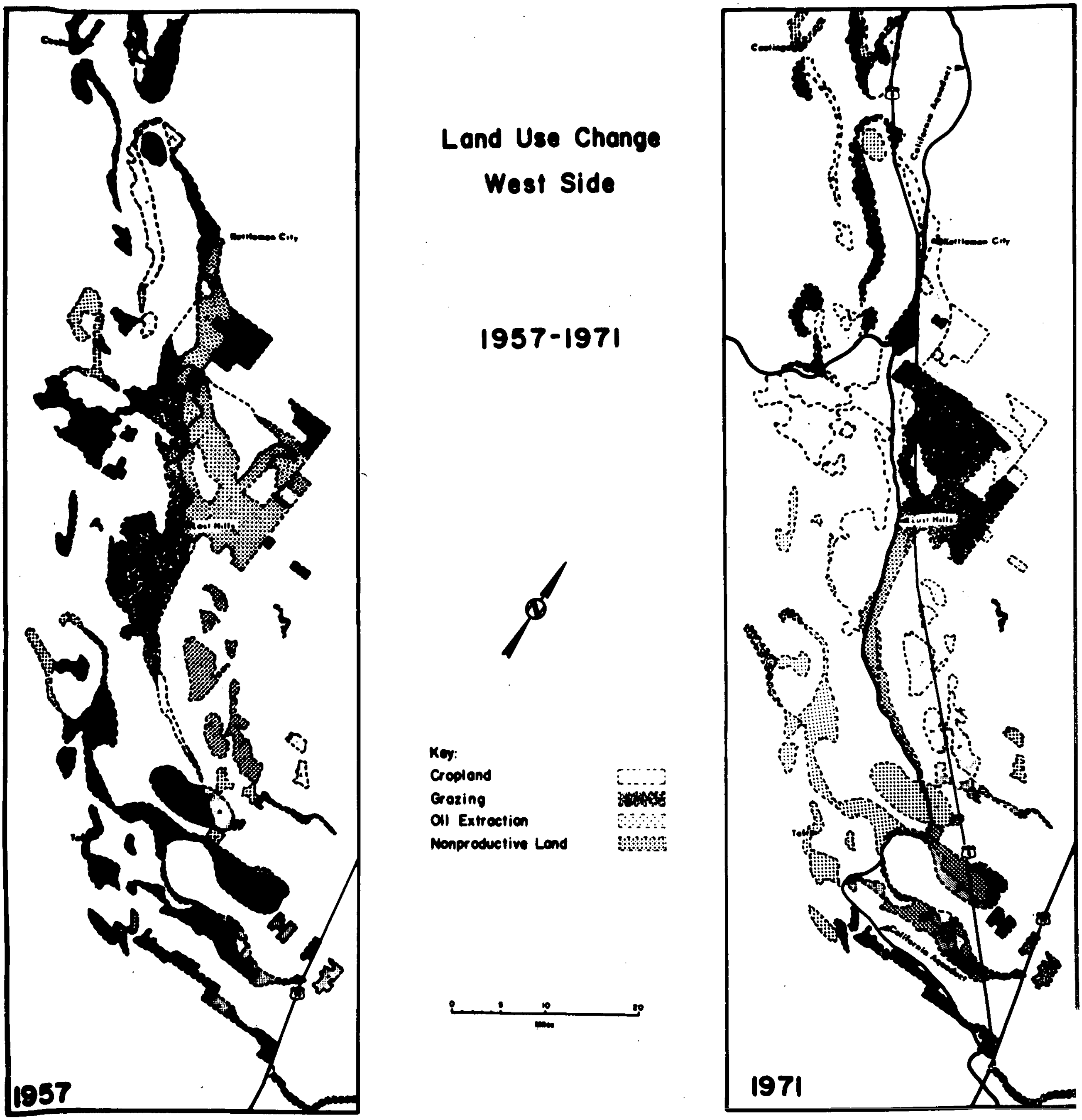

Figure 6.2. Maps depicting land use change for the time period 1957-1971.

TABLE 6.2 LAND USE CHANGES 1957-1971

1957	1971 LAND USE CHANGES IN ACRES				
	CROPLAND	GRAZING	OIL EXTRACTION	NONPRODUCTIVE	TOTAL
CROPLAND		71,475.2	14,028.8	15,257.6	100,761.6
GRAZING	167,321.6		71,680.0	20,070.4	259,072.0
OIL EXTRACTION	6,758.4	18,841.6		1,331.2	26,931.2
NONPRODUCTIVE	64,819.2	68,300.8			133,120.0
TOTAL CHANGE IN LAND USE ACREAGE	238,899.2	158,617.6	85,708.8	36,659.2	519,884.8

NET CHANGE IN LAND USE CATEGORIES (ACRES)

CROPLAND	GRAZING	OIL EXTRACTION	NONPRODUCTIVE
Loss: 100,761.6	Loss: 259,072.0	Loss: 26,931.2	Loss: 133,120.0
Gain: 238,899.2	Gain: 158,617.6	Gain: 85,708.8	Gain: 36,659.2
Change: +138,137.6	Change:-100,454.4	Change: +58,777.6	Change:-96,460.8

The data presented in the maps and tables indicate a definite trend towards intensification of land use. Less intensive land uses, (i.e. non-productive and grazing) have lost substantial acreages, while more intensive ones (i.e., cropland and oil extraction) have increased significantly. In particular, the increase in cropland acreage indicates the marked influence of the California Aqueduct and Interstate Highway 5. The trend in land use observed to date should continue, as water deliveries from the Aqueduct approach maximum allocation levels and Interstate 5 develops into a major transportation artery.

6.3 CROP IDENTIFICATION

In most agricultural areas, it is very difficult to identify major crops on imagery from a single date. The difficulty arises from the fact that similar spectral responses are exhibited by a variety of crops when imaged at any particular time. However, crops, which display similar tonal signatures at one point in time, may not have the same appearance at other stages of a growing season. Plants undergo phenological changes as they grow and mature. These changes are reflected in a variable signature for a crop as it progresses through its growth cycle. A remote sensing survey of agricultural conditions must take these factors into consideration and incorporate some form of sequential monitoring.

The West Side poses certain indigenous problems for the development of crop identification techniques. As a direct result of the California State Water Project, a great deal of formerly unirrigated land has come under cultivation. The major portion of the new land is in close proximity to the California Aqueduct. The additional water permits a wide variety of crops to be grown, although local soil conditions must be considered. Excesses of boron and other salts in the soil limit the crops which can be successfully grown. Presently, the majority of crops in the area are being cultivated on an experimental basis in order to determine those best-suited to environmental conditions and which are marketable. As a result, crop patterns in specific fields are in a continuous state of flux, and no fixed crop rotation schemes have emerged.

In order to effectively evaluate the capability of remote sensing imagery for the identification of crops on the West Side, one must collect a considerable amount of ground truth data. Table 6.3 is a summary of the crop data which have been collected so far. The most noticeable characteristic of the table is the overwhelming dominance of cotton as a crop. Of the 19 crops observed, cotton accounted for almost 50% of the fields and about 50% of the total acreage. Alfalfa, the next most widely occurring crop, accounts for less than 15% of the fields and total acreage. Furthermore, the top four crops in acreage are all field crops. Ninety percent of the fields and total acreage were in field crops, while vegetables, fruits and nuts, and grapes accounted for only 10% of the fields and total acreage.

Table 6.4 considers the same crops in terms of the field sizes found in association with them. Here, again, the field crops stand in marked contrast to vegetables, fruits and nuts, and grapes. Field crops show almost a 2:1 ratio in favor of large size fields. Discounting odd sized fields, 291 fields were in the 40 acre class, and 407 were in the 160 acre class. The other crops were almost evenly divided between 40 acre plots and 160 acre plots. As more data are acquired, the relationship between

TABLE 6.3 NUMBER OF FIELDS AND ACREAGE IN CROPS ON THE WEST SIDE OF THE SAN JOAQUIN VALLEY FOR FIELD TRANSECTS DURING A 15-MONTH TIME PERIOD.

CROP	NUMBER OF FIELDS	ACRES
Cotton	375	60,400
Alfalfa	113	20,350
Barley	125	16,800
Sugar Beets	50	8,260
Melons	28	5,220
Safflower	43	4,820
Tomatoes	28	4,560
Milo	24	3,000
Almonds	7	1,240
Asparagus	2	1,240
Sudan Grass	4	1,090
Corn	6	840
Carrots	9	820
Lettuce	1	600
Peaches	5	520
Grapes	4	400
Broccoli	3	360
Onions	5	300
Rice	2	200
....		
TOTAL	834	131,020
Field Crops	742	115,760
Vegetables	76	13,100
Fruits and Nuts	12	1,760
Grapes	4	400

TABLE 6.4 FIELD SIZES ASSOCIATED WITH WEST SIDE OF SAN JOAQUIN VALLEY CROPS

NUMBER OF FIELDS BY FIELD SIZE (ACRES)

CROP	20	40	160	200	600	640	800	840
Cotton	18	139	195	2	10	10		1
Alfalfa	5	51	90	2		4		1
Barley	6	50	63	1	2	5		
Sugar Beets	1	17	25	2	1	4		
Melons	5	10	10		2	3		
Safflower	1	16	26					
Tomatoes		12	16				2	
Milo	2	14	6			1	1	
Almonds		3	3			1		
Asparagus					1	1		
Sudan Grass		2	1					1
Corn		1	5					
Carrots	1	3	3	2				
Lettuce					1			
Peaches	2		3					
Grapes		2	2					
Broccoli			1	2				
Onions	1	2	2					
Rice		1	1					
....								
Field Crops	33	291	407	7	13	24	1	3
Vegetables	7	27	37	4	4	4	2	
Fruits and Nuts	2	3	6			1		
Grapes		2	2					

crops and field sizes may become more pronounced and can be used to help identify crops.

Basically, the technique of crop identification which is being developed incorporates two major elements of agricultural systems: (1) a monthly record of the sequence of crops growing in specific fields (crop rotation cycles on an individual field basis); and, (2) a calendar depicting the general growth and harvesting pattern of the various crops grown in an area. This information indicates what crops are grown, when they are grown, and normal rotation cycles followed in fields. Using sequential imagery, it is then possible to identify crops on an elimination basis. Given imagery at a particular point in time, the first step is to determine whether a field is vegetated or bare soil. If a field is vegetated, the crop calendar is examined to find out what crops would be growing during this time frame. This narrows the range of choice as to what the crop in that field might be. The final step is to check the history of the particular field under question (by examining earlier photography when possible) in order to: (1) find out when the crop was first planted; and, (2) determine the pattern of the prior rotation cycle in that field. The above procedures should permit, in theory, high accuracy identification of crops in most instances.

Figure 6.3 is presented to illustrate the above system, the fields outlined in black being the focus of attention. The upper left photo was taken in April and shows a bare soil appearance, since there is insufficient vegetation to produce reflectance in the infrared band. The upper right photo shows conditions in early September, when the vegetation is in full growth and is highly reflective. The lower left photo shows that a

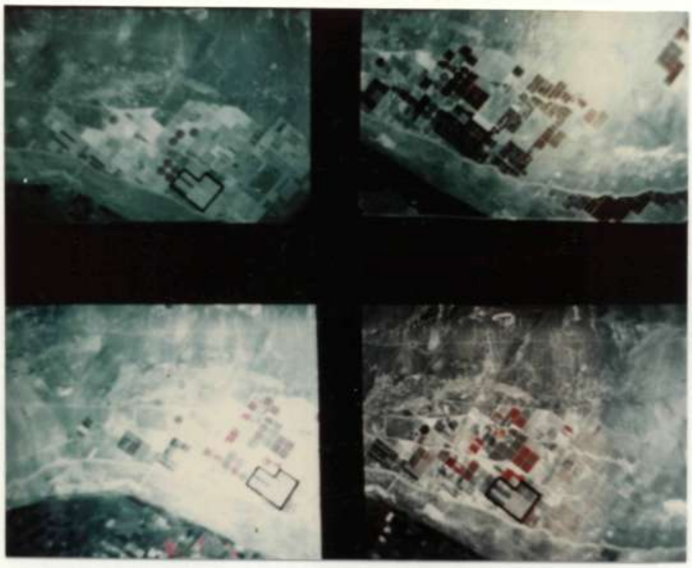

Figure 6.3. The sequential photos above show an identity pattern for detection of cotton. The fields outlined progress in a cycle from bare soil to vegetated condition to phenological change (defoliation) to bare soil. Such patterns can be related to crop calendars for the identification of crops.

Figure 6.4. This ground photo of cotton was taken in July and shows the crop in a fully vegetated condition.

phenological change has taken place in October. By December (as seen in the lower right photo), the crop has disappeared from the fields. Relating these data to a crop calendar, the crop can be identified as cotton. Cotton is planted in early spring, reaches maturity during the summer (Figure 6.4), is defoliated in early winter prior to harvesting (Figure 6.5), and is plowed under by December 15 (according to law).

A major problem in applying this system of identification to the West Side is that much of the area is in an experimental state. There has been no stabilization of crops grown, nor of rotation cycles. A further complication is the lack of sufficient sequential imagery of the area. In order to test the system, it is necessary to circumvent the latter problem. This is being done by simulating sequential photography with adjusted monthly crop ground truth data. The data, which have been collected for over a year, were transformed from identifying the specific crop in a field to identifying whether the field was vegetated or bare soil. The assumption, based on considerable previous research, was that this is information which aerial photographs can provide almost 100% of the time with almost no error (particularly with color infrared).

Some preliminary tests were conducted on April, 1971, color infrared, 1:60,000 photography. The objective was to determine what problems might result from the simulated photographic data, and how these might be compensated. Four people unfamiliar with the system were asked to identify the crops in approximately six hundred fields. The results were initially disappointing — only 60% of the fields vegetated in April were identified correctly. However, it soon became obvious that the sequential photography, simulated from ground truth, was causing some confusion. Further adjustment

Figure 6.5. This ground photo was taken in October and shows a cotton field that has been defoliated prior to harvesting. Note change in reflectance characteristics on contrast to Figure 6.4.

of the ground data is necessary to provide the interpreters with a more accurate simulation of what would appear on an air photo. Once these adjustments have been made and the crop calendar refined, testing will be resumed on a non-dry run basis.

6.4 IRRIGATION SYSTEMS

A marked characteristic of the new agriculture on the West Side is the almost complete absence of row flooding as a form of irrigation. The high cost of leveling often steeply sloping land, subsidence of soil owing to hydrocompaction, the necessity to leach soils, the problem of hardpans forming from standing water, and the relatively high cost of water ($15 to $30 per acre-foot) are all considerations that argue against the row flooding method.

Over 90% of the new acreage is presently being irrigated by some form of sprinkler system. The cost of such systems is high, varying from $120 to $1000 per acre, but they possess a number of advantages with respect to the West Side environment. The rate of water application can be controlled much better and spread more evenly than with row flooding. There is a minimal loss of water through runoff. Finally, land does not have to be leveled for the first planting of crops or for successive plantings (a costly operation in an area like this where subsidence is a problem). Examples of some systems in use are:

1) Stationary and Side-Wheel Line Sprinklers. Both utilize sprinklers attached to a pipe which extends the width of a field. With the stationary system, pipes are located from 10 to 50 feet apart. This allows complete coverage without having to move

irrigation pipes. The side-wheel system is composed of a single pipe forming an axle for several large wheels. Water pressure produces the power which moves the sprinkler slowly along the length of the field. The approximate cost of side-wheel is $250 per acre. Stationary systems range from $400 to $1000 per acre, depending on the distance between lines.

2) Trimatic. This system is similar to the Side-Wheel except that, instead of irrigating an area along the main pipe, a series of secondary sprinkler pipes are dragged behind it. The approximate cost is $400 per acre.

3) Hose Pull. This system consists of a single pipe with many hoses attached to it. It is portable and primarily used to irrigate trees. The approximate cost is $500 to $600 per acre.

In general, portable systems are least expensive and are used for irrigating field crops. Semi-portable systems are in a middle price range and are normally found in association with vegetable crops. Permanent systems are the most expensive and are used for tree or other very high value crops where a high return justifies the high investment.

Mission 164 photography was examined, and it was found that the various kinds of irrigation systems could be identified on the imagery. Each sprinkler system produces a definite soil moisture pattern related to the manner in which the water is applied. Figures 6.6 and 6.7 illustrate soil moisture patterns, associated with different sprinkler systems, that are identifiable on aerial photography. The detectability of such systems on imagery through moisture patterns will help solve the problem of crop identification, since particular sprinkler systems are used with certain classes of crops.

Figure 6.6. Stationary and Side-Wheel line sprinkler irrigation systems on the Antelope Plain. The closely-spaced dark lines indicate the presence of stationary line sprinklers, while the more widely-spaced patterns represent mobile systems.

Figure 6.7. Line sprinklers and row-flooding east of Taft. The row-flooding techniques can be seen just west of the California Aqueduct in the center of the photo. The characteristic pattern of the latter technique is a dark return fading into lighter tones across a field, caused by the release of water at one end of the field which then spreads across the field.

6.5 URBAN CHANGE DETECTION

The objective of this study is to develop methods for detecting and monitoring urban change with data from high altitude and satellite imagery in conjunction with minimal ground truth collection. In order to achieve this objective, the investigative focus is directed towards change occurring in urban communities on the West Side related to the California State Water Project and Interstate Highway 5. It is expected that the structure and function of existing urban sites will alter in a corresponding fashion to other sectors of the area, as part of the more general regional transformation process. Photography from Mission 164 (April, 1971) is being used to establish a base from which to monitor change, while Apollo 9 and ERTS-simulation imagery have been examined as a prelude to acquistion of ERTS imagery.

Urban sites that are representative of economic conditions which may produce change were selected for close examination. Kettleman City, Huron, and Coalinga are communities where the impact of regional transformation may produce visible landscape expressions of change. Basic land use maps have been constructed from photography at a scale of 1:60,000. These show general land use of the areas in which the communities are situated. Subsequent maps (from future imagery) at this scale will display changes in these basic categories, such as industrial parks, recreation development, or expansion of agriculture into areas previously unused. Maps of the urban areas have been constructed at a scale of 1:4500, since a larger scale is required to record and display the detail necessary to study an urban center. Indicators of change within the urban sites are expected to be morphological — commercial buildings, processing plants, residential expansion, and improved transportation networks.

Kettleman City exemplifies the condition of a number of the small towns found on the West Side. It was developed as a minor service and residential area for local oil developments. The lack of continued growth of the oil industry in the area has caused the town to stabilize and then stagnate, there being no other local economic basis for development. However, the town is situated halfway between Los Angeles and San Francisco and is within 2 km of Interstate 5. A local state highway, 41, links Kettleman City to Interstate 5 and it is anticipated that growth will occur along this corridor in the form of services such as motels, gas stations, and restaurant facilities. Transportation will serve as the stimulus for anticipated changes in this town. Figure 6.8 shows an aerial view of the site, Figure 6.9 is a large scale map of urban land use, and Figure 6.10 is a map of the surrounding land use.

Huron represents an entirely different situation. The town developed as a supplier for local agricultural activities, furnishing machinery, packing sheds, processing plants, and other services. The expansion and intensification of agriculture, resulting from the availability of California Aqueduct water and the construction of Interstate 5, is expected to induce further growth in Huron related to its role as a supplier of agricultural services. Local observers contend that it may very well become the West Side's leading agricultural center. Monitoring will, therefore, concentrate on identifying new processing and handling facilities, new agriculturally oriented business establishments, and residential growth. One example of change already observed to be taking place is the construction of a new, small housing tract on the eastern side of the town. Figure 6.11 is a color infrared photograph of Huron, Figure 6.12 is a map showing the

LAND USE KEY FOR FIGURES 6.9, 6.10, 6.12, 6.13, 6.15, and 6.16.

California Aqueduct

Irrigation Canals

Transportation

Boundaries of Numbered Land Uses

1 Agriculture

2 Oil Extraction

3 Oil Storage and Facilities

4 Industrial

5 Grazing Land

6 Non-productive Land

Urban Area

Farm House Complex

Figure 6.8. The Kettleman City area, with the California Aqueduct running across the upper third of the photo and Interstate 5 in the upper left. Note the intersection of Interstate 5 and State 41 at far left, a link that may stimulate the town's growth.

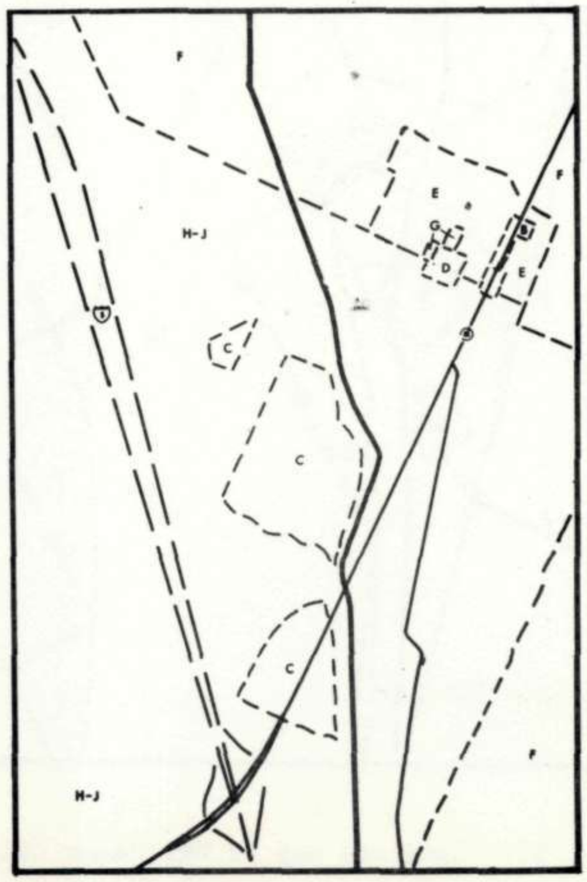

Figure 6.9. Urban land use, Kettleman City.

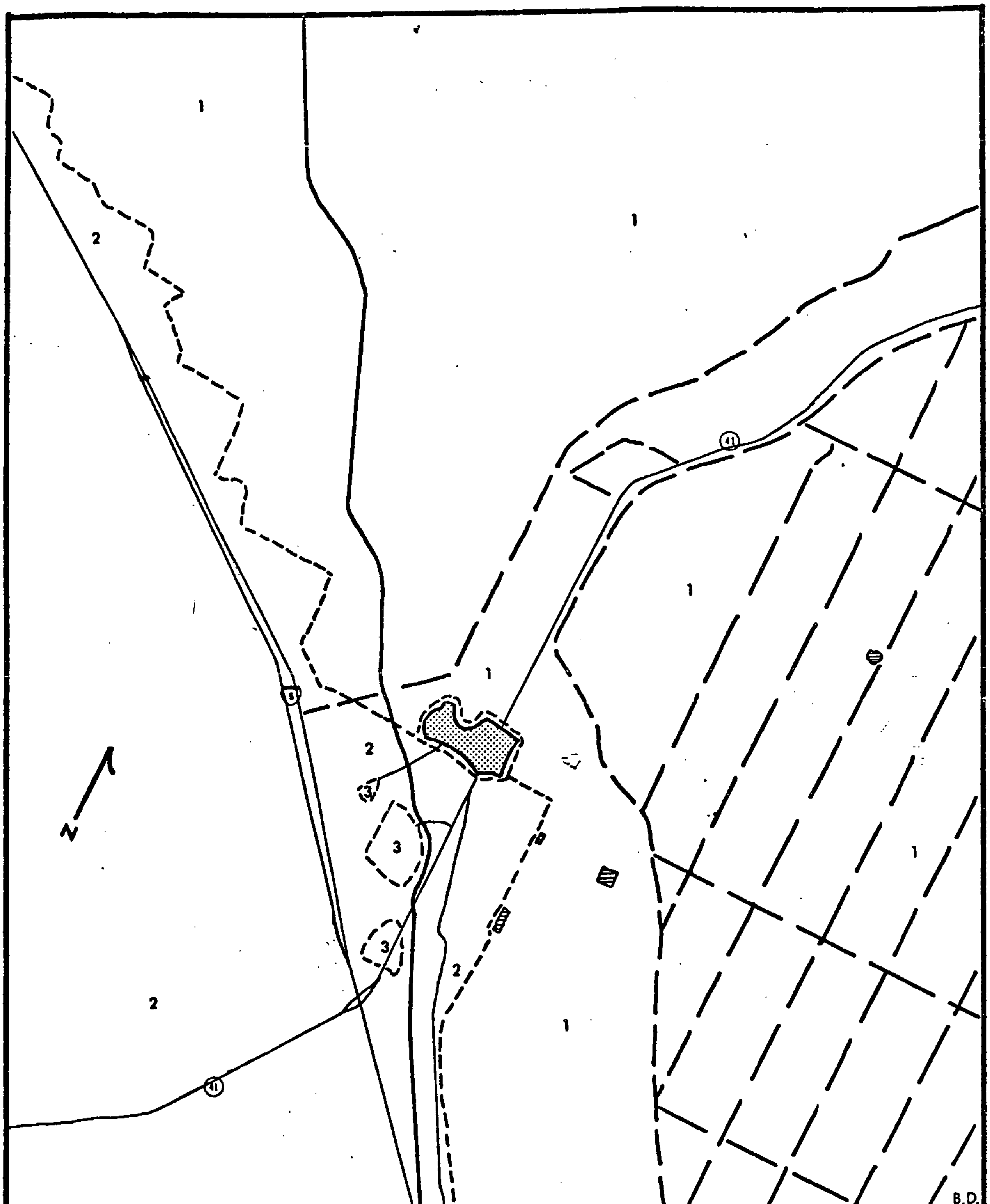

Figure 6.10. Land use map of Kettleman City area.

Figure 6.11. An aerial view of Huron, an agricultural center located in the midst of an established cropping area.

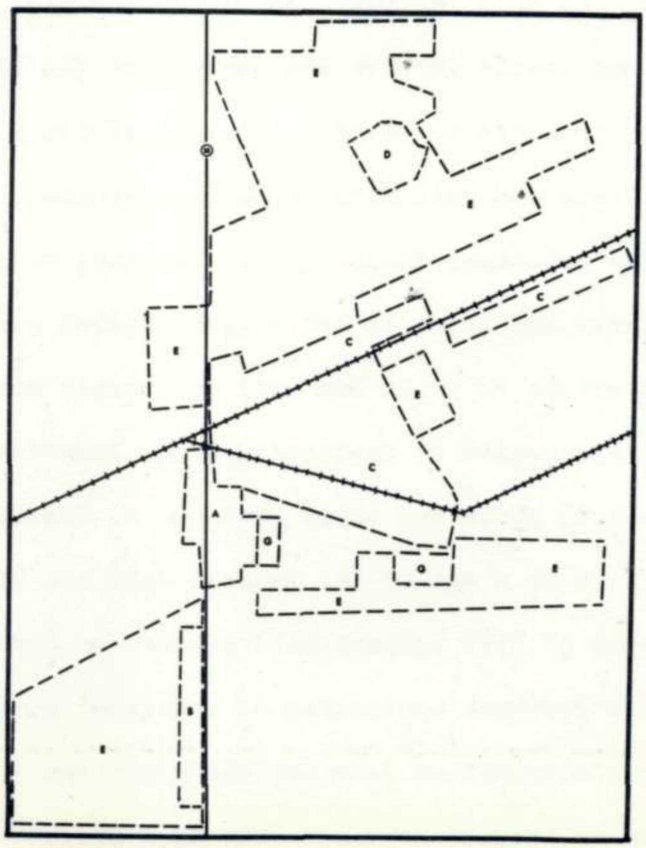

Figure 6.12. Urban land use, Huron.

diversity of land use within Huron, and Figure 6.13 is a map illustrating the various land uses in the local area where the town is situated.

Coalinga is the second largest city on the West Side with a population of approximately 6,000. It first developed as a coaling station (from which the name Coalinga is derived), but the primary force in its growth was the oil industry. The city served as a supplier of tools and machinery for oil drilling, a residential site, a shopping center, and other general services that a large community can offer. Stabilization and automation of the oil industry, a poor and diminishing local water supply, and a peripheral location to major areas of agriculture have served to impede further growth. Local officials expect that Aqueduct water and the new highway will provide Coalinga with avenues for diversifying and expanding its potential function as a regional center for the West Side. Aqueduct water will augment and vastly improve the quality of the existing supply, while the highway is expected to enhance the accessibility of the city to the region's residents and motorists travelling between Los Angeles and San Francisco. The principal shopping area is being reconstructed into a mall format, and there are plans to build agricultural processing facilities. Changes are starting to occur and will be closely monitored. Figure 6.14 is an aerial perspective of Coalinga and its immediate surrounding environment. Figure 6.15 shows the urban land use of Coalinga at a large scale, while Figure 6.16 is a map of the general land use of the area.

Acquisition of ERTS imagery will provide an opportunity to test the hypothesis that frequent monitoring of important morphological characteristics of urban communities from orbital platforms is possible. Two existing forms of imagery were examined as a prelude to receipt of ERTS

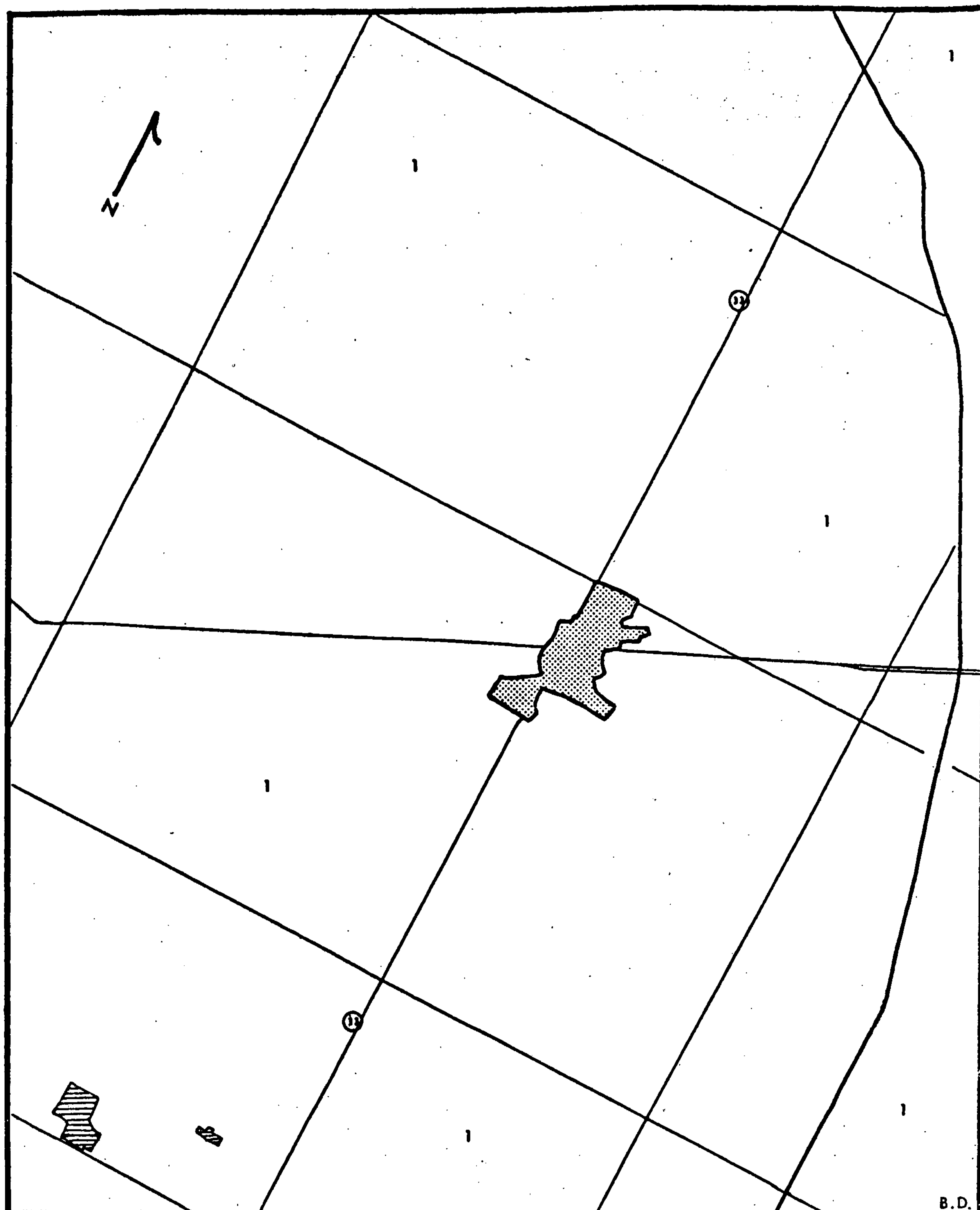

Figure 6.13. Land use map of Huron area.

Figure 6.14. Coalinga is one of the largest urban areas and is expected to develop into a regional center. This color infrared view shows the city in a setting of varied land use — agriculture, oil extraction, and grazing.

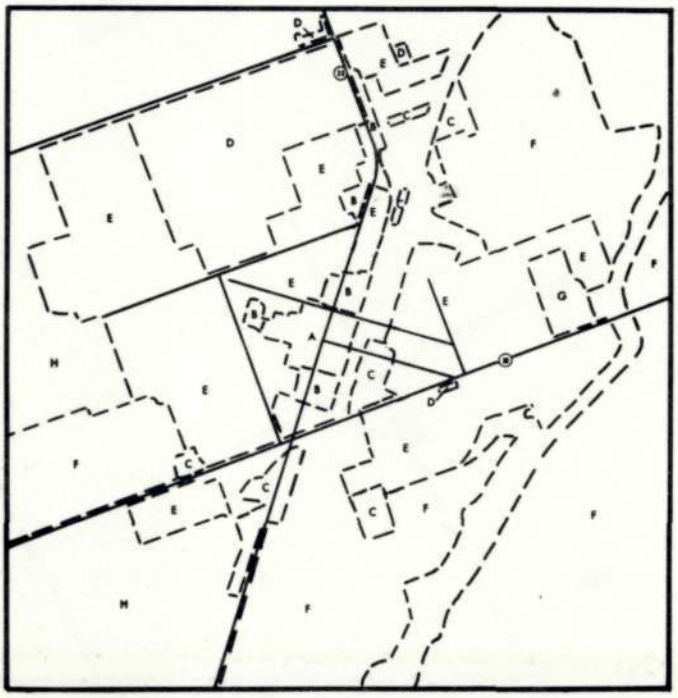

Figure 6.15. Urban land use, Coalinga.

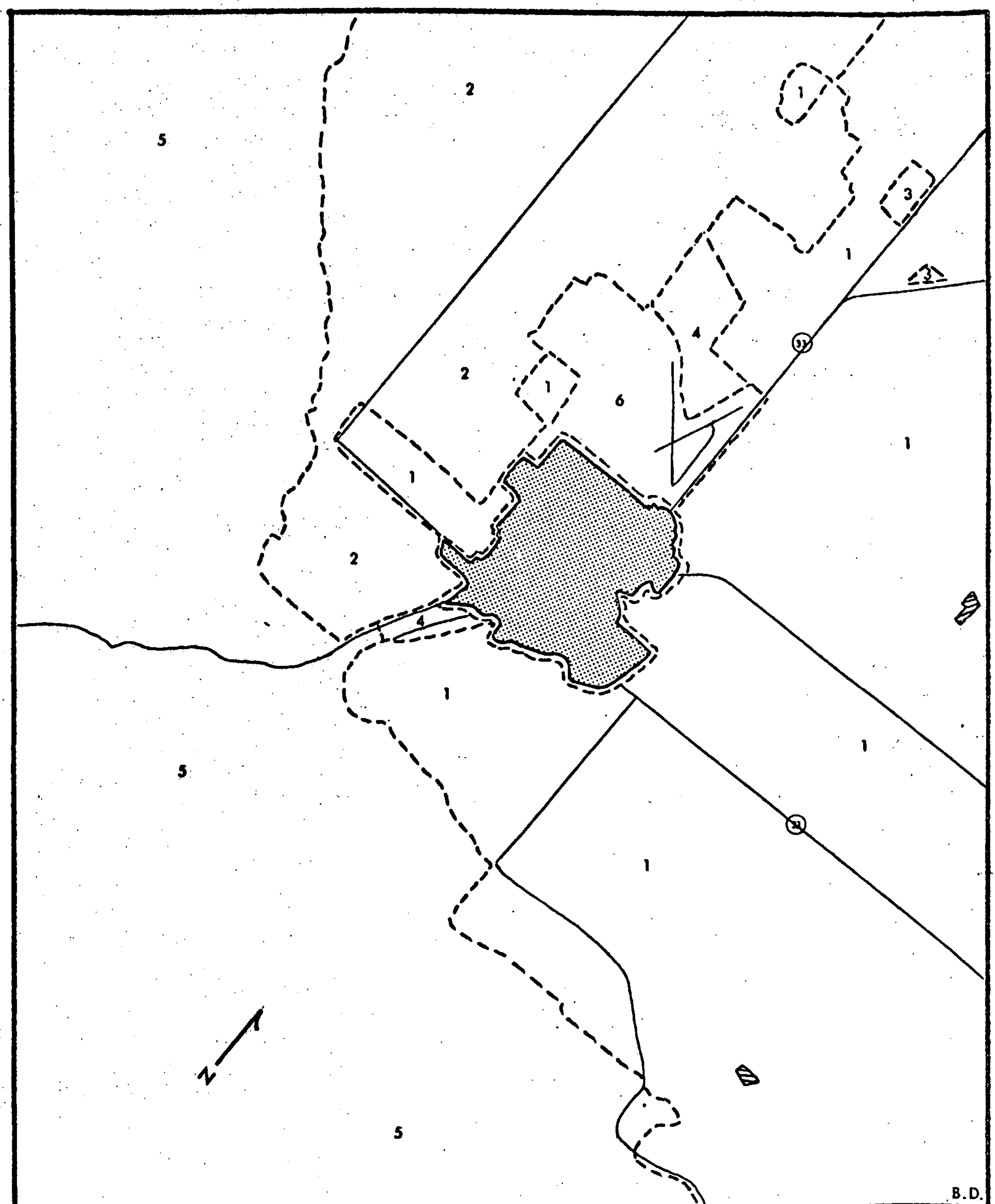

Figure 6.16. Land use map of Coalinga area.

imagery: (1) Apollo 9 (S065) multispectral photography of the Coachella Valley; and (2) ERTS-simulation photography of the West Side.

Examination of urban communities in the Coachella Valley, particularly Holtville and Brawley, on the Apollo 9 black-and-white photography demonstrated that the red band provided the most information with visual photo interpretation. However, the green band seemed to offer more potential when examined with a spot densitometer. In neither case was intra-urban detail sufficient to monitor large scale phenomena, although grosser morphological characteristics where readily detectable — i.e., urban areal extent, CBD size, major transportation networks. It is expected that these features may be used to infer population size, change-producing factors, and future expansion. On a preliminary basis, it is concluded that: (1) the red band will be of most value for analysis of transportation networks; (2) the green band will be best for monitoring urban areal extent and intra-urban phenomena; and,(3) an imaging interval of six months (± 2 months) should provide adequate frequency for monitoring change.

Examination of ERTS-simulation imagery has, in general, supported the conclusions derived from the Apollo 9 investigation. The quality is surprisingly good and detail extraction is excellent. From it, maps comparable to those of 1:60,000 scale can be constructed. Coalinga's CBD, transportation routes, and even larger buildings can be delineated. There is also excellent separation between parks, institutional grounds, and agriculture. Detailed information for Huron and Kettleman City is less than for Coalinga, but is still adequate for monitoring areal expansion. Growth along Kettleman City's connecting corridor also may be possible. In general, the quality of the imagery is quite sufficient for monitoring most of the desired phenomena.

6.6 VEGETATION PATTERNS

The objective of this study is to produce a vegetation map of the perennial species for the West Side of the San Joaquin Valley, which is comparable to previously published maps. It is hoped that the major boundary changes and some other minor patterns visible from the available imagery, can be explained with reference to human use of the land in the intervening time. Further communities delineated on the new vegetation map will be correlated with published soil maps and other soil data, specifically concerned with salt and boron concentrations, in the hope that some indicators among the native plant communities may be found to suggest areas of potential problems for agricultural development.

Previous research on the vegetation phase of the West Side study included the gathering of published data on these vegetation communities and similar ones found elsewhere in the Southwest. Past vegetation maps were found to be of possible use in a comparative study. A reconstruction of pre-European vegetation was attempted by R. L. Piemeisel and F. R. Lawson, and a vegetation map illustrating the situation in 1937 was published in "Types of Vegetation in the San Joaquin Valley of California and Their Relation to the Beet Hopper" (U.S.D.A. Tech. Bull. No. 557, 1937). We made preparations for remapping the West Side area using the same classification of communities. Necessary sampling methods were developed and some ground truth was collected in preparation for the construction of the new vegetation map when the imagery became available. In this preliminary work it was concluded that, since the annual vegetation consisted almost completely of introduced grasses and forbs, which showed little regional pattern, the later study would concentrate on explaining the regional variation in perennial species.

With the imagery now available, efforts were focused on the construction of the vegetation map. Patterns visible on the photography were isolated and related to variations in the shrub communities observed on the ground in subsequent field investigations.

The anticipation was that communities mapped by Piemeisel and Lawson could be distinguished on the imagery, in order that the proposed vegetation map depicting the present situation would be strictly comparable to the map published previously and illustrating past conditions. Some difficulty was encountered because the earlier work gave only non-quantitative, and often imprecise, descriptions of the communities. The present study will attempt a more exact characterization of the various communities. The simplicity of most of the mapped perennial associations enabled them to be delineated and mapped satisfactorily. All the associations described and mapped by earlier workers were mapped in this study also, although certain of the categories were found capable of further refinement to show patterns of internal variation observed both on the ground and from the imagery. The mapped communities are listed below with a brief description, and an indication of the degree of accuracy with which the boundaries could be differentiated on the photographs.

1) Winter Annuals — a community of annual plants, largely introduced grasses, distinguished from the other types by the absence of a shrub component. (fair)
2) Desert Saltbush — a shrub community dominated by a single saltbush species, *Atriplex polycarpa*. (good)

3) Spiny Saltbush — a shrub community similar in structure to the preceding type, but dominated by another saltbush species, *A. spinifera*. (fair to good)

4) Lowland Types — a community of several shrubs commonly recognized as salt tolerant. (good)

   i. Seep weed — a community with some variety of salt tolerant types, but where seep weed (*Suaeda*) is the most abundant species. (good)

   ii. Mesquite — a community similar to the above but where mesquite (*Prosopis*) is present and is conspicuous because of its treelike proportions. (excellent)

   iii. Samphire — a community of small areal extent, and found in the most low lying areas. It is dominated by a *Salicornia* species. (poor)

In drawing boundaries we found the color infrared imagery to be the most useful, although the color photographs were occassionally helpful to clarify difficult interpretation areas. Photography at the scale 1:60,000 yielded more detail, but the coverage at this scale was not complete and the 1:120,000 imagery was used to do most of the mapping. The latter scale showed virtually the same gross patterns as were visible at the larger scale.

The vegetation map is essentially complete and an example, Figure 6.17, has been reproduced from the rough form as an illustration. Figure 6.18 is a color infrared aerial photo of the general area, the specific area corresponding to Figure 6.17 being outlined. It is expected that the final map will be at the scale of 1:250,000.

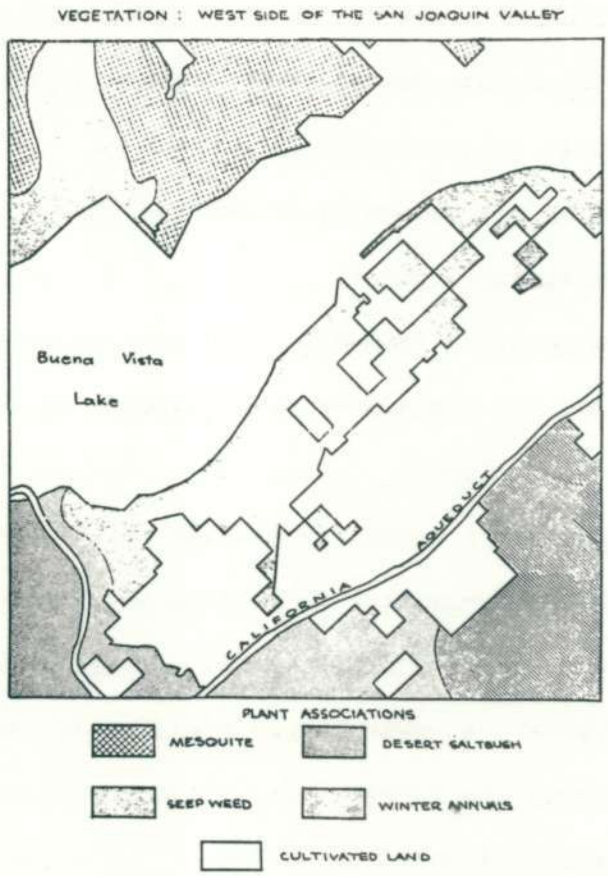

Figure 6.17. Sample vegetation map of Buena Vista Lake area.

Figure 6.18. Color infrared air photo of Buena Vista Lake area. Area outlined corresponds to sample vegetation map in Figure 6.17.

The new vegetation map illustrating the present situation on the West Side of the San Joaquin Valley shows some differences from the situation as mapped in 1937 and from the reconstruction that was thought to depict pre-European patterns. Some differences may be the result of errors in mapping but the differential regional retreat of community boundaries requires other explanation. Grazing, burning, clearing for agriculture, and human modifications of natural drainage patterns appear to have been important. The true nature and relative importance of each of these factors are questions yet to be answered. Answers will be sought by obtaining information for sample areas singled out as being typical of much larger areas. Several large holdings have been owned and used by families over a long period of time, and it is thought that information on past human utilization may be available for some time into the past. Furthermore, precise information about the nature of the vegetation at known points can be obtained from old terrestrial photographs. One important source of such photographs is believed to be a collection used in a study by W. H. Heisey conducted in the 1920's for the Carnegie institution through Stanford University. It is expected that the sites of the photographs can be relocated, and the nature of the change in the structure and species composition at such sites can be investigated to produce further documentation of changes in community boundaries.

Further investigations leading from the construction of the vegetation map will be concerned with the characteristics of the soils on which each of the types occurs. Correlations with data on the levels of concentration of important salts and boron will be attempted. It is expected that the various plant communities will show different tolerances to these important chemical components of the soil. Soil analysis data are available from studies conducted by researchers at Agricultural Experiment Stations in the San Joaquin Valley and at University of California, Davis. Analyses from some 400 points in non-cultivated lands can be relocated, and hence, their relationship to the mapped communities determined. The patterns of perennial communities may prove to be of use as an indicator of soil types and may be valuable to indicate regions which may present problems for future agricultural development.

6.7 BORON PROBLEMS

Boron is an essential element in the growth cycle of all plants. The specific requirements of plants vary greatly from species to species; however, the minimum requirements are quite small, ranging down to 0.2 parts per million (p.p.m.). Some plants are so intolerant of boron that symptoms of toxicity may be produced at levels of concentration as low as 0.3 p.p.m. On the other hand, some cultivated plants have very high tolerances and naturally occurring concentrations in soils rarely result in plant damage. This variability in the response of plants to boron concentrations indicates the need for a map of the distributional pattern of the phenomena on the West Side (where boron occurs in highly variable concentrations), Agricultural planners need this type of information to determine what crops can be grown in what locations, and what remedial measures may need to be taken to improve soil conditions.

Investigations of potentially toxic levels of boron in soils prior to cropping have been restricted to laborious laboratory analyses of soil samples taken at varying depths from point locations. Detection of patterns in the spatial distribution of boron hazards has not been attempted, for the most part, because of several factors: (1) the great expense of laboratory analyses; (2) the difficulty of interpreting and generalizing the complex relationships between plant responses and boron from field observations; and (3) the unavailability of cheap and efficient techniques for acquiring needed data.

In view of the above considerations, the objectives of this particular investigation are threefold: (1) to study the relationship of boron and the soil chemistry of boron compounds to crops; (2) to map and analyze the spatial distribution of boron compounds for selected sites where field data are available; and, (3) to evaluate the capability of remote sensing imagery to provide data needed for the identification and analysis of the spatial patterning of boron compounds.

The initial major effort has been the collection, compilation, and display of soil analysis data. A review of the literature on boron toxicity in plants and the chemistry of boron in soils is also nearly completed. It was recognized at the onset of the study that these steps would have to be completed before any meaningful interpretation of photography could be made. The most significant finding from the ground truth data was that the distribution of boron concentrations appears to be a highly localized phenomenon. Boron concentrations can change dramatically over extremely small areas. This may well indicate that there is no general regional patterning, but that the distribution is instead related to very discrete and specific environmental conditions.

Color, color infrared, and filtered black-and-white photographs were examined, as well as thermal infrared imagery, in a preliminary fashion for evaluation. In terms of correlation with the ground data collected, the imagery does appear useful and patterns do show up to varying degrees at all scales. Color infrared photography offers the greatest promise, since boron does cause significant damage to vegetation. Larger scale imagery, perhaps 1:10,000, with good resolution would probably be even more useful because there is highly localized variation associated with boron concentrations. Late summer or early fall would be the optimum time for acquiring photography, since these are the time periods when boron concentrations in the leaves of plants are the greatest.

Chapter 7

ASSESSMENT OF THE IMPACT OF THE CALIFORNIA WATER PROJECT IN SOUTHERN CALIFORNIA

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Contributors: H. Homer Aschmann, C. Johnson, J. Bale, W. G. Brooner, V. B. Coleman, D. Goehring, R. A. Minnich, D. A. Nichols and J. Viellenave

Department of Geography, Riverside Campus

7.1 INTRODUCTION

Our research effort under this integrated study consists of investigations of remotely sensed data applications that contribute to an understanding of the southern California environment and its resources. These investigations are being conducted at various locations and using regional scale parameters, by a variety of researchers, and for a variety of related topical applications.

7.2 RECENT DATA ACQUISITION AND FACILITIES

7.2.1 NASA Mission 164

The successful continuation of several of the investigations reported herein was greatly enhanced by the completion of several recent aerial photographic overflights. The most significant of these was NASA Mission 164, a high altitude (RB-57F) aerial reconnaissance overflight providing almost complete coverage of the southern California regional study area at approximate scales of 1:60,000, 1:120,000, and 1:475,000. A summary of all recently acquired photographic data is given later in Table 7.1.

NASA Mission 164 was conducted between March 31 and April 5, 1971. Most of the data from the flight were received by the Riverside investigators in late May, 1971. Part of the requested data were not received at that time. This fact was reported to NASA/MSC personnel and the missing data were delivered in January 1972.

All the data from Mission 164 have now been indexed for location. The large scope of the task required that indexing for exact areal coverage be accomplished as necessary while the data were used during various investigations. Only a few areas were found to be lacking coverage. For these areas, however, other remotely sensed data (i.e., photography) are available and the void areas are not considered extensive enough for documentation or re-flight requests.

An important image quality problem of Mission 164 color infrared photography concerns exposure. Exposures for the RC-8 and Zeiss cameras were pre-set for flight and provided proper film exposure for the more heavily vegetated and moist areas of central and northern California. In southern California, however, vegetation is less dense, the terrain is more highly reflective (particularly over desert areas), and there is a higher angle of incident solar energy. Camera exposures do not appear to have been adequately adjusted for these factors and, as a result, the color infrared photography is generally over-exposed by approximately one-half f stop. The combined effects of over-exposure and apparently low infrared sensitivity of the color infrared film render much of the photography of marginal utility for the analysis of vegetation and other environmental components in the arid, desert regions. Between the 1:120,000 scale (RC-8) and 1:60,000 scale (Zeiss) color infrared photography, the latter is superior in terms of resolution, color balance, and spectral sensitivity. As a result, it has already proved to be preferable for investigations employing Mission 164 data and in studies that can tolerate the less extensive areal coverage.

7.2.2 Additional Remotely Sensed Data Acquired

Mission G06 (July 13, 1970) acquired, from local sources, color infrared photography for the City of Riverside at approximate scales of 1:12,000 and 1:24,000. Our group has used this photography for various urban analyses in the local area. Mission G07 (July 21, 1970) acquired, from local sources, color infrared photography of Santa Cruz Island at an approximate scale of 1:22,000, and portions of the coastline between Santa Barbara and Palos Verdes at an approximate scale of 1:24,000. This photography is available for various coastal studies. NASA Mission 157 (February 9, 1971) acquired color (1:50,000) and color infrared (1:100,000) photography of the Los Angeles earthquake area and also of extensive portions of the metropolitan Los Angeles basin. This photography is useful for various urban land use studies and urban area analyses, and for coastal studies where coverage exists. Mission G08 (April 7, 1971) acquired, from local sources, color infrared photography, at an approximate scale of 1:16,000, for portions of the San Bernardino Mountains devastated by forest fires in the fall of 1970. This photography facilitated a detailed study of the forest fire as well as an update and addendum to a previous study of montane vegetation, which was sponsored jointly by NASA and the Geographic Applications Branch of USGS. The above photography that was acquired from local sources did not employ NASA support; a report of our findings based on that photography is included here, however, because the data are being used, or are available, for various NASA-sponsored investigations of the southern California environment.

7.3 SUMMARY OF CURRENT INVESTIGATIONS

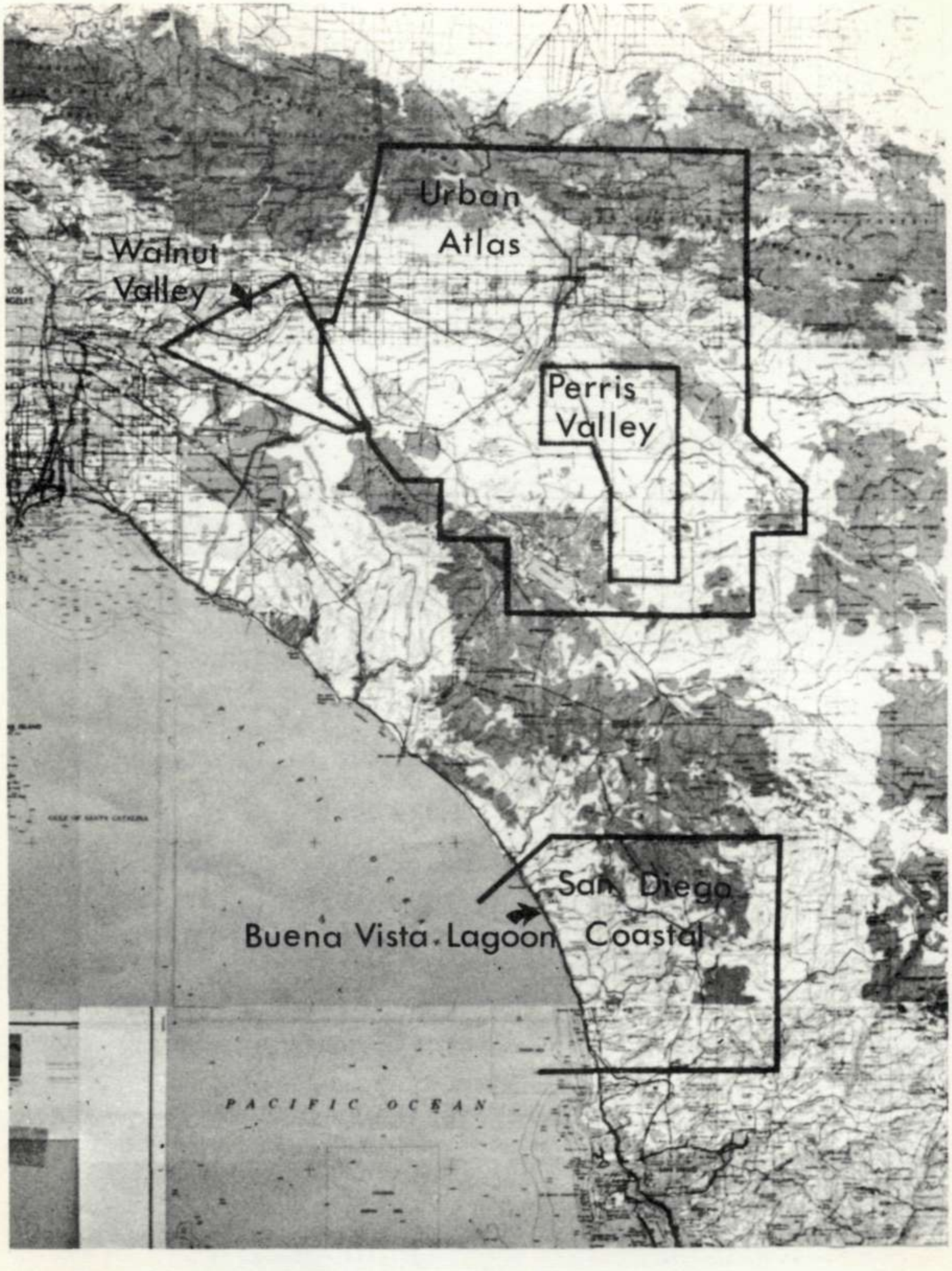
Several investigations are in progress which deal with the applications of remote sensing data in the study of earth resources in southern California. Briefly, these investigations by researchers at the University of California, Riverside, are as follows: (1) inventory of rural land use and monitoring land use change related to Lake Perris in the Perris Valley, California (test site locations are shown on Map 7.1); (2) development of methodologies and production of gross land use maps, using computer graphics, for the NASA funded USGS Atlas of Urban and Regional Change, with a land use study of the Riverside-San Bernardino region; (3) utilization of synoptic photography to develop techniques for urban and regional planners to establish guidelines in rural-urban transition situations, and to monitor and evaluate the impact of pending urban developments on land use change through a case study in the Walnut Valley, California, area; (4) an update of a previous NASA study to map montane vegetation in southern California from color infrared photography using recently acquired high altitude data, and the application of these mapping techniques to assess microclimatic and weather conditions associated with forest fires; (5) a preliminary investigation into regional and local ERTS monitoring sites in coastal San Diego County; (6) the development of models and methodologies for utilizing remotely sensed data for regional information systems; (7) the discussion of the current

Table 7.1. RECENT REMOTELY SENSED DATA ACQUISITIONS

Department of Geography
University of California, Riverside

Mission	Date	Film	Approximate Scale	Area
G06	7/13/70	CIR	1:12,000	City of Riverside
G06	7/13/70	CIR	1:24,000	City of Riverside
G07	7/21/70	CIR	1:22,000	Santa Cruz Island
G07	7/21/70	CIR	1:24,000	Coastline area, Santa Barbara to Palos Verdes
*157	2/9/71	Color	1:50,000	Los Angeles Area
*157	2/9/71	CIR	1:100,000	Los Angeles Area
*164	3/31-4/5/71	CIR	1:60,000	Southern California
*164	3/31-4/5/71	CIR	1:120,000	Southern California
*164	3/31-4/5/71	CIR	1:475,000	Southern California
*164	3/31-4/5/71	Color	1:120,000	Southern California
*164	3/31-4/5/71	Color	1:475,000	Southern California
*164	3/31-4/5/71	B/W	1:475,000	Southern California (multiband)
G08	4/7/71	CIR	1:16,000	San Bernardino Mountains

*NASA Sponsored



Map 7.1. Test site locations for Southern California Impact Assessment Project.

status of the computer mapping capability using examples from the above study areas; and, (8) an examination into the use of remote sensing techniques for assessing environmental quality in southern California.

Several of the above NASA-California grant studies are related to, or are integrated with, other studies being conducted by researchers at the University of California, Riverside. In such cases, proper credits of joint, or combined, activities and support are given in the following discussion of specific activities.

7.3.1 Rural Land Use Inventory and Change: Perris Valley

A primary investigation of the Riverside researchers during the past 18 months has been that of preparing a data base for analyzing the impact of the California State Water Project, and its terminal reservoir, Lake Perris, on the land use and development of the surrounding Perris Valley. Researchers are investigating the effects and implications of water transfer on domestic, industrial, agricultural, and recreational land uses and regional development, as observed and recorded by high altitude aircraft and spacecraft remote sensing devices. These studies initially followed a rather intensive analysis of a small study area, and considered several social and economic factors which can influence regional land use and development. Results of these studies have been reported previously and are only summarized in the following discussion. Recent approaches have been designed to expand the area of study, and subsequently to generalize and reduce the detail and resolution of data recorded and analyzed. Thus, an approach to a local environment is evolving into one of a regional environment, yielding a technique that is more applicable to the areal analysis of spacecraft and simulated spacecraft type data.

A Summary of On-going Studies

Previously reported studies included (1) a land use survey of a sample study area using both ground observations and the interpretation of high altitude color infrared metric photography; (2) a survey of residential attitudes towards the development of Lake Perris and the Perris Valley, and activities by local developers and planners in the area; and (3) a preliminary study of methods for estimating potential population, development and expansion, and/or land value increases in the Perris Valley using conductive sheet analog models.

The sample study for land use survey was Riverside County census tract 426. The tract is 29.81 square miles, or 19,081 acres, in area and lies adjacent to the future Lake Perris. Land in agriculture was tabulated and analyzed. It was found that approximately 39.4% of the total census tract area was irrigated agriculture, primarily vegetable and forage crops, and approximately 50.5% of the area was dry farmed, primarily barley and wheat. Another 11.1% of the total area was classified as "presently unused."

The study area was subsequently enlarged to 175 square miles and surveyed using both ground observations and aerial photo analysis. The selection of the study area boundaries was dictated by high altitude aircraft photographic coverage obtained on NASA Mission 128B (approximate scale 1:100,000). Suitable base maps for field surveys were prepared and the area was sample surveyed at the time of NASA Mission 164. Recorded for each field in the sample survey were crop-type and irrigated/dry farmed data. All data were recorded on a master map of the study area. The delivery of Mission 164 photography delayed any further analysis of Perris Valley land use until the beginning of the present reporting period, May 1, 1971.

The questionnaire survey, conducted in the spring of 1971, attempted to assess by limited sample how people in the rural areas of the Perris Valley felt about the California State Water Project and the development of Lake Perris. The area surveyed was the western half of census tract 426, which excluded any towns or urban-like developments. The principal sources of livelihood for those persons surveyed were farming (dry and irrigated), horse ranching, and poultry raising. These persons were also the most affected by land prices, property assessments and taxes concomitant to the creation of Lake Perris.

As previously reported, the local residents had never been contacted in any way regarding their attitudes toward the California Water Project and the survey results were most interesting. For the most part, the people supported the project; they felt population would grow because of Lake Perris and that industry would develop in the area. Their feelings were divided almost evenly on whether or not they favored the development of industry. However, most of them definitely felt that pollution of the environment would increase. Most of them said they would move in the event of a substantial increase in population and industrial development. To the question, "If you dry farm, would you change to irrigation if Lake Perris water rates were reasonable?", the response was split, 47% said yes, 21% no, and 30% gave no response.

The questionnaire was not perfect. This was partly due to the vagueness of some questions. But on the whole, despite the rather arbitrary sampling technique, the response was very good and informative. The people want the project and regional growth, yet many indicated they would move because of it. Perhaps this dichotomy can be explained because no one can really comprehend what the impact of Lake Perris will be on this area. While land owners may gain tremendously through the sale of their land at rapidly increasing land prices, they also may see that the continuance of agriculture in the area is in jeopardy.

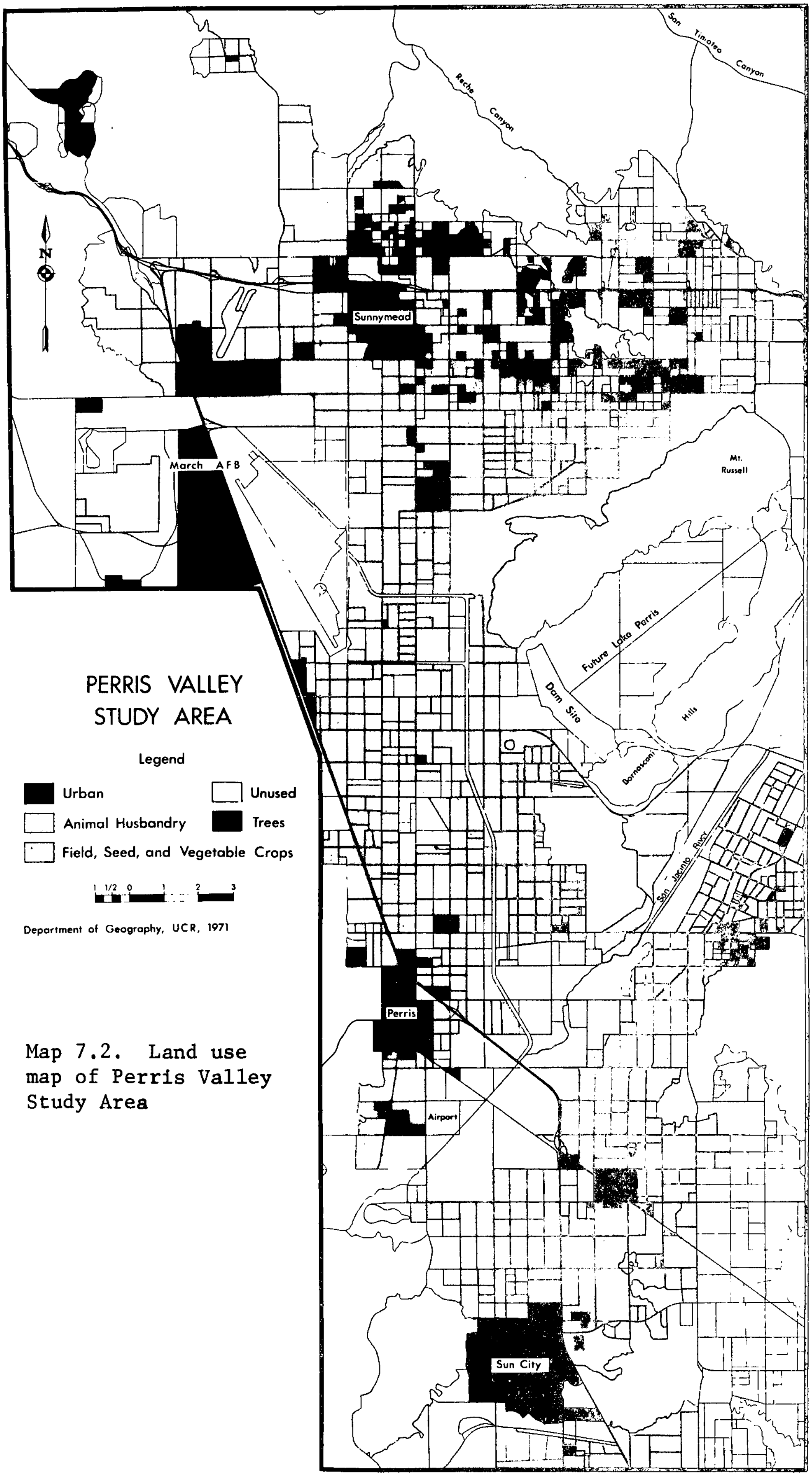
The general attitudes toward development and change in the Perris Valley do not seem, by casual observations, to have shifted significantly in recent months. The Riverside County Planning Commission has recently initiated a general plan study for the Moreno Valley, which is that portion of the Perris Valley study area north of the Ramona Expressway and including the Lake Perris site. It is anticipated that Mission 164 data will be utilized in the study. It will be many months before its completion, however. In previous reports it was suggested that a similar, more expanded survey of regional attitudes be conducted. This suggestion is still endorsed although it is felt that a present survey would be premature. Rather it is recommended that such a study be initiated several years hence, after the initial impact of Lake Perris has been felt in the region.

Similarly, the earlier applications of conductive sheet analog models for analyzing potential population, development and expansion, and/or land value increases in the Perris Valley proved to be both enlightening and useful in preliminary studies. Further efforts of this type are recommended in the future. It is believed that spacecraft type data will be very useful in such studies.

Research Undertaken Since May 1, 1971

Soon after the beginning of the present reporting period, May 1, 1971, Mission 164 high altitude photography was received. Because of the large quantity of data obtained during Mission 164, considerable time and effort were first required to evaluate and index the data. Upon completion of the data evaluation and indexing, it was possible to resume investigation of the Perris Valley Study Area.

As previously stated, the Perris Valley Study Area was enlarged at the time of the Mission 164 overflight to an area of approximately 175 square miles. This area, shown on Map 7.2, was based on similar data coverage by Mission 128B. Concurrent to the Mission 164 overflight a ground survey was conducted to record agricultural land use in approximately 53% of the Perris Valley and vicinity. Acreage for each land use category surveyed on the ground was as follows: field and seed crops, including wheat, barley, oats, alfalfa, and sugar beets, approximately 38,000 acres; vegetable crops, including onions and carrots, approximately 800 acres; tree crops, primarily oranges and avocados, approximately 1,100 acres; and animal husbandry, including feed lots, poultry industry, horse breeding farms, and permanent pastures, approximately 3,000 acres. There were approximately 19,000 acres classified as fallow, plowed, and recently harvested; and 18,000 acres located mostly on the hillslopes and high saline areas along the San Jacinto River drainage were classified as undeveloped or abandoned. Urban and residential areas account for



Map 7.2. Land use map of Perris Valley Study Area

approximately 8,000 acres; March Air Force Base is about 2,000 acres; and the state-owned Lake Perris site and surrounding Mt. Russell and Bernasconi Hills comprise 22,500 acres. This represents a total of 112,500 acres, or about 175 square miles of ground survey.

Considerable time has been required to convert the interpretations from Mission 164 data and the ground survey data into information suitable for analysis and evaluation, and to expand the base maps to provide a study area in the Perris Valley amounting to about 175 square miles. USGS 7-1/2 minute topographic sheets were used in conjunction with the aerial photography to prepare the base maps. Mission 164 imagery of 1:60,000 scale generally proved more useful in determining field boundaries than 1:120,000 scale imagery. The next step was to interpret land use from the 1:60,000 and 1:120,000 photography and correlate the interpretations with available ground survey data.

One of the purposes of the investigation is to determine, from remotely sensed data, to what degree the California Water Project will affect the extent of irrigation in the Perris Valley. This, however, has not been possible to determine at either 1:60,000 or 1:120,000 scales (although irrigation is generally assumed for all vegetable, fruit, and tree crops in this area). Ground resolution on either scale of photography is generally not fine enough to determine row crops (except trees) and it therefore has become necessary to classify vegetable crops with field and seed crops when mapping the photointerpreted data. At the scale of 1:120,000 it often has been impossible to determine the existence of abandoned or recently planted orchards, partly due to resolution but primarily due to film color balance--an intense greenish cast of the film subdues all but the most intense shades of red. This also prohibits discrimination of recently seeded fields from bare ground, although this distinction can generally be made on the 1:60,000 scale imagery. The 1:60,000 scale imagery has thus far proven to be the most useful data acquired during Mission 164 for the present needs and purposes of this study. Lack of sidelap, however, has sometimes caused increases in interpretation errors where it has been necessary to use the smaller scale, 1:120,000 imagery. In order to circumvent this problem, it was necessary to further generalize the land use categories as previously employed in interpretation and ground survey.

Generalization of land use categories usually implies a loss of certain information. There are, however, several advantages to generalizations which still retain useful categorization. Because of the low resolutions specified for the high altitude aerial photographs for pre-ERTS simulation studies, and the ERTS data itself, it will be impossible to discriminate the detailed information implied in our previous data classifications. A data base to be used for such future data evaluations should consist of categories which are applicable and meaningful to the interpretation of low resolution data. Also, the study and mapping of large regions, as is discussed later in this report, necessitate data generalizations when such areas are mapped and analyzed at small scales. Therefore, a new set of land use classifications for the Perris Valley Study Area is introduced on Map 7.2. These are: (1) Urban (including all urban and "urban like" areas, and areas owned by local government); (2) Tree Crops (all types); (3) Animal Husbandry (including poultry, feed lot and horse breeding activities, and permanent pastures); (4) Field, Seed, and Vegetable Crops (i.e., generally all agricultural land uses not classified in (2) or (3)); and (5) "Unused" Land (including mountain and hill areas, areas of high soil salinity, etc.). Within these five categories, approximately 487 square miles have been interpreted and mapped.

Map 7.2 shows approximately 688 square miles of the Perris Valley Study Area, of which approximately 487 square miles have been mapped for a 1971 land use data base from both Mission 164 photographic interpretations and concurrent ground survey data. General location annotations are given on the map, including urban areas, March Air Force Base, and the state-owned land surrounding future Lake Perris (unmapped in above figures). The approximate areas for each category are as follows: Urban, 58 square miles; Tree Crops, 10 square miles; Animal Husbandry, 10 square miles; Field, Seed and Vegetable Crops, 239 square miles; and "Unused" Land, 170 square miles.

The Perris Valley land use data base is still incomplete. Progress is underway to expand the boundaries further and to integrate the Perris Valley Study Area with the Riverside-San Bernardino and vicinity regional study (Section 7.4). This expansion and integration will allow the data base to be computerized for rapid display, analysis, and update. It will also adopt the regional land use classification scheme which is extremely flexible in that it provides for both detailed and generalized data depending on the fidelity of the source materials.

7.3.2 Urban-Regional Land Use

The Riverside-San Bernardino-Ontario Study Area is one of 27 selected urban test sites presently under study in an experiment in urban analysis and change detection using remote sensing techniques. The program is being coordinated by James Wray, Geographic Applications Program (funded by NASA's Earth Resources Program), U. S. Geological Survey. What is conceived is an original multi-faceted urban area atlas, presenting land use maps compiled from high altitude aerial photography (1:120,000 scale) and ancillary data. Mosaicked photography will be overlain by a land use map and a statistical area grid which then can be easily compared with attached population and housing census information. All information will be presented in a graphic as well as statistical format.

Locally, not all of this study area can be presented cartographically within the text of the Urban Atlas. Only a portion covering a variety of landscapes is mapped. This includes the central cities of Riverside, San Bernardino and Ontario, as well as many adjoining urban, agricultural and undeveloped and montane natural areas. One area of greatest likelihood of dynamic change in future years is in the general vicinity of the Perris Valley, including Lake Perris. The total study area at present is approximately 2,000 square miles, shown as the Urban Atlas area on Map 7.1. Beyond the presentation of land use and ancillary data, other methodological objectives are also sought.

As the principal contribution to the project by the researchers at UC Riverside concerns land use information, they are investigating additional methodological possibilities. After the best available high altitude photographic and other land use information has been acquired, the effort is to develop improved interpretation, presentation, and analysis techniques in developing a data base useful in other research studies and applications. This, in effect, is the development of a Geographic Information System. As many as 74 land use categories will be interpreted from aerial photography acquired during Mission 128B (May 1970, 1:50,000 and 1:100,000 scales) and Mission 164 (April 1971, 1:60,000 and 1:120,000 scales). These land use categories will later be processed and converted to 17 basic land use types for the Urban Atlas. The initial interpretation of greater detail is justified owing to the fact that this effort will not be terminal, but rather an on-going land use study.

Upon completion of the interpretation, land use areas will be digitized (x-y coordinates) by 4-hectare cells and recorded in format for computer processing, storage, and manipulation, as well as image and map rectification. The same statistical areas will be used as during the 1970 Census of Population. Additional high altitude aircraft or spacecraft (e.g., ERTS) remotely sensed data may then be evaluated and interpreted in a similar manner in the future to determine the location, kind, and intensity of land use change and development.

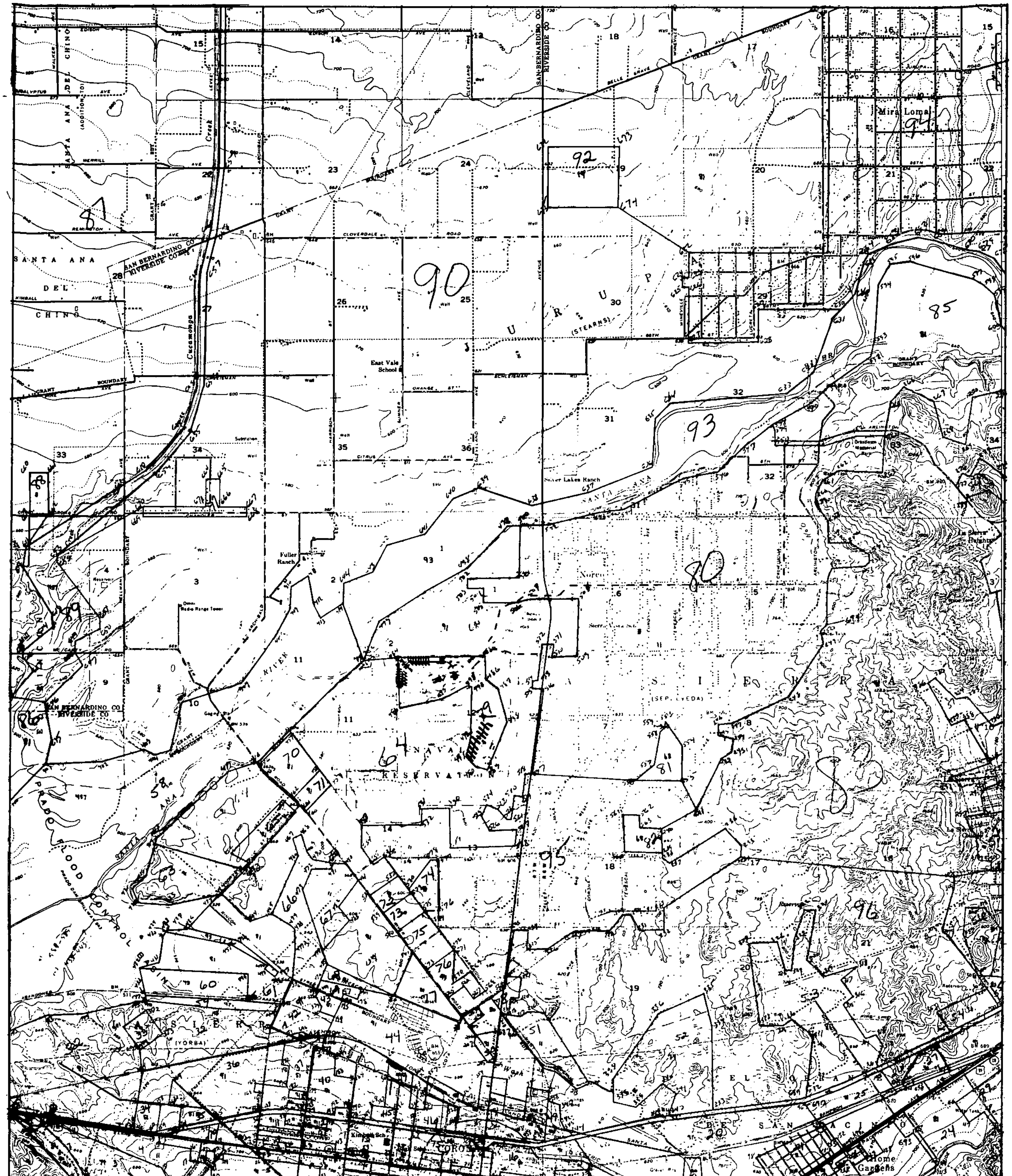
More than five years of experience and accumulated remote sensing technology, and improved research methods and techniques serve to permit this investigative team to pursue the objectives beyond the requirements of the USGS-GAP program inputs simultaneously. This is advantageous not only to refine that input but to advance the state-of-the-art of synoptic, change-detection monitoring of urban areas. In this sense, the Urban Atlas project is opportune because it is now perceived as a critical milestone in our research methodologies. Familiarity with local urban-rural-wildland environments should improve the accuracy of, and simplify, land use information extraction, as well as permit researchers to explore more fully automated data handling techniques for developing methods of periodically updating data bases.

Land use interpretation for the entire area has not been completed. Each 9" × 9" transparency has been mapped on overlays at a scale of 1:120,000. Although image-map rectification and various outputs (areal computations, thematic maps and mapped distributions) can be produced by computer graphics, budgetary limitations have slowed the USGS contribution to the study (the production of orthophotos' mosaics to use as base maps) and resectioning tasks are presently being done by hand. Overlays for an urban site focusing on both Riverside and San Bernardino will be resectioned using 1:24,000 USGS topographic sheets. This area will serve as a focus for monitoring and analyzing urban change using simulated ERTS or ERTS imagery. (Examples of these products are shown on Maps 7.3A and B.) Progress to date has included the assemblage of necessary photography, maps, and other data sources, initial programming for conversion of interpreted data for computerized mapping, initial photo-interpretation of general land use categories, and the production of finished maps for sample areas by hand resectioning methods.

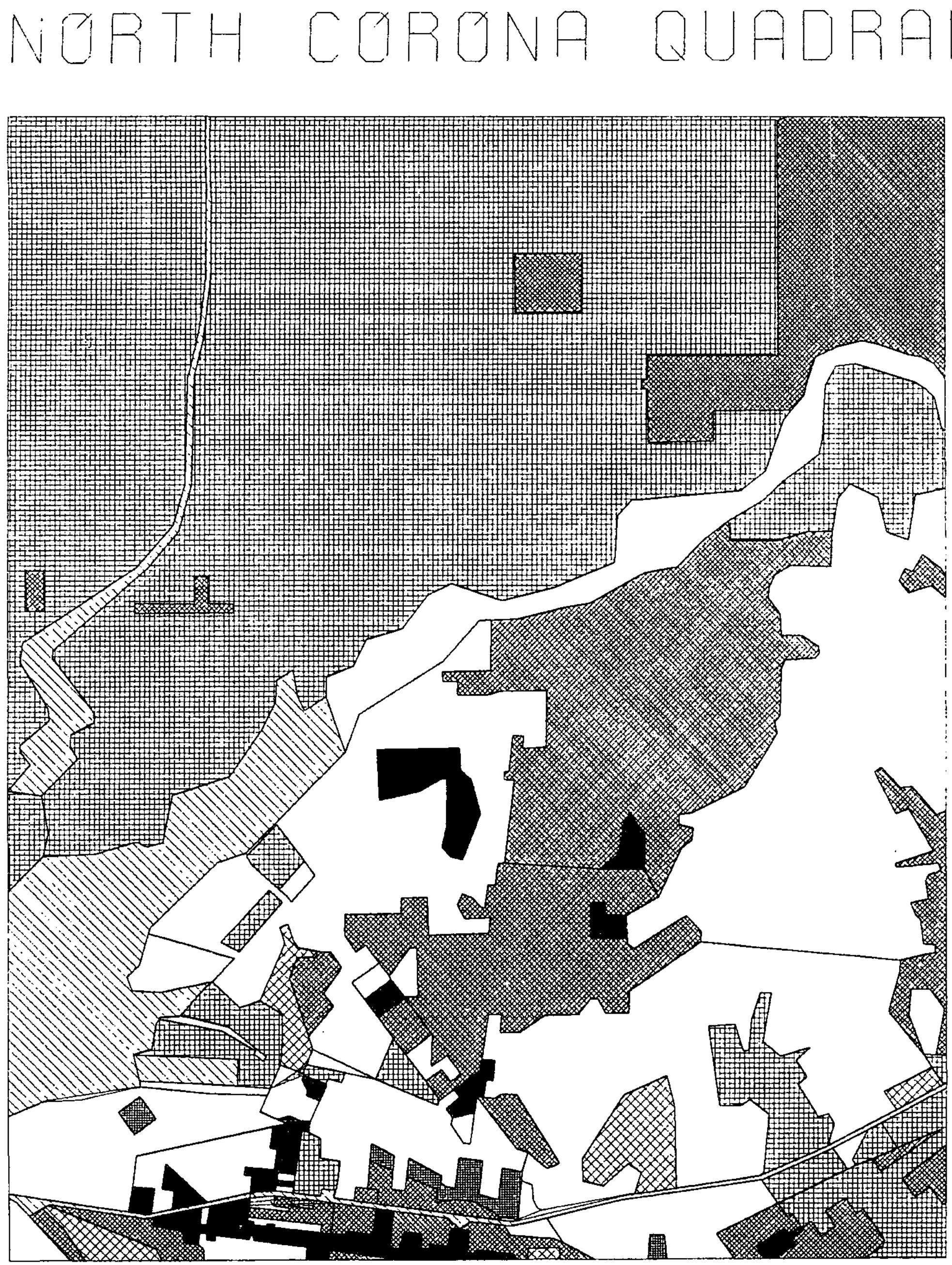
7.3.3 Monitoring Rural-Urban Transitions

Introduction

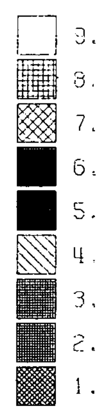
A preliminary investigation of one Riverside researcher, now completed, concerns the use of synoptic remotely sensed imagery for monitoring regional



Map 7.3A. This is a preliminary example of a land use map overlay for North Corona Quadrangle in the regional land use study area, interpreted from 1:60,000 and 1:120,000 scale aerial photography. The classification codes are preliminary.



Map 7.3B. Sample preliminary computer produced land use map of North Carona Quadrangle (Riverside County). The original data source was 1:120,000 scale aerial photography. This map required four hours to outline, two hours to digitize (x-y coordinates), two hours for data preparation, and 30 minutes computer plotting time.



change (i.e., involving rural patterns) in which urban land use successions can be predicted ahead of their actual development. This is a study in urban dynamics that has both practical and theoretical values. Urban and regional planners thus can foresee transition problems and monitor them as they develop. Students of urban morphology can observe the processes of rural to urban transition and land use succession.

Background and Procedure

The study began one year ago with a slightly different objective. Synoptic imagery was to be used in examining freeway impacts on agricultural land use, the expectation being that agricultural uses would change as anticipation of the freeway rose, as the actual construction proceeded, and as the route finally was completed. It was expected that labor and capital inputs to land would be intensified to raise productivity in keeping with higher carrying costs for rural land now taxed at urban rates. Instead, the phenomenon of factor disinvestment, or the minimization of factor inputs to land was observed. Sinclair described this phenomenon in a recent journal article, "Von Thünen and Urban Sprawl," (Annals of the Association of American Geographers, Vol. 57, 1967), but he did not test it empirically, nor did the few other investigators who observed it analyze its causes. Examples of disinvestment patterns and their origins are yet unclear. Rather than a progressively more intensive production-factor-use-agriculture approaching an urban fringe in accord with the 150 year-old Von Thünen theory (which suggests that land rent appreciates from locational utility, and that land uses are ordered by their ability to pay these rents and the transportation costs), the opposite case prevails. Land use patterns are suboptimal because urban proximity clouds the long-run planning horizon and forces fringe land owners to adopt short-run plans. This is particularly true in dynamic situations, e.g., when a major transportational route is constructed. Production factor use is minimized because labor earns higher returns in the city; capital has higher returns in land speculation or in investments other than farming. Land, as a consequence, is farmed without much capital or labor input, and such extensive uses as grazing, and the farming of barley and other field crops prevail in areas "clouded" by urban proximity.

An excellent site for examining disinvested agriculture is the route of the Pomona Freeway between downtown Los Angeles and eastern Los Angeles County through the Walnut Valley, which was basically rural in 1955 when freeway plans were first announced. A study of the evolution of land use in this region is contained in Technical Report T-71-5 supported by NASA and Project THEMIS. Subsequent reports will test this modification of the Von Thünen theory in other urban fringe situations, and will attempt to isolate those urban growth factors that account for these patterns. Other cities, as they are selected, will be studied both in the field and by NASA photo coverage and will be subjected to the change detection, recording, and interpretation methods established earlier. Allowance will have to be made for different agricultural peripheries, urban growth histories, and other peculiarities of individual cities.

The research method in the study was simple and straightforward. Aerial photographs were used to compile land use maps for six periods before and after the completion of the freeway (1953, '58, '60, '65, '69 and '71). After the complete land use of the earliest period had been mapped, only change was recorded on subsequent maps. Area measurements were recorded for each period so that a current compilation and land use map could easily be constructed. By a materials-balance technique, types of land use input to and output from the rural-urban conversion process were recorded, and studies were made periodically of the nature of these events (with a civil or political division overlay, this can be done for small areas). Parcel histories could be determined, but in most cases they are obscured when the land use does not conform to property lines. The object was to examine whether a set of events of intensification and/or disinvestment is a precursor of land use succession. Events may differ because of site characteristics and, by the amount of prior investment into land, the peculiarities of the geographical situation can be considered.

From this determination it was shown that Sinclair's thesis applied in the test site in that (a) a disinvested agricultural zone exists, (b) the zone was widened because the freeway was built, and (c) a somewhat predictable sequence of events did take place in the conversion of land from rural to urban use which may take place in other areas. Further, it was demonstrated that this is easily recorded with a number of research tools, particularly that of the remote sensor.

Photographic Requirements

Photographic requirements for such a study are neither strict nor liberal. Timing the overflight is important for the sake of seasonality among agricultural patterns. Resolution is much more important. For example, demonstrating a decision to intensify production to derive higher returns that offset rising operational costs requires imagery that can resolve crop types in the field, e.g., recently mowed alfalfa is often confused with some types of row crops. This is not necessary for other patterns, particularly those that are urban in nature.

The NASA Mission 164 color infrared photography used for the latest periodic survey was available at 1:60,000 and 1:120,000 scales. The larger scale imagery has generally proven more useful in determining field boundaries than the 1:120,000 scale imagery. Ground resolution at either scale is generally not fine enough to determine row crops (except trees) and it has therefore become necessary to classify vegetable crops with field crops in 1971 (crop types, cropping patterns and "crop calendars" should be established for each area). The 1:60,000 scale imagery has thus far proven to be the most useful data acquired during Mission 164 for the present needs and purposes of this study. Lack of sidelap causes increased interpretation errors where it is necessary to use this smaller scale imagery.

Film emulsion is also important. Color infrared film is preferred to normal color and to black and white films and, given the future higher platforms to be used for this research, the haze penetration capability of an emulsion should be strongly considered. Color enhancement techniques may enable identification of crop types, but if human photo-interpretation is required this would defeat the speed and accuracy benefits available with larger scale photography, with or without color.

Results

The study area is a five-sided figure, topographically defined by the highest summits of two hill masses which enclose the relatively narrow Walnut Valley (Map 7.4). Parts of three and all of a fourth incorporated city lie in the study area but most is still unincorporated. The orientation of the study area follows the route of the freeway; as such, its dimensions are approximately eleven miles east-west by seven miles north-south. It includes 37,023 acres (14,989 hectares) of mixed land uses, with agriculture and vacant land predominating (Table 7.2).

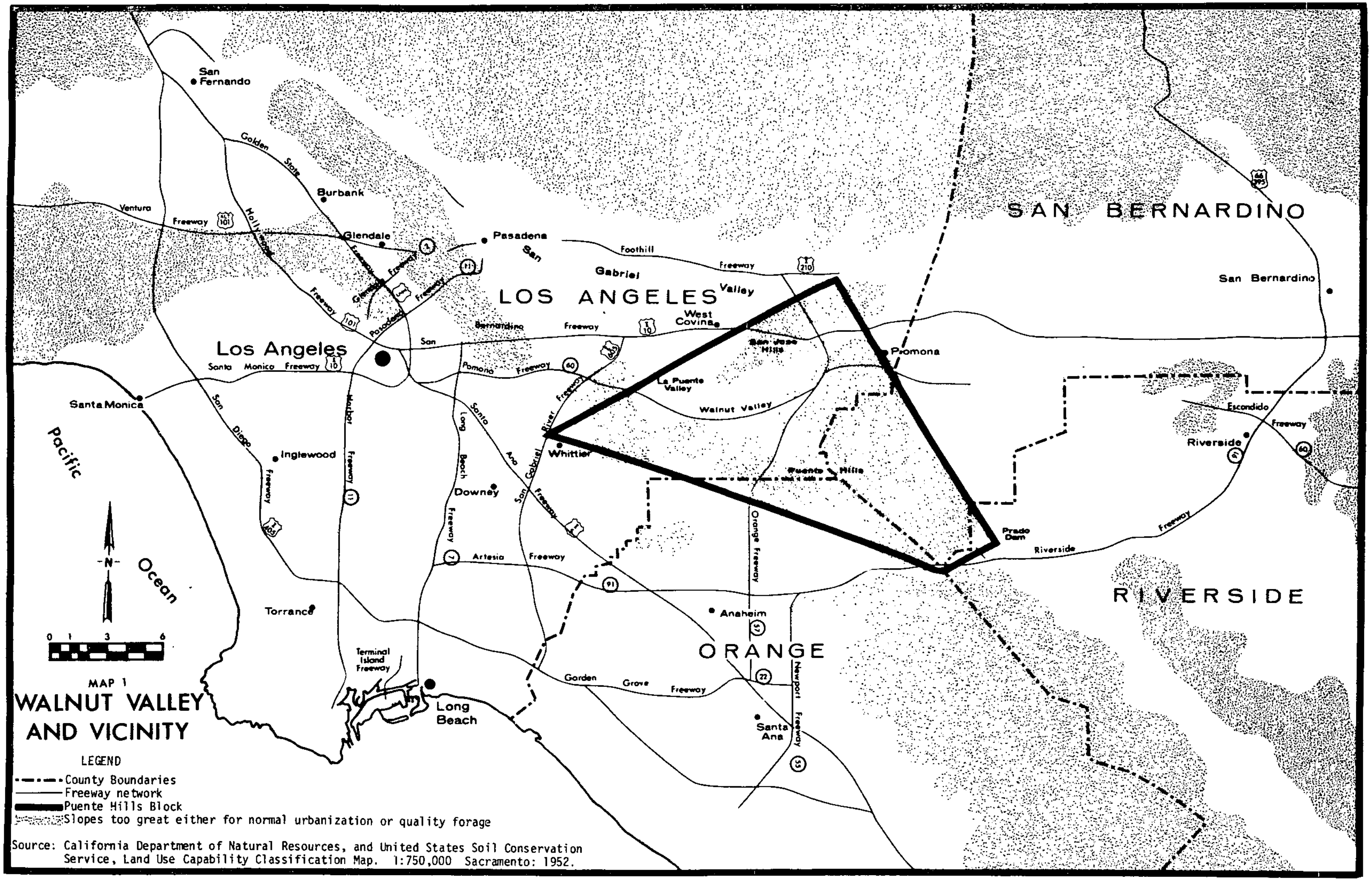
Urban land uses succeeded agriculture on 4.719 acres (1,910 hectares) of agricultural land, and only 1,076 acres (467 hectares) of vacant land were absorbed by urbanization. With that in mind, nearly twice as much urban land use and population can be sustained by absorbing the remaining agricultural land, thereby raising the holding population of the region (Statistical Area 26.0, Los Angeles County Regional Planning Commission) to approximately three times its present figure (179,000).

Land use changed within agriculture in a number of ways before urban land use (residential, industrial, institutional, etc.) succeeded. Five types of decisions were made by land owners, known as:

1. Intensification: the increase in factor use as in the replanting of citrus, the enlargement of a dairy, or the planting of row crops in place of field crops.

2. Direct conversion: the change of productive agriculture to urban use, as in the replacement of good citrus groves by a subdivision.

3. Succession: the following of low-productivity agriculture by



Map 7.4. The Puente Hills Block is a physiographically defined region which includes the Walnut Valley Study Area. Only a portion of the valley was studied. That which was selected contained a variety of land uses ranging from several agricultural uses to some urban use. The relative proportions changed through the course of the study period, as indicated in Table 7.2.

Table 7.2. PERIODIC LAND USE IN THE WALNUT VALLEY AREA OF SOUTHERN CALIFORNIA
(in acres)

Source: Aerial Photo Interpretation

Land Use Type	Date of Survey					
	1953	1958	1960	1965	1969	1971
AGRICULTURE						
Citrus						
good	868	507	342	143	137	137
fair	1,314	1,154	831	297	102	102
poor	91	50	154	348	231	231
abandoned	24	29	113	137	140	140
Walnuts						
fair	1,207	554	280	69	36	36
poor	134	304	443	321	257	251
abandoned	40	80	46	98	72	62
Avocados	13	13	13	13	13	13
Field Crops	3,020	3,393	3,334	2,988	2,753	2,542
Row Crops	285	340	325	170	178	178
Mown Grasses	3,157	2,991	2,879	2,147	2,127	2,092
Grazing	3,200	3,018	2,915	2,795	2,762	2,760
TOTAL AGRICULTURE	13,353	12,439	11,675	9,511	8,808	8,544
URBAN						
Residential	228	821	1,726	3,554	4,016	4,417
Industrial	66	215	324	523	740	755
Commercial	6	9	9	56	84	154
Recreational	0	0	39	341	363	363
Institutional	156	156	166	279	373	373
Agricultural	230	277	267	287	264	264
Vacant	321	517	361	306	456	502
TOTAL URBAN	1,007	1,999	2,892	5,446	6,294	6,828
VACANT	22,663	22,595	22,456	22,056	21,919	21,651
TOTAL LAND USE	37,023	37,023	37,023	37,023	37,023	37,023

urban use, as urban barley fields or deteriorated citrus is followed by a subdivision.

4. Disinvestment in Lieu: the following of productive agriculture by a less productive agriculture, as when citrus is replaced by barley farming.

5. Disinvestment: the allowing of agricultural uses to deteriorate in situ. Land owners adopted these strategies in different proportions depending on the urgency with which they perceived conditions for land use change. Population growth was continuous in Southern California through the first decade of this study period and slowed only recently. Walnut Valley growth, however, was an exception to this general case since growth was great. Freeway announcement, construction, and completion stages are fairly well defined in the rate of housing constructed as in land owner decision-making processes. Owners tended to adopt land sale enhancement strategies (disinvestment in lieu) in periods of "booming" growth and disinvestment strategies when sales (lending rates, financing availability, etc.) were off. The intensification of agricultural land use was a much less important decision than expected. In broad terms, the expanding Los Angeles fringe through Walnut Valley triggered land use change to urban uses and agricultural decline through disinvestment stages. Urban land use succeeded when land was "properly prepared," i.e., already cleared of arboreal crops to minimize land development costs, or where terrain was easy to develop. Some land holders found buyers and sold acreage with producing crops despite agricultural opportunity costs, and converted to urban uses by the direct conversion method.

Research concerning the preparation and transformation of rural land to urban uses is continuing at the Riverside campus. Theoretical statements are at best hypothetical on the basis of even intimate observations at a sample location. In order to substantiate previous statements, the hypothesis of disintensification of agricultural land use immediately prior to urbanization will be tested in four other areas. Tentatively these areas are: (1) The Dairy Valley area of Cypress in Los Angeles County; (2) the Placentia area of Orange County; (3) an area of the East San Gabriel Valley in Los Angeles County; and, (4) either the Dominquez Hills or Venice area of Los Angeles County.

The above locations each exhibit a different agricultural land use. Hopefully this additional research will not only lend credence to the hypothesis under consideration, but will also establish what other types of agricultural land uses undergo factor input reduction before giving way to urbanization.

Potential Applications

The Walnut Valley study suggests that decision-making may follow both optimizing or maximizing and also "satisficing" planning principles. Timing the proper strategy or development decision requires matching interim land use that has a rate of return commensurate with the discount rate on undeveloped urban land with every inflection in the change of the discount rate. That is, every influence, e.g., freeway construction, that affects the discount rate affects interim land use decision-making. Optimizing strategies presuppose a sufficient range of possible interim land uses and do not recognize the multiplicity of factors determining

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actual land use patterns. In unique settings these factors range from chance events in some remote historical period to current decisions made for understandable but non-economic reasons. "Satisficing" (Simon, Models of Man) is a behavioral or psychological response to planning in a complex situation where the decision-maker lacks information, access to production factors, etc., and his alternatives are restricted. "Satisficing" provides for land use that is "good enough" given the strictures of the particular situation.

Urban and regional planners need to recognize the ways in which urbanized landscapes evolve. They make few land use maps, owing to their cost by traditional field survey methods and, as a consequence, a man's utility is limited to a historical or illustrative value, and its major value, when used synoptically to observe economic patterns rearranging themselves, is lost. The application of remote sensing data can help change the situation. Urban fringe problems are widely recognized: (1) disparate land usage and the gross inefficiency of any distribution system that services disconnected development whose conversion is not phased incrementally; (2) from an agricultural investment view, blighted landscapes have a social cost in the loss of interim use returns due to "clouded" planning futures and the disinvestment strategies which they prompt; and (3) agriculture produce also incurs a higher transportation cost. While a policy regulating rural-urban land use conversion in increments of growth is lacking in the United States, this synoptic method points out where land owners may initiate a conversion long before the necessary formal procedures are begun. Planners may then take corrective measures. By remotely observing tangible land use evidence of decision-making, the synoptic, photographic interpretation and other techniques employed here married to urban growth theory (land economics and locational theory) greatly facilitate the planning of the urban fringe.

7.3.4 Mapping Montane Vegetation

Introduction

A previous NASA-funded study produced a discussion on the application of mapping montane vegetation in southern California (Minnich, Bowden, Pease, 1969). The study included several vegetation maps of the San Bernardino Mountains in areas where color infrared aerial photography had been acquired from NASA and other sources. The original photo-interpretations were made by Richard A. Minnich. Subsequent to NASA Mission 164, Minnich re-examined the earlier effort, evaluated the more complete photographic coverage of Mission 164, and made certain revisions to the vegetation map. The following addendum to the earlier study provides a number of technical revisions as well as extension of the area mapped. No effort is made here to reproduce the revised map. It is hoped, however, that this may be done in the future.

Addendum to "Mapping Montane Vegetation in Southern California with Color Infrared Imagery"

Parts of the original vegetation map of the San Bernardino Mountains are revised from interpretation of color infrared imagery of subsequent research missions, including NASA Mission 164 (April 1, 1971; scale 1:60,000 and 1:120,000) and coverage of the Big Bear Fire (Western Aerial Survey, April 7, 1971; scale 1:16,000). Areas of major revision are along the Mill Creek ridge eastward to Kitchin Peak (formerly not covered), the Lucerne Valley scarp, and the Bear Fire area.

Superior resolution of new imagery also resulted in more detailed mapping over much of the study area. More complicated mapping could have been accomplished originally, but this was prevented in publication for cartographic reasons.

Since the north-south flight lines in Mission 164 at a scale of 1:60,000 failed to overlap, a portion of the Mill Creek ridge -- from Oak Glen to Raywood Flat -- that area is mapped at a scale of 1:120,000 and therefore has reduced detail. Due to simplicity of vegetation along the Lucerne Valley scarp to the north, there was negligible loss of information from small imagery scale. More information is gained in the Big Bear Fire area due to better scale and resolution of the 1:16,000 scale imagery.

Two changes are made to the Plant Classification:

1. Lodgepole-Limber Pine Forest (Pinus Murrayana-Pinus flexilis) in the dwarfed or krummholz state (LP_K) is mapped as a contrast to erect forest (LP).

2. Terrace chaparral (C_{TER}) is changed to hard chaparral (C_H) since both categories are dominated by similar flora.

A survey of the new imagery flown to assess Big Bear fire damage, characterized spectrally by deficient infrared enhancement but excellent resolution, allowed for comparison and evaluation of original mapping problems related to vegetation types. Changes in the revised map reflect these same problems which are described below.

Because desert plants are small and display no consistent color signature, desert vegetation can be interpreted with least reliability, particularly in ecotonal areas where Desert Chaparral (C_D), open Pinion-Juniper Woodland (PJ_O), and Juniper-Joshua Woodland (JJ) coalesce (e.g., in the Whitewater, Mission, and Morongo drainages, and in the Ord Mountains). Necessary reliance on definite color signatures for identification of Coastal Sage Scrub and Chaparral types, instead of physiognomy, made the original mapping of these plant groupings suffice despite improvement of resolution. However, additional groves of Knobcone Pine (Pinus attenuata, CE_{kb}) and Coulter Pine (Pinus Coulteri, CE_{cp}) in chaparral were identified and mapped. Since the exaggerated crown structure of Big Cone Douglas Fir (Pseudotsuga macrocarpa, CF_{bs}) could be resolved on the old imagery, little additional information was obtained on this chaparral conifer. No misidentification of chaparral conifer species was evident on the original mapping either by direct or habitat recognition (Coulter Pine) as stipulated in the report.

The distribution originally shown for the Montane Coniferous Forest (PF) is considered accurate although minimal detail on internal floristic composition was obtained from enhanced resolution. Areas of Montane Coniferous Forest with Sugar Pine (Pinus Lambertiana) as subdominant, however, were identified by recognition of the similar but less exaggerated crown structure of this species compared to Big Cone Douglas Fir. Little hope exists in the possibility of mapping areas dominated by either Ponderosa Pine (Pinus ponderosa), Jeffrey Pine (P. Jeffreyi). White Fir (Abies concolor) or Incense Cedar (Libocedrus decurrens). Further, in the original imagery photographed during the summer growing season, the sclerophylous evergreen tree oaks (Quercus chrysolepis, Q. Wislizenii), and Black Oak (Q. Kelloggii) exhibited similar color signatures. This fact, in combination with poor resolution, originally prevented discrimination of the three species. The problem was partially solved during the recent coverage when deciduous Black Oak was not in leaf. As a result, the sclerophylous oaks can be observed as subdominants in primarily lower, drier portions of the Montane Coniferous Forest. Contrasts in the old and new imagery also make certain the identification of stands of Mountain Mohogany (Cercocarpus ledifolius) as a brush undercover in drier margins of the Montane Forest. These new distinctions in Montane Coniferous Forest are not mapped for lack of time and complete photographic coverage.

Areas mapped as Lodgepole-Limber Pine Forest (LP) are considered accurate due to obvious morphological differences of these subalpine trees compared to adjacent Montane Forest conifers. On the other hand, deficient resolution of the original imagery prevented their being mapped as subdominants along the upper elevational margin of Montane Coniferous Forest. Color signatures on the new imagery indicate that the three dominants of Timberland Chaparral (Arctostaphylos patula, Castanopsis sempervirens, and Ceanothus integerrimus) are individually mappable.

The mapping of Pinion-Juniper Woodland (PJ) is considered excellent by simple recognition of definitive physiognomic characteristics of the dominant trees as in the case of Lodgepole-Limber Pine Forest. Areas of "dense" Pinion-Juniper Woodland (PJ_D) are less reliable because of problems in discerning Western Juniper (Juniperus occidentalis) from Pinion Pine (P. monophylla). Due to poor resolution, only areas of

Juniper whose prevailing size is greater than Pinion Pine could originally be mapped under this category. Further, individual Junipers cannot be identified consistently on the basis of color signature. Larger scale aerial photography may resolve this problem. Areas of Great Basin Sage species (GB) which form a dominant undergrowth in wetter margins of Pinion-Juniper Woodland (PJ, PJ_D) and occasionally in drier parts of Montane Coniferous Forest (PF) can now be mapped beyond the present indicated distribution to dry basins and flats adjacent to Baldwin Lake and Rose Mine.

The mapping of areas composed of marginal ecotonal forests characterized by admixing of tree species from Chaparral and Montane Coniferous Forest -- in particular Dry Forest (DF), Transition Forest (TF), and Interior Oak Woodland (C_{WD}') -- may have errors. Confusion rests not so much on the uncertain identification of conifers as on that of the oaks discussed above. In areas where it has been determined that Black Oak is not in foliage, stands of Dry Forest can be separated from large groves of Coulter Pine in Emergent Oak Chaparral (CE_{cp} found in C_{WD}) by discriminating between Quercus Kelloggii and Q. chrysolepis, respectively. Areas of Dry Forest can also be separated from Interior Oak Woodland by identification of Q. chrysolepis or Q. Wislizenii, with Q. Kelloggii absent in the latter. Boundaries between Dry Forest and Montane Coniferous Forest may be inaccurate because of difficulty in consistently separating areas of Coulter Pine from Montane Forest Conifers due to physiognomic similarity. Even with enhanced resolution, the best interpretive technique is to observe tree shadows to determine whether branches extend to the ground or if the main trunk is visible, characteristic of mature Coulter Pine and Montane Forest conifers, respectively. Improved resolution also resulted in the separation of Transition Forest into two distinctive types. On steep north facing slopes and south facing slopes above 6000 feet elevation, areas of Transition Forest with Big Cone Douglas Fir mixing with Montane Forest conifers could be mapped by clear-cut identification of Big Cone Douglas Fir. However, areas of Coulter Pine also could be found mixing with Montane Forest conifers on usually steep south facing slopes. The boundary between this form of Transition Forest and Montane Coniferous Forest is quite adequate because of the nearly synonymous upper elevational limit of Coulter Pine and the sclerophylous oaks (Q. chrysolipis, Q. Wislizenii), the latter being easily identified on color infrared imagery by their bright red color signatures. Reliance on this technique is supported by the observation that these oaks may occur without Coulter Pine in drier portions of the study area, but not conversely. Therefore, if sclerophylous oaks are present on a high south facing slope, one is nearly assured of the presence of Coulter Pine, with certain verification possible by study of branch structure from shadows. The combination of sclerophylous oak with Coulter Pine could be classified as Conifer Emergent in Chaparral (CE_{cp}), but in higher elevations Montane Conifers are likely to be in association, justifying the Transition Forest classification.

The chief problem encountered with color infrared imagery in vegetation analysis of montane areas of Southern California is in finding proper combinations of infrared enhancement, and resolution. The original imagery is perhaps too "red" causing difficulties in the identification of species exhibiting strong red records, such as the oaks. Conversely, color infrared enhancement is beneficial in the mapping of plant groupings with poor red records, such as chaparral. Poor resolution of the old imagery prevented direct identification of plants in terms of their physical structure. When color signatures were indefinite, poor resolution forced identification of species from the pattern displayed by a group of individuals in space and not from a study of the individual itself. Thus, if homogeniety of spatial arrangement of the group were not consistent throughout the range of the species, mapping would be impossible. For example, lack of homogeniety in physiognomy and plant arrangement made mapping of Mountain Mohogany, Western Juniper, and Great Basin Sage species prohibitive, even with spot verification in the field. The reds on recently acquired imagery are periodically washed out due to over-exposure, sun angle problems, and film inconsistencies. This is compensated for by excellent resolution, so that direct identification can be carried out. However, while the introduction of new imagery made cause for explanation of possible inaccuracies on the original map, the revised map is not materially different. This indicates that the original, and therefore both maps are basically accurate, except perhaps in areas dominated by Desert Woodland and marginal ecotonal forests where minor boundary errors may occur. More importantly, the plant classification contained in the original report remained stable. Plant combinations which appeared to be consistent vegetation groupings in the study area remained as status quo, despite the addition of the newly acquired aerial photography. This result supports the view that color infrared aerial photography offers a new alternative in the recognition and classification of plant groupings not only in the San Bernardino Mountains but also in other areas.

Once this methodological framework was completed, and the investigator was confident of his ability to map vegetation with the necessary detail, a study was initiated to evaluate damage to brush and forest vegetation from a recent fire in the San Bernardino Mountains. Most brush species in the study area are suitably adapted to a pyrophytic environment such that their recovery in approximately ten years is unquestioned. Emphasis in the current survey is on the sustained damage to coniferous forest vegetation and the possibilities of determining fire weather patterns at the line of burn.

The use of color infrared photography is very appropriate for fire damage to vegetation evaluations. Because the near-infrared record of this film is indicative of live, photosynthetically active foliage, and the absence of this record is often indicative of dead matter, the film enables analysis of fire damage to be quickly carried out over large areas. For this purpose, depending on the scale and boundary accuracy desired, small scale imagery such as acquired during Mission 164, is highly useful. For detailed analysis of individual species damage and mortality, larger scale color infrared photography was acquired in April, 1971. The resulting use of "multi-scale" photographic data is proving highly successful.

In the present study the mapping of conifers is based on several categories which indicate the degree of damage as visualized and interpreted in the near-infrared record in tree crowns. Further, with more thorough interpretation, the role of the "Bear Fire" on conifers has been evaluated ecologically and floristically. Finally, death rates have been ascertained through demographic procedures. All mapping has been completed to date. Maps are presently being digitized to provide computer access and manipulation of the interpreted data which may then be statistically analyzed.

Subsequent portions of this investigation will include the mapping and analysis of other burned areas. Comparisons of the patterns produced by the combined effects of terrain, vegetative cover, and fire weather conditions should provide synoptic information which when applied to unburned areas will facilitate forest management in the realm of both fire suppression and prevention.

7.3.5 Preparations for ERTS-A Data

Our proposed investigations using ERTS data fall into four general categories. The organization of these objectives in terms of site location is controlled by the fact that these are areas of specific geographic interest and by the fact that certain of these areas have been the focus of on-going research for the past several years. The general research objectives include: (1) the mapping of land use patterns including an assessment of environmental impact of various uses; (2) the detection and analysis of land use change including the spread of urban areas, and the transformation of wild desert areas into urban and agricultural land use; (3) attempts to map and monitor environmental pollution in selected areas; and (4) the development and construction of models to explain "synoptic patterns" which are visible in the imagery.

Sites

Some sites for these investigations have already been chosen and under observation for two years in conjunction with the NASA California Project. Pre-ERTS and ERTS oriented research is already under way for the high desert, urban Riverside-San Bernardino, and Perris Valley sites. Information has been gathered, land use and thematic mapping is complete, and methodologies and techniques for computerized data mapping and presentation have been developed.

Included in both the NASA California and ERTS-A proposals was a research design for coastal environments. This research was scheduled to begin in calendar 1972. During the past three months a regional test site was chosen in northern San Diego County (Map 7.1). Smaller local sites within this area were used to assess the ERTS simulated data record provided by NASA.

Preliminary Coastal Site

The coastal environments of San Diego County have, since the end of the Second World War, been the focus of intense human activity. Environmental modification as a result of this activity has proceeded at an ever increasing rate. At the present point in time the least artificial environments from the high La Jolla terraces to Camp Pendelton north of Oceanside can be found in the shallow lagoons which mark the points of entry of San Diego County's intermittent streams to the Pacific Ocean. There are six of these lagoons which still contain water. None represent a truly natural environment and some have been rendered more artificial than others.

The forces behind environmental changes are of course economic, relating to short term profits. Changes throughout this coastal plain focus on increased development of regional transport networks, urban expansion, and an increasingly concentrated development of recreational facilities.

Buena Vista Lagoon is located between Oceanside and Carlsbad on the coast of northern San Diego County. It is one of the least modified of any of the six coastal water bodies and for this reason has been chosen as a test site for monitoring environmental change using remote sensing techniques.

Objectives

To the time of writing, these coastal investigations have focused on assessing the film as a data source. The most pressing question was "how much detail is available" or "to what scale will interpretation be possible with the 70 mm simulated ERTS imagery."

A simple qualitative test was devised where a 1969 data record provided by low altitude larger scale photography was compared to December 1971 U-2 70 mm film which has been enlarged. The comparison illustrates the utility of the ERTS simulation.

Data Sources

The data records for this test are provided by CIR transparencies in a 35 mm format at the stage of interpretation. The initial slides were taken in January and March of 1970 as part of USGS contract No. 14-08-0001-12083 by Tracor, Inc. of San Diego, California. These slides are compared to a copied enlargement of part of a frame of 70 mm film imaged from a U-2 aircraft as part of the NASA California Project. For comparison the copy is also presented in a 35 mm format, however the same information could be interpreted from the original 70 mm film using a small magnifier (for presentation in this report all 35 mm reproductions have been enlarged 2X).

The comparison is non-quantitative and preliminary. A quantitative technique for assessing the utility of small scale aerial photographs is under development within the Riverside shop and will be applied at a later date.

Analysis

Analysis is facilitated by Figure 7.1 a, b, c, and d, which are reproductions of the three photographic data sources, and a map representing land use change that has occurred between the 1970 dates and the 1971 date. Recognition of change is facilitated by arrangement of descriptive material in Table 7.3. Each column of the table contains a point by point description of a site where change has occurred, and each point of discussion is keyed by a letter prefix to the 1971 photography and the map of land use change.

Conclusions

Once a suitable data base has been compiled high quality small scale aerial photographs provide a suitable data source to monitor change. If the data record from subsequent spacecraft missions is comparable in resolution to the 70 mm imagery obtained in the U-2

Fig. 7.1. Buena Vista Lagoon

Table 7.3. ANALYSIS OF CHANGE - BUENA VISTA LAGOON

FEATURES	Figure 7.1a	Figure 7.1b	Figure 7.1c
A (Lagoon Mouth)	It is not visible	It is barely open, and has not recently been disturbed.	Channelized with large fill areas north and south of opening.
B (Lagoon Shore)	Areas of fresh fill show on both photographs; under the freeway interchange and near the shopping center.		More extensive fill below interchange. More luxurient vegetative growth around back side of lagoon in other fill areas.
C (Shopping Center)	Shopping center is present in both 1969 photos. It appears recently constructed. There is little vegetative register around area.		Significant change in vegetative register due either to ornamental plantings or preseral natural growth.
D (Land cut and fill along Freeway)	Freeway construction underway, areas of cut and fill are present but not as extensive as in U-2 imagery.		Cut and fill scar covers entire slope north of Freeway access road.
E (Freeway Interchange)	Construction work on offramps started.		Construction complete for entire cloverleaf.
F (School)	Three buildings present. Grass on associated playing fields in poor condition.		One, perhaps two new buildings added. Grass and playing field in better condition and increased in size.

flight in December of 1971, it too will serve as a useful data source for monitoring regional change.

7.3.6 Regional Information Systems

The development of equipment and methodologies for geographical information systems is a major topic of investigation at the University of California, Riverside. These investigations and developments have for several years been supported by sources other than NASA. Because of the successful applications of the information system equipment and techniques being developed, and because of the increasing need for the present and future NASA-California Grant investigations to handle large quantities of regional data, it is important that the two studies increasingly be more closely integrated. Several of the present studies, reported herein, have already made use of the system to various extents.

A recent technical report by Nichols, "A Demonstration of the Use of the Grid System Utilizing Multi-Source Inputs," is included in the present discussion because it provides a basic framework in which the relevant uses of remotely sensed data in a geographic information system can be viewed. Although Nichols' study was not directly supported by NASA, it is based on the use of NASA photographic data (Mission 128B) and applies important concepts to a portion of the study area for NASA sponsored investigations being conducted at the University of California, Riverside.

Nichols demonstrated the use of a grid cell digital system when seeking to integrate data derived from high altitude aerial photography (or spacecraft data?) with other sources of information, e.g., topography, geology, vegetation, transportation, land use, etc. The system has the capabilities of data storage, retrieval, and manipulation. Further, a regional data bank file possessing spatial characteristics can be displayed with computer graphics and manipulated in the computer. For regional information systems to utilize as input any remotely sensed data, primary factors must be considered: resolution and regionalism. Obviously the two needs are ambivalent; consequently a compromise which minimizes the adverse effects of both must be sought.

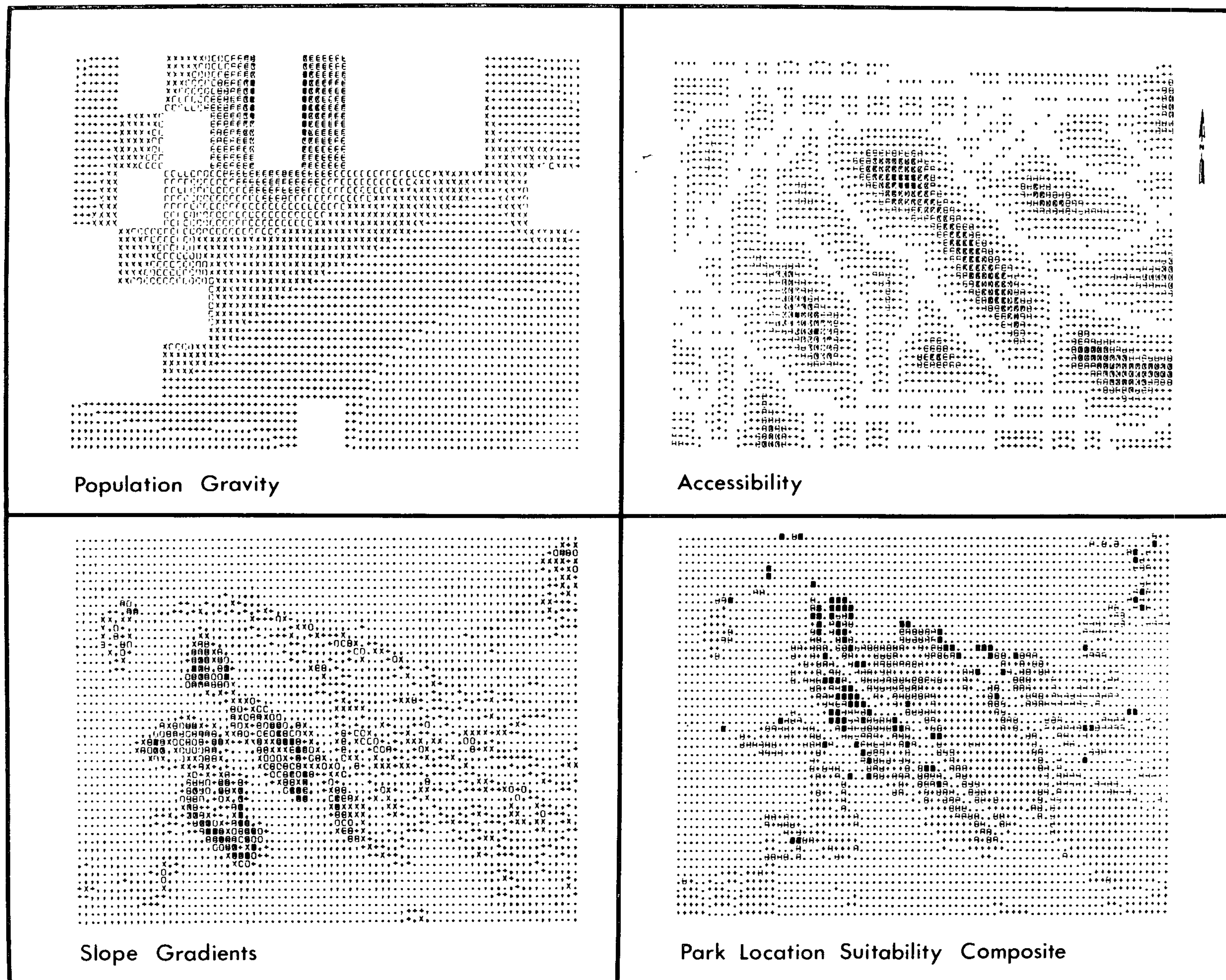
Resolution for remotely sensed data inputs must be considered for two reasons. First, the image must provide sufficient detail to be useful for the inventory of the desired data, i.e., identifying transportation arteries, counting dwelling units, etc. Second, the resolution must be compatible with the desired fidelity of the inventory. A perfect survey is not necessary and often is impossible, even with ground survey methods, but the inventory data must be adequate for use in whatever application is chosen. Regionalism of the remotely sensed data is dictated, however, by the data rectification needed in order to reconcile the remotely sensed data with the various other types of data inputs. It is also dictated simply by the desire to minimize data handling.

Nichols considered the requirements of resolution and regionalism and the utilization of remotely sensed data to develop location analysis methodologies. The application he chose to demonstrate was a model for regional park location in a study area east of Riverside, California. The area covers a wide variety of land uses, ranging from dense urban areas to agriculture, to mountainous open spaces.

Perhaps the singularly most peculiar aspect of the study area is that it is bisected by the San Bernardino and Riverside County line. As such it has been a neglected area in open space and resource planning by both of the county planning agencies. Another reason for choosing the area is its "open space" nature. With public opinion demanding more rational urban development and more preservation of open space, it seems illogical to let such a prime area be ignored. Lastly, the area was chosen as a matter of practicality, for there was adequate NASA high altitude aerial photography covering the full area.

A grid overlay, based on the UTM system, was divided into grids of one-ninth kilometers, with each grid square thus encompassing approximately 27 acres. Data were interpreted from 1:100,000 color infrared aerial photography (Mission 128B) and combined with various ancilliary information available from maps and other data sources. Several maps of the study area were then produced; Map 7.5 shows several examples. Map 7.5A shows population gravity; dark areas represent unpopulated areas with high population attraction, blank areas are populated. Map 7.5B shows accessibility; dark areas represent high inaccessibility and blank areas are "through" arteries. Map 7.5C shows slope gradients; dark areas represent steep slopes. Map 7.5D shows the park location suitability composite, derived from all available data sources; dark areas represent high suitability.

Photos at scales <u>larger</u> than 1:100,000 were generally concluded to be inadequate for such a study because they did not provide the overall view necessary for regional information systems. Scales between 1:100,000 and 1:120,000 appeared to most adequately meet the



Map 7.5. Population gravity: dark areas represent unpopulated areas with high population attraction. Blank areas are unpopulated. Accessibility: dark areas represent high inaccessibility. Blank areas are "through" arteries. Slope gradients: dark areas represent steep slopes. Park location suitability composite: dark areas represent high suitability.

conditions for compromise between the factors of resolution and regionalism. Scales smaller than 1:120,000 would be appropriate only if resolution requirements could be satisfied.

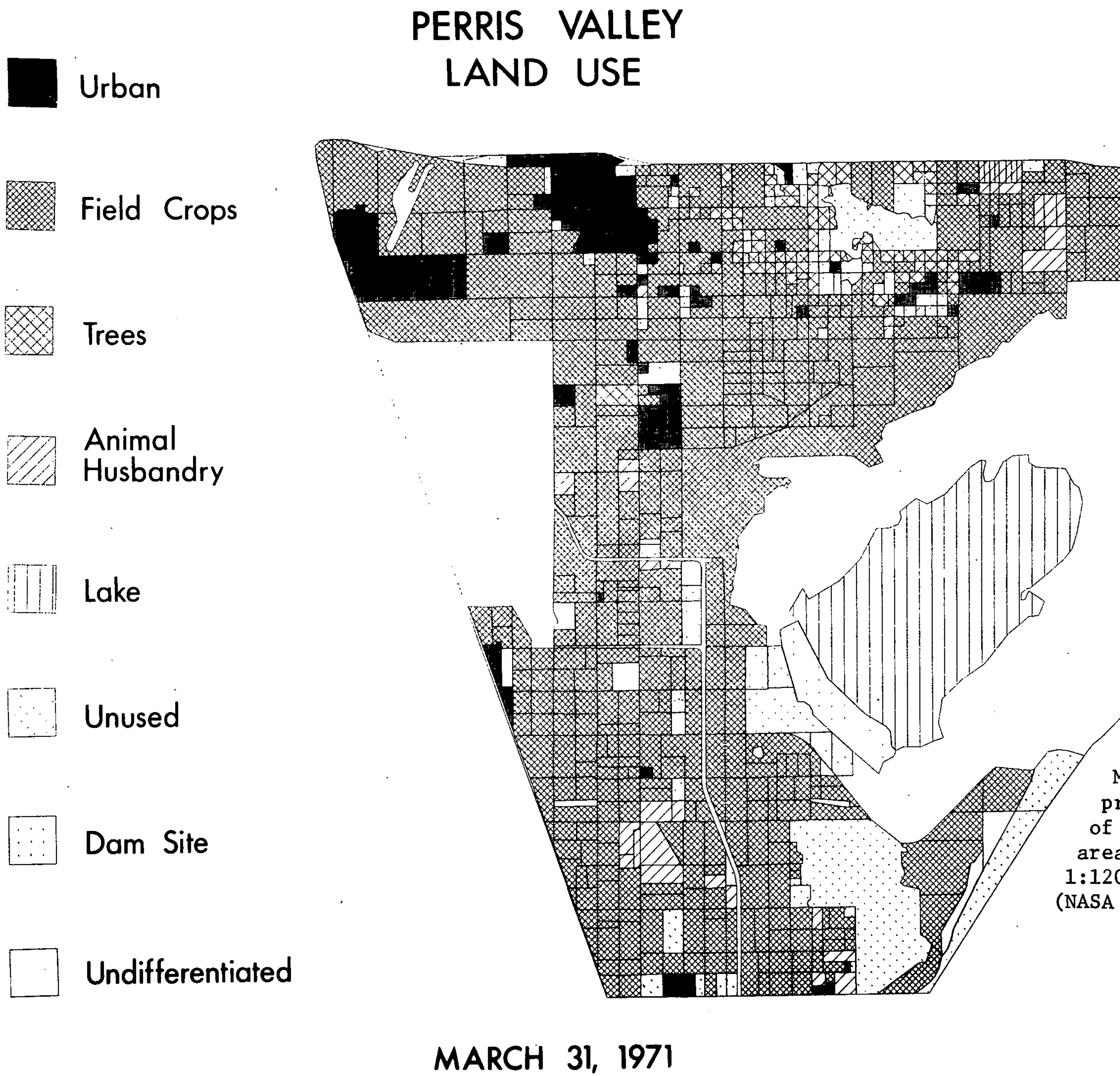
7.3.7 Computer Prepared Thematic Maps

Mapping requirements of the forthcoming Earth Resources Satellite experiments are already placing a great burden on many cartographic services. Preparation of initial base maps of Southern California test site areas and experimental updating of thematic changes detected from current underflight imagery prove the need for an automatic thematic mapping system. Several systems for computer mapping are available to the Riverside campus and are being modified to our needs. While the following discussion will deal primarily with a cartographic line type thematic map program (CALFORM) there is a close relationship between each of our computer mapping systems.

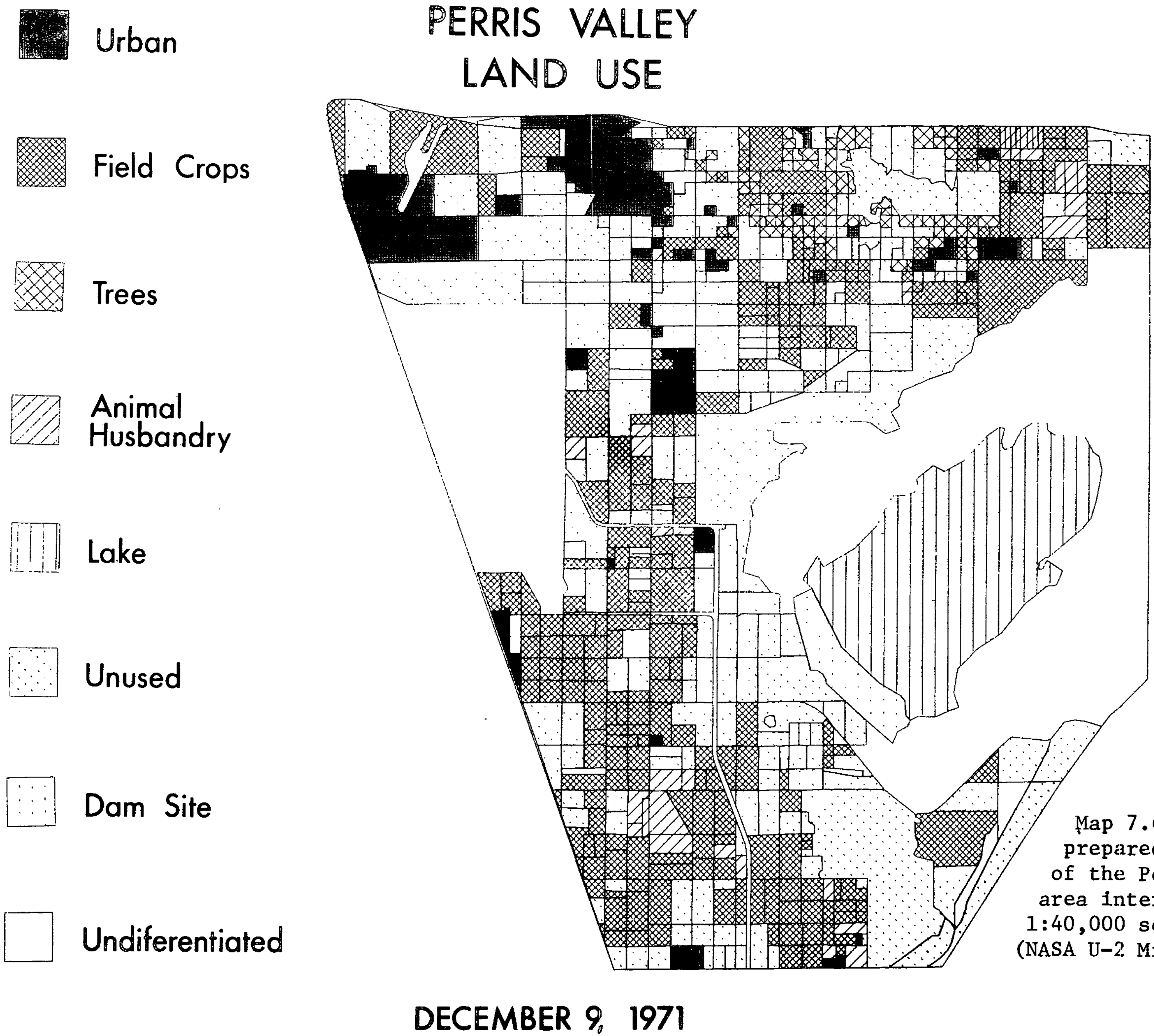
The GRID mapping system discussed in the previous section and the Polygon Information Overlay System (PIØS) will be utilized in conjunction with CALFORM to develop a computer based Geographic Information System. Each of the three systems have their attributes and each have short-comings. The PIØS system is an efficient method for converting image data into digitized form for computer manipulation. The grid system with its equal area cells is essential when correlating spatial data from several sources. Thematic maps prepared by CALFORM best simulate cartographic maps that we are accustomed to viewing and in many instances are the most perceptually acceptable. Current investigations at Riverside intend to utilize the polygon input system and then convert the data to equal area grid cells within the computer itself. This procedure will eliminate a great deal of slow tedious manual coding required to produce the GRID maps for multi-source correlations such as the data discussed by Nichols in the previous section.

The development of a computer based information system for correlation of multi-source data will increase the need for thematic maps. The GRID mapping program produces thematic maps on the line printer simulating various legends by various density levels produced by over-printing of type symbols (Map 7.5). The CALFORM mapping system is much less flexible than the GRID system, but it produces a much clearer line drawing looking much like a map drawn by a human cartographer (Map 7.3B).

CALFORM computer input differs greatly from the GRID system which limits its flexibility within the computer, but enables very rapid updating of information once the base map has been prepared. The CALFORM program records the x-y coordinate of each vertice of every polygon (regardless of shape or size) and in addition it numbers each polygon. Once recorded the only requirement for reproducing an individual area or cell is to tell the computer the cell number desired and what legend code it should draw in the cell. The legend can be changed for any cell on each subsequent computer run. As an example Maps 7.6 a, b, and c are computer prepared maps of the Perris Valley study area discussed in a previous section. Six hundred thirty six cells or polygons were identified with the 44,928 acre area. One thousand three hundred sixty seven vertices were identified and their x-y coordinates were read into the computer to a resolution of one-thousandth of an inch (0.001") by means of a coordinate digitizer. Obviously the vertices serve more than one polygon most of the time.

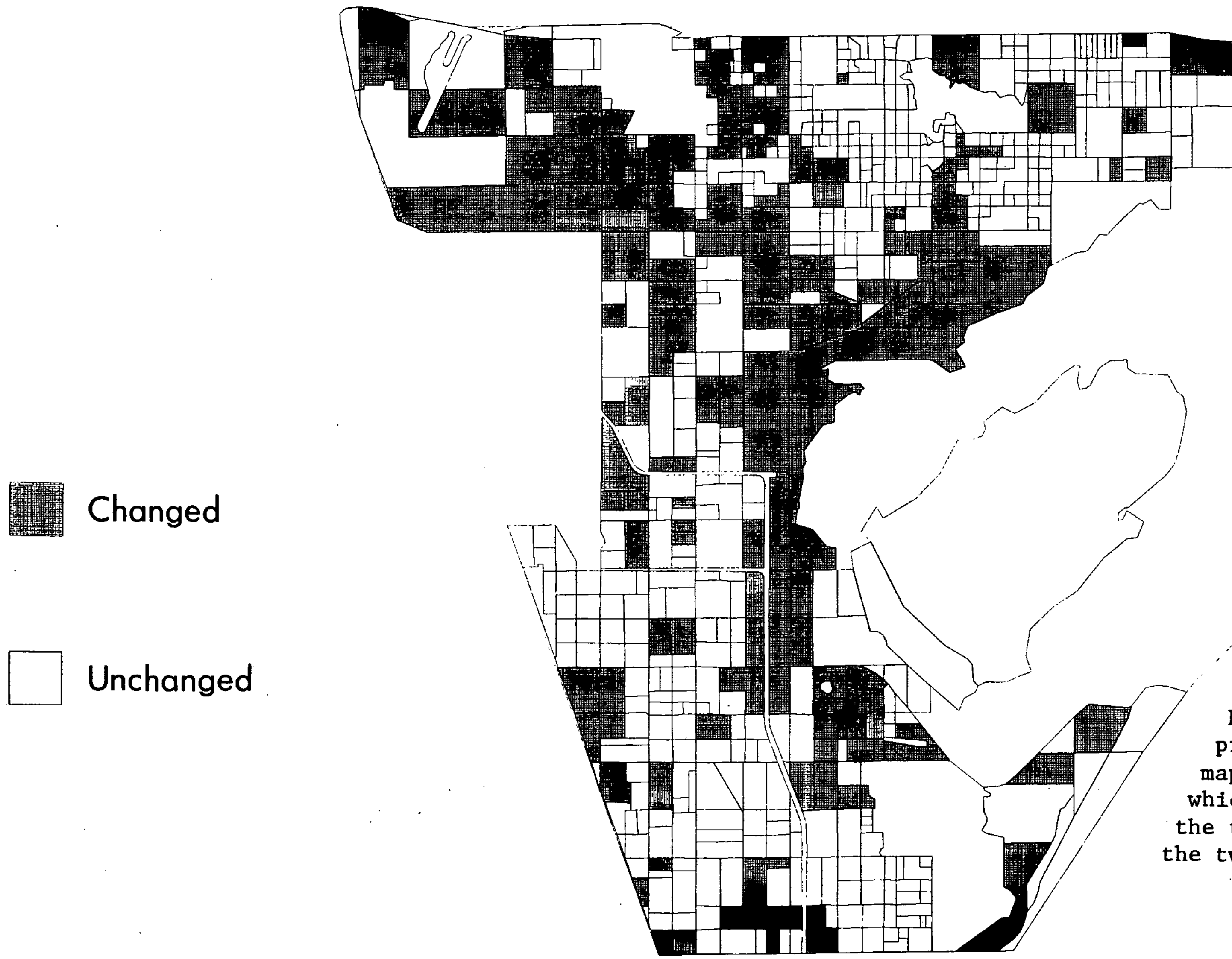


Map 7.6A. Computer prepared CALFORM map of the Perris Valley area interpreted from 1:120,000 scale imagery. (NASA Mission 128.)



Map 7.6B. Computer prepared CALFORM map of the Perris Valley area interpreted from 1:40,000 scale imagery. (NASA U-2 Mission.)

PERRIS VALLEY LAND USE CHANGES



Map 7.6C. Computer prepared CALFORM map showing areas which changed between the time period of the two previous maps.

It has been found that the digitizing process proceeds faster if an outline of the thematic boundaries are first outlined on an overlay of the image or associated base map (Map 7.3A). Once the overlay has been prepared it requires about four hours to digitize an average land use map the size of a 7.5 minute togographic sheet. However, a vegetation or soils map of the same size may require up to 40 hours. The great advantage of the CALFORM map is the short time it takes to update the data. Map 7.6a depicts a portion of the Perris Valley area interpreted from March 31, 1971 imagery (NASA Mission 164). Map 7.6b illustrates the land use interpreted from U-2 imagery of December 9, 1971. The latter interpretation took about 30 minutes and the change in the previously prepared computer map took only 30 minutes. The excellent resolution on the U-2 imagery assisted greatly in the rapid interpretation.

Another attribute of the CALFORM thematic map system is the ability to quickly produce a new map to show a single category of data or information. Map 7.6c is an example of a single category map showing the changes that took place between the two time periods of the previous two maps. Any one category or combination of categories could be produced with less than an hour's preparation time once an initial CALFORM map has been prepared.

The Perris Valley computer maps showing updated information show the need for modification of the CALFORM program to provide acreage calculations. Acreage calculations would enable the preparation of a table of change to be made (Table 7.4). Within the Perris Valley area a most important seasonal variable is the consumption of water by

Table 7.4. PERRIS VALLEY LAND USE SUMMARY OF ACREAGE AND CHANGE
(All Units in Acres)

CLASSIFICATION	March 31, 1971			CHANGES		December 9, 1971		
AGRICULTURAL AREAS	DRY	IRRIGATED	TOTAL	DRY	IRRIGATED	DRY	IRRIGATED	TOTAL
FIELD CROPS	13,590	6,110	19,700	-7,310	-3,410	6,280	2,700	8,980
TREE CROPS		900	900				900	900
ANIMAL HUSBANDRY (Poultry, Horses, Cattle, Sheep)			900					900
UNUSED (Vacant, fallow)	3,540		3,540	+7,310	+3,410	14,260		14,260
UNDIFFERENTIATED			370					370
TOTAL AGRICULTURAL	17,130	7,010	25,410			20,540	3,600	25,410
NON-AGRICULTURAL AREAS								
URBAN AREAS			2,040					2,040
DAM SITE			510					510
FUTURE LAKE SITE			4,300					4,300
LAKE HILLS & RECREATION			5,700					5,700
MARCH AIR FORCE BASE			3,100					3,100
OFFSITE IMPROVEMENTS (Roads, Ditches, Flood Control, etc.)			3,868					3,868
TOTAL NON-AGRICULTURAL			19,518					19,518
TOTAL ACREAGE			44,928					44,928

agricultural activities. The table indicates that 3410 acres of field crops which normally utilize irrigation water were permitted to lie fallow on December 9, 1971. An additional 7310 acres of field crops that are dry farmed were also out of production. The timely reporting of such data can prove invaluable to water resource agencies.

Preparation of computerized base maps for the test site areas in southern California utilizing the CALFORM system is proceeding. These additional maps will be used in testing the ability of ERTS-A imagery to provide evidence of change in the environment.

7.3.8 Remote Sensing of Environmental Quality in Relation to Land Management

Remote sensing of the environment can be applied as a technique to monitor environmental quality. The phenomena sensed are those which influence quality and include numerous things that man can experience. Many phenomena in man's experience are unlikely to be subjected to remote sensing. These phenomena cannot be ignored simply because we are not capable of monitoring them. For this reason, a system of remotely sensed indices of environmental quality may be developed and used effectively to inform but should not be used to dominate policy.

In a like manner, resource managers have been negligent in failing to fully use remote sensing techniques as a means to aid future land management. All too often, detection of effluents, evaluation of already blighted areas or spot checking of conditions is as far as remote sensing gets used. Unfortunately, newly formed political and popular fronts for the assessment and improvement of environmental quality run the risk of using ill-informed and ill-considered popular action that will alleviate some problems detected by remote sensing and aggravate other, more serious problems.

It seems clear that no policy regarding environmental quality, whether remote sensing is involved or not, could be meaningful if it took less than a regional perspective or outlook and often a world-wide view is desirable. It also seems clear that when dealing with land use and/or land management nothing less than predictive models for future use and preventive models for future quality deterioration are necessary.

Land does not exist in any definable "pure" form -- geologically or ecologically -- and land pollution means departure from a normal rather than departure from a pure state. Because the land is both diverse and subject to natural or cultural change, the key problem is to determine if the changes are within a broad "normal" range or if they are degradative. And, can degradation be identified, classified and judged? Is it harmful to man and nature?

A land environment is always subject to pollution be it volcanic dust, deer manure or disposed beer cans. Most pollutants are soon broken down or integrated into the environment through decay, burial, settlement and so forth. Over the eons, absorption, oxygenation, and consumption easily clear and disperse small amounts of pollutants. Interaction in the environment among land, air, water and biomass tends to stabilize or control excessive pollution. Except in geologic time spans, little alteration occurs on the natural landscape. However, man has recently upset the cycles of erosion, deposition, decay and regrowth by impressing on the total environment a new and demanding cultural landscape.

Cultural or human pollution of the land has expanded exponentially in the last two centuries. Streams have become sewers unable to dispose of or control the material dumped into them. Rural areas are collectors of discarded junk and urban cities are ribbons of refuge and garbage surrounding dismal housing and uncontrolled development. At the same time, water and air have also been polluted and ecological systems disturbed and interrupted. The magnitude and intensity of the problems have become so much greater in recent years that they have blossomed into major political issues. The problems have also generated conflicts penetrating all segments of the economic system.

At the present time, limited government action is the rule to be followed. Standards are to be set, action ordered and so forth by various local, national or international governmental agencies. There are very few guidelines for either the private citizen or private industry to follow to be a lesser land polluter. The concept that the only social responsibility of business is to use resources and engage in activities designed to increase profits so long as the business stays within the rules of the game (Friedman, 1962) places the burden on government to set the rules.

However, damage to the land arises from so many sources that only intense cooperation by private and public factions can produce the slightest positive result. And then the index we use to measure the results may also be misleading.

The most widely used index is the Gross National Product (GNP) which represents the goods and services produced in a given period and moving through market channels. As the name implies, GNP is "gross" because it disregards the conventional kind of depreciation, the wearing out of plants and equipment, etc. However, tax deductions are allowed for depreciation to business for such declines. Yet, nobody depreciates the land, allows for wear out or pollution in any form. The GNP does not take account of depreciation of environmental quality. In fact, increase in GNP is often at the expense of resources. If pollution, for example, eroded rather than bolstered the GNP, government agencies and private industry might well have cleaned up the environment years ago (Janssen, 1970).

Unfortunately, much of our pollution is unmeasurable in money terms such as effect on GNP. How does one value a beer can on the landscape when the production and consumption of the beer and container added to the gross national wealth? Somehow a change in indices is necessary before individuals or agencies can take action to remove or retard pollution. One may detect a sugar beet field full of salinity, but to advise the farmer on action or guidelines to remove or reduce salinity is a different situation, expecially if it lowers his annual income.

In the less clearly defined realm of culturally altered landscapes our mobile population is capable of spoiling one region after another. Except possibly in Alaska, so little "wilderness" remains that, even if it all were preserved, it cannot serve a population that seeks it out as a relief from its culturally blighted landscapes of normal residence. The potential for degradation of the quality of living is all around us. First noted in the deteriorating environments of the urban scene, it is now prevalent in all parts of western societies' landscape (Aschmann, 1971).

Within the capability of remote sensing lie three critical and applicable possibilities as summarized from Aschmann (op. cit.):

1. The capability to inventory our entire national territory in terms of environmental characteristics that affect the quality of human living.

2. Early detection of slight but progressive environmental changes.

3. The identification of patterns and associations of variable and disparate environmental features, both natural and cultural, that society can associate with desirable or undesirable environments.

The first of the three above is most critical. The least elastic of the nation's (and the world's) resources is land and land space. Space on, above or below the urban concentrations is of greatest value yet the non-urban space remains critical to our natural resources but is being progressively pre-empted.

It seems worthwhile to inventory in some detail the spaces in and around urban population concentrations to determine what fractions remain and in what land use. How much of the nation's land is in "single-purpose, pre-emptive land use"? What are the evolving patterns?

Urban and regional planners need to recognize the ways urbanized landscapes evolve. They make few land use maps, owing to their cost by traditional field survey methods, and as a consequence a map's utility is limited to a historical or illustrative value and its major value, when used synoptically to observe economic patterns rearranging themselves, is lost. The application of remotely sensed data can help change the situation. Urban fringe problems are widely recognized: (1) disparate land usage and the gross inefficiency of any distribution system that services disconnected development whose conversion is not phased incrementally; (2) from an agricultural investment view, blighted landscapes have social cost in the loss of interim use returns due to "clouded" planning futures and the disinvestment strategies it prompts; (3) agricultural produce also incurs a higher transportation cost. While a policy regulating rural-urban land use conversion in increments of growth is lacking in the United States, a synoptic method comparing a series of photographs can point out where land owners may initiate a conversion long before the necessary formal procedures are begun. Planners or policy makers may take action when they observe agricultural patterns entering an urban-transition process. By remotely observing tangible land use evidence of decision-making, the synoptic, photographic interpretation and other techniques married to urban growth (land economics and locational theory) greatly facilitate the planning of the urban fringe (Goehring, 1971).

Evolving land use and management change, can be detected early with the use of synoptic remotely sensed imagery. Goehring (1971) found evidence that urban land use successions can be predicted several years ahead of their actual development. Urban and regional planners can foresee transition problems and where they occur, while they develop. Whether they can or will do anything about the problems depends on policy.

Basically, detection of environmental quality should mean early detection of indices or surrogates so that action can be taken. When blighted districts are fully developed they are easily identified visually by almost any observer. We need to recognize earlier the signatures of blight or declining environmental quality. We need to recognize those combinations of physical landscape and cultural management that are associated with and precede blight.

During the 1960's, we established that impoverished rural environments, urban housing quality, land deterioration and classes of socio-economic conditions were definable from remote sensing methods. All of our research efforts, mostly in Chicago, Asheville Basin, and southern California were checking the system to see if we could compete with ground based observers in doing land use, land and housing quality, inventory and evaluation of existing land resources. Now it is time we used our capabilities to project the future of land use and guide land management in a meaningful way to protect environmental quality.

However, one proceeds with the above if he knows, or thinks he knows, what is desirable environmental quality. It seems that man needs, in addition to food, clothing and shelter, numerous other items to be satisfied. The most important is diversity. A monoculture of monolandscape seems to be unattractive, whether it is continuous similar suburban homes or flat, horizon seeking grain fields. Yet there is no extensive documentation on such important indices as (1) change (2) boundary or (3) individualism. Nor is there historical documentation of the relation of the above three to attitudes or environmental quality. Mullens, working with imagery of Los Angeles, found he could class urban housing quality in relation to middle class income by examining three factors -- vegetation, litter and open space.

In a like manner, hazards to living (earthquake, fire, flood, tidal wave, landslide, etc.) are identifiable in a regional and often local sense. All of these are predictive, rather than after the fact. They are not monitoring of past events that deteriorate man's happiness but are projections of where the deterioration can come from. Of course, such items as housing density, industrial location, and recreation area use are well within the realm of being remotely sensed.

In the 1970's, those of us who have looked at remote sensing applications for a long time are starting to realize some of the actual potential. An example might be the determination of environmental land quality prior to the invasion of an interstate highway plus the prediction of what it will do -- not just locally but regionally and nationally. Aschmann states that the concept of the "right and wrong side of the track" has been with us for a long time. But remote sensing should be able to furnish us the data to foresee an area that will become the "wrong side of the track" when and if certain phenomena occur.

Of course, information taken from remotely sensed data is only useful as a surrogate of what the real scene is. This is the case where both privacy and social contacts are sought on alternate bases. Crowdedness, or the lack of it, of things on the land is most certainly detectable by remote sensing. What is not distinguishable is the desire for privacy or social contact. However, as one builds the totality of environment from those data bits of remote sensing, often a picture or some insight is formed. Land use, transportation facilities, energy supplies, recreation opportunities, or more simply "the role of man's activities on the land" are readily subjected to analysis with remote sensing methodology.

Occasionally, there are surprises such as finding out that urban vegetative condition sensed with color infrared photography is directly correlated with quality of housing and neighborhood income. On the other hand, some apparent sensors are not as useful as the engineering might lead you to believe. Thermal infrared scanners at one time seem to be a potential tool for night-time traffic monitoring but as yet have failed to make the step.

There has been too much publicity on how remote monitors can detect crop vigor, thermal outflows, stream effluents, forest fires and others. It is time we brought the need for land use planning, prediction of land and environmental quality and the capabilities of remote sensing together. In a nation that has the technology and hardware to sense every acre of land but no regional, state or national land use policy, the time for both is overdue.

There is no question that remote sensing's greatest contribution is in the detection and inventory of land use. No other method of survey or analysis comes near to remote sensing when land use data is desired. As has been stressed earlier, once the land use is known, then the real or potential "land pollution" can be described. Just as important is that land use is a prime key to existing and potential air and water pollution.

Overall, the "state-of-art" of remote sensing is technically advanced to the point of being very useful for detection of land pollution. The major drawback is "what" to detect and "how will it effect policy?" In effect, before any evaluation as to "benefit-cost" can be made, costs that have previously been part of the social or cultural pollution of production must be subtracted. As a result, standard economic series such as GNP will have a rather bleak look for a long time. If pollution control efforts should expand significantly, new guidelines will be needed to interpret what the statistical series are telling us and what the remotely sensed data are telling us about economy and environment. Once the policy changes are made, the new data will not be comparable to data in use today. As a result, remote sensing of the environment will play a much more significant role in early detection of pollutants and serve as a method of monitoring policy and regulation enforcement.

7.4 FUTURE STUDY

During the past year several significant accomplishments have been achieved in regards to future studies. The Perris Valley Study Area investigations are essentially complete for the present. A data base for a large area has been established which will allow further monitoring for land use change and development using future remotely sensed data. The Regional Information Systems study has provided significant methodological developments in a small area which can now be expanded over large regions to enable rapid and accurate semi-automated analysis of environmental resources and land uses, with automated data storage and manipulations. The Urban-Rural Transitions study yielded important theory and data for interpreting and analyzing these areas of dynamic land use change using remote sensing techniques. The Addendum to "Mapping Montane Vegetation..." utilized and critically tested the applicability of high altitude aerial photography for the mapping of discrete wildland resources with positive results and techniques. Delineation of coastal test sites and organization of research objectives for those areas on a preliminary basis have indicated the utility of ERTS simulated imagery. Computer mapping techniques have allowed development of systems of data handling and manipulation which greatly facilitate presentation of monitored change. And finally, the analysis of land pollution in southern California using remotely sensed data has summarized our learning effort in understanding very important and complex landscape phenomena.

Each of these efforts contributes to the study of Urban-Regional land use, which is in the initial stages of development and data interpretation. Classification, data formating, data processing, data display for maximum utilization, and multi-faceted data analysis are some of the problems which have been dealt with, all of which are present in the land use interpretation and analysis of large and complex urban-regional areas. While several of the other studies will continue (e.g., Perris Valley, Urban-Rural Transitions, land pollution, and environmental quality), all the problems and developments will be represented in the Urban-Regional Land Use project. Furthermore, this project is designed so that boundaries of the study may be enlarged at any time to include other areas, such as the southern California coastline, when it becomes important or opportune to do so. Investigations will also continue to prepare for and utilize pre-ERTS simulation photography and ERTS data, as they become available, to map, analyze, and update environmental phenomena in the three ERTS test sites.

7.5 STUDIES PUBLISHED, SUBMITTED FOR PUBLICATION, AND IN PREPARATION, DECEMBER, 1971

Published

The following papers have been published or have been issued as Technical Reports (Interagency). Items 3 and 4 were wholly supported by the NASA Grant. The remainder were partially supported by this grant, including data requirements.

1. Aschmann, H. H. 1971. Prolegomena to the remote sensing of environmental quality. *The Professional Geographer.* XXIII, 1. January. pp. 59-63.

2. Bowden, L. W. 1971. Remote sensing of the Baja California coast. In: Proceedings of the Second Coastal and Shallow Water Research Conference. University of Southern California. Los Angeles. October.

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8. Brooner, W. G. and D. S. Simonett. 1971. Crop discrimination with color infrared photography. *Journal of Remote Sensing of Environment.* II, 1. October. pp. 21-35.

9. Goehring, D. R. 1971. Monitoring the evolving land use patterns on the Los Angeles metropolitan fringe using remote sensing. Technical Report T-71-5. Department of Geography, University of California, Riverside. October.

10. Johnson, C. W. 1971. Computerized land pattern mapping from mono-imagery. In: Proceedings of the Seventh International Symposium on Remote Sensing of Environment. University of Michigan. May 17-21. Also: Technical Report T-71-3. Department of Geography, University of California, Riverside.

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15. Sullivan, A. E. and W. G. Brooner. 1971. Remote sensing of chaparral fire potential: case study in Topanga Canyon, California. Technical Report T-71-1. Department of Geography. University of California, Riverside. March.

Presented Papers

Items 1-4 were wholly supported by the NASA Grant. Item 5 was partially supported by this grant, including data requirements.

1. Bowden, L. W. 1971. The use of remote sensing to study the impact of urbanization on environmental quality in southern California. Presented at: Applications of Remote Sensing to Urban and Regional Planning. Department of Engineering, University of Wisconsin. Madison, Wisconsin. October.

2. Bowden, L. W. 1971. Remote sensing of urban environments. Presented at: Department of Urban Planning, California Polytechnic College. November 19.

3. Bowden, L. W. 1971. The view of earth from space. Presented at: Kaiser Foundation, Southern California Permanente. Fontana, California. November 20.

4. Coleman, V. B. and W. G. Brooner. 1971. Remote sensing of land use change and development: Perris Valley, California. Presented at: Meetings, Association of Pacific Coast Geographers. Victoria, British Columbia, Canada. June.

5. Pease, R. W. 1971. The remote sensing contribution to climatology: present and future. Presented to: Physical Geography Panel, Meetings of the Associations of American Geographers. Boston, Massachusettes. April.

Submitted for Publication

The following papers or contributions, partially supported by the NASA Grant, have been submitted for publication.

1. Brooner, W. G. and J. E. Estes. Color enhancement techniques for environmental information. To: Commission on Geographical Data Sensing and Processing, International Geographical Union.

2. Johnson, C. W. The design of a computer oriented land use mapping system. To: Commission on Geographical Data Sensing and Processing, International Geographical Union.

3. Pease, R. W. Data acquisition with false color film. To: Commission on Geographical Data Sensing and Processing, International Geographical Union.

Reports in Preparation

The following studies, partially supported by the NASA Grant, are in preparation; progress is discussed in this report.

1. Bale, J. B. and J. Minch. Coastal geomorphology and shore classification of Baja California del Norte, Mexico.

2. Departmental staff. Models and analyses of urban/regional land use: Riverside-San Bernardino and vicinity.

3. Minnich, R. A. Inventory and analysis of Montane Fire: a computer model from the Bear Fire.

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Chapter 8

DIGITAL HANDLING AND PROCESSING OF REMOTE SENSING DATA

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8.1 INTRODUCTION

An important part of the integrated study of Earth Resources carried out by the University of California is the combined use of all available sensing devices which provide information of interest to earth resource scientists. Two considerations influence the use of multisensor data. Firstly, the data collected in each of several different bands on each of several different dates will need to be analyzed in various combinations. Secondly, with the launch of the ERTS A Satellite, sets of multisensor data in an electronic format will become available to the project as one of the major data sources. Thus a significant component of our work is the efficient or optimal use of the large amount of data available which has bearing on the study of specific earth resources. Three approaches are used in the analysis of the available data:

Human Photo Interpretation

Electronic Image Enhancement

Automatic Data Processing

These three approaches complement one another and are all pursued within our study. In order to articulate and understand these different approaches

we show in Figure 8.1 a block diagram of the acquisition, analysis, and enhancement of remote sensing imagery. For each of the features of interest a set of attributes, Y, makes it possible to study this feature from remote sensing imagery. For instance, the work of the spectral analysis unit of the Forestry Remote Sensing Laboratory is directed toward the study of spectral attributes of vegetation. The work of Coulson and Walraven systematically considers polarization effects of features and natural surfaces. By the time the attributes of the feature of interest have been recorded, in block 3, as spectral images or scans, these attributes have been modified by several partially known or unknown effects. These effects will include, for instance, the mixing of features due to insufficient image resolution, the variations of sunlight illumination, and degradation due to atmospheric scattering and turbidity. The analysis of the resulting imagery will be affected to various degrees by all of these poorly known effects. In some cases, such as the mapping of rangeland resources, the task can be done conveniently by considering a single spectral image or a standard color combination of spectral images. In other cases, such as monitoring water quality, the task is sufficiently more difficult that more sophisticated analysis techniques are needed.
In its generality, the study of ground features from remote sensing data falls within the framework of statistical decision and estimation theory. The study of spectral and other properties of surfaces is now called the acquisition of *a priori* information. The transformation of the attributes of the feature of interest into attributes of the images or scan is a probabilistic mapping. Thus, for a given feature of interest the recorded attributes have a statistical distribution which has to be taken into

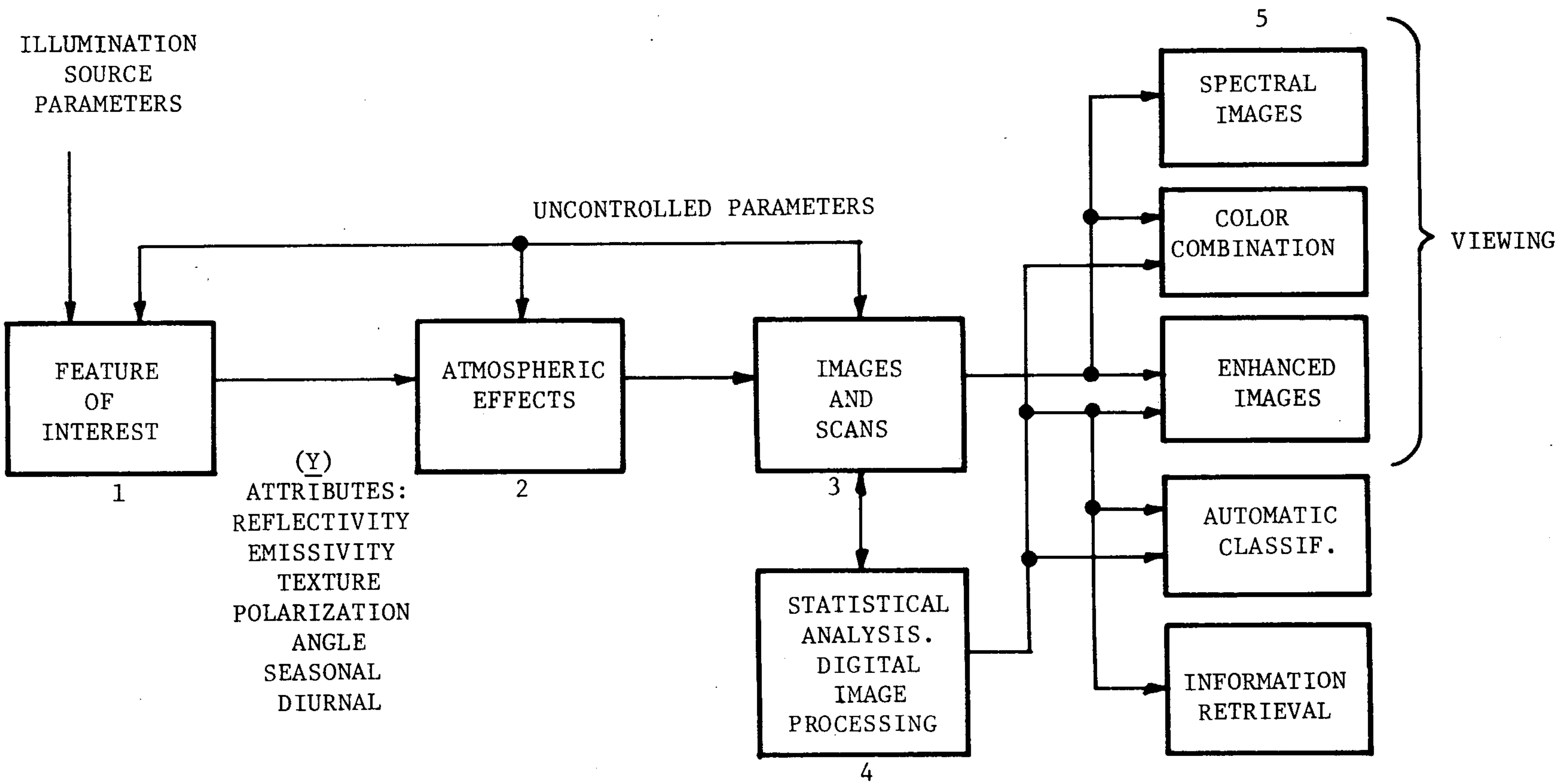

Figure 8.1 Flow diagram of the acquisition, analysis and enhancement of remote sensing images

account in studying this feature. The number of images or scan can be large, seven for ERTS A, and the number of observed attributes can be even larger. Thus the intelligent exploitation of the relevant information requires the ability to handle large amounts of data in a concerted fashion. Our group, shown as block 4 in the diagram of Figure 8.1, brings to the integrated study both the experimental facility and personnel with the knowledge and background needed to perform the systematic exploitation of the available information. Such elaborate methods are most pertinent for tasks which cannot be done by directed observation of conventional black-and-white or color combined imagery. For this work the data processing facility being established as part of the University of California program emphasizes man-machine interaction rather than bulk processing of data. It uses as a central processing element a digital computer; thus the development and use of data processing algorithms becomes principally a problem in computer software development. With this approach it becomes possible to make use of the very extensive digital computation facility already available at the University of California. By the acquisition of a very modest number of specialized computer peripherals, an extremely versatile and flexible facility is being made available to the program. This digital signal processing facility, also used on other NASA sponsored image processing work, is described more fully later in this report. It will be connected this year to the CDC 6400 digital computer of the Campus Computer Center.

Our facility and programs should allow us to answer among others the following questions for the various investigations in our integrated study:

1. Which spectral bands and what resolution capabilities are needed in a specific discrimination problem?

2. How should spectral bands be combined to perform feature enhancement?

3. How well can *a priori* information (e.g., signature analysis) be relied upon to design enhancement algorithms?

To handle these questions our approach is to rely both upon ground truth and the images transmitted from ERTS A. For digitized images a quantitative analysis will be conducted of the effect on spectral components as well as on texture of images due to the features of interest. The results of this analysis in the form of one and multidimensional histograms, Fourier spectra, etc., will allow us to eliminate irrelevant data, rank the usefulness of relevant data to a specific enhancement task, and guide the design of enhancement programs. Our philosophy is to perform the steps of the analysis rapidly using a small data array, observe intermediate results in a color display, and make use of and try to quantify all clues available to a trained observer. Some of the programs needed to perform this task have already been written and are described later in this report.

8.2 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

The progress to date on our part of the integrated study can be divided into the following broad categories:

1. Detailed specification of plans for the digital processing facility which is at the heart of our current and future activities.

2. Assembly and construction of the digital image processing facility.

3. The conduct of preliminary work on means and programs for data acquisition and handling and developing of a system for use in programming various digital image processing tasks.

4. The conduct of preliminary work on digital signal processing algorithms of broad relevance to feature enhancement of remote sensing data.

8.2.1 Digital Processing Facility

The major share of our time since our last progress report has been devoted to the development of a digital processing facility. Progress has been very substantial and, in some aspects, in advance of our anticipated schedule.

For our work we make use of an IBM 1800 Computer which has been modified by the addition of an array processor designed and built for the specific task of digital signal processing. The array processor speeds up by a factor of 20 a number of operations of interest in signal processing. Thus, this small digital computer has a substantial computing power for the type of processing of prime interest to the integrated project. Further the IBM 1800 will be connected by a high rate data link to the CDC 6400 of the Computer Center at Berkeley. Thus we have a highly desirable situation in which data acquisition, simple data processing, and image display can be done in a dedicated facility available for real time and interactive work, while a large computing facility and a large software system can be used on a time-sharing basis for large computations and elaborate processing.

A diagram of the overall system configuration is shown in Figure 8.2. In the following section we report on our progress in the design and

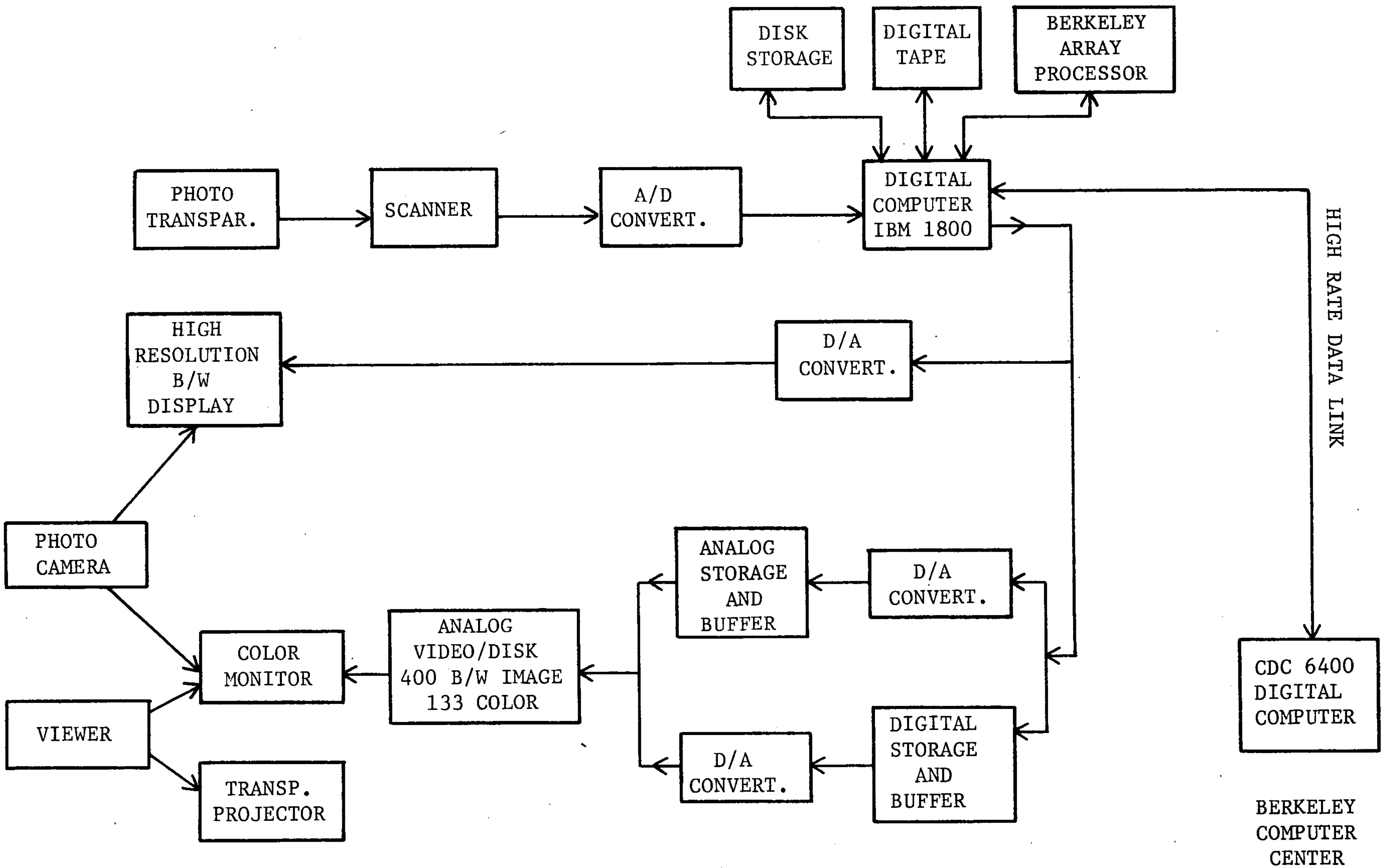

Figure 8.2. Digital Image Processing Facility

construction of several of the computer peripherals required for our work.

Image Storage and Display System

After careful examination of the alternative ways of displaying multispectral images processed digitally at a suitably high rate (30 frames per second), we decided to use as a storage and output device an analog video disk. This video disk stores black-and-white images or color images and can output any of them repeatedly at the standard television rate. Thus a substantial file of images processed by different techniques can be stored and displayed in rapid succession on a cathode ray tube monitor for comparison by an observer. This valuable feature should reduce in many cases the need for extremely rapid processing.

A. Video Disk

The video disk selected for our facility is an analog storage device manufactured by Data Disk Incorporated. The video disk is capable of holding 300 frames of 525 line double interlaced, 30 frame/sec video data. Each frame occupies one track of a 14"-1800 rpm nickel-chrome disk. The mode of operation of the video disk, for color display is shown in Figure 8.3 and described below.

1. Based on electrical signals, the computer writes the three color components of an image (Red, Blue, Green) one after the other on three tracks of the video disk.

2. Once the three color components have been stored in the disk they are read simultaneously and in perfect synchronization.

3. The three color components drive the three electron guns or the control grids of a television color monitor. Thus a full color image is generated 30 times per second for flicker-free viewing. The video disk provides synchronization signals, coming from a clock track, to the Digital-Analog buffers and to the B/W and color monitors.

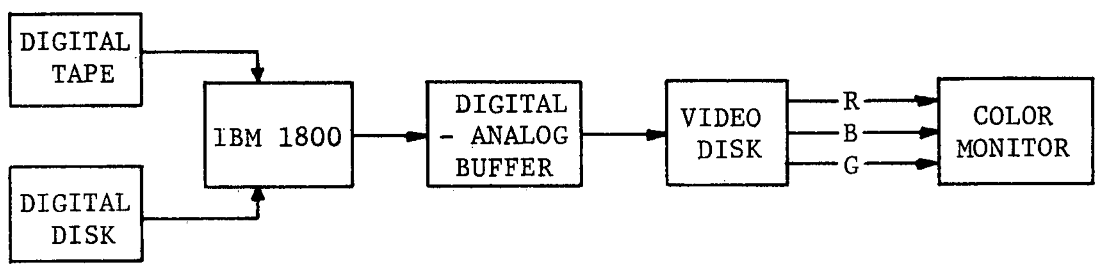

Figure 8.3 Mode of operation of the video disk for color display

The need for the Digital-Analog buffer shown in Figures 8.2 and 8.3 arises because of the gross mismatch between the output capability of a digital computer and the signal bandwidth requirements of the analog video disk.

For the video disk the signal bandwidth, assuming an 8-bit gray scale, is approximately 60×10^6 bits per second which is faster than the I/O channel bandwidth of most digital computers; in particular, it is faster than the data channel of the IBM 1800 computer. It is therefore necessary to provide some form of rate conversion when outputting from the digital computer to the video disk. We have chosen two different methods of scan conversion. The analog method is based on the Hughes Model 639 Scan Converter described below. A digital method of buffering is also being built and should provide images of substantially higher quality. The digital approach is also described below.

B. Analog Buffer

The analog buffer is a Hughes Model 639 Scan Conversion Memory. The heart of this device is a storage tube with a resolution of 1200 lines which will store for several minutes an image with gray scale, written at an arbitrary slow rate. In operation, the IBM 1800 computer will build up an image on the storage surface, point by point, by providing to the scan converter the x,y coordinates and the intensity value to be stored. Our program currently requires 60 seconds to build up an image. Once the image is stored it can be read out continuously 30 times per second and thus stored immediately on the video disk which provides synchronization signals. The stored image is only of fair quality and in particular the gray scale is not very wide. After experiencing considerable difficulties, due in part to the fact that this product is new on the market, and after making some modifications of our own design, we now have this unit operating satisfactorily so that it is able to provide images of adequate quality for viewing.

C. Digital Buffer

Video Interface Buffer (VIBE). A simplified block diagram of the digital buffer (VIBE) is shown in Figure 8.4. We describe the operation at the functional level only, reserving detailed description to a user's manual.

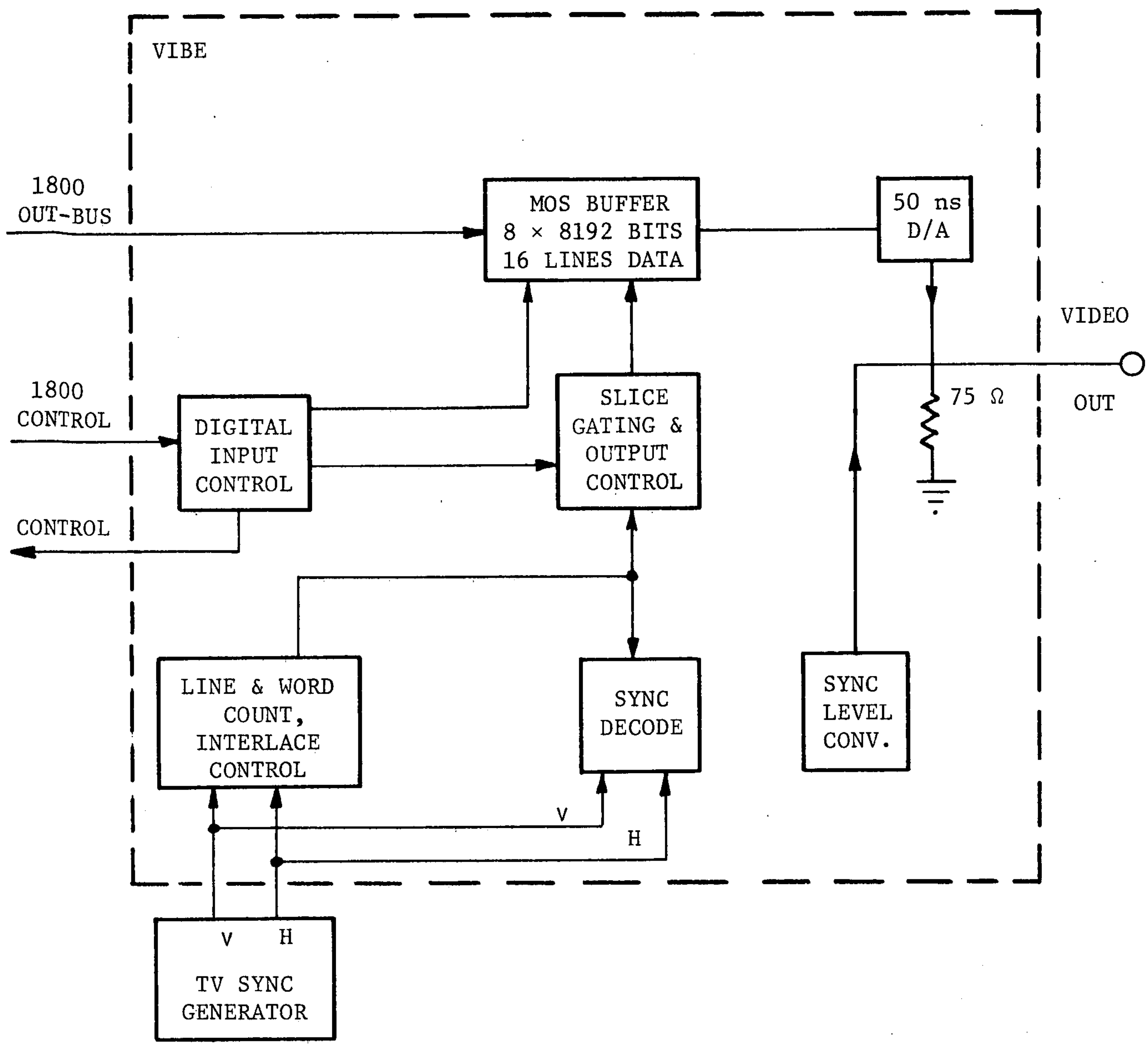

Figure 8.4 Simplified block diagram of VIBE

16 line (8 × 8192 bits) MOS shift register buffer

The heart of the digital buffer is the 8K byte MOS shift register memory (Intel 1403 at 1 cent per bit) capable of a two phase shift rate of 5 mhz. We multiplexed the shift registers using a 4 phase 10 mhz clock to obtain a data rate of 100 ns per byte. Of the 6.35 μs in a horizontal line, 51.2 μs is used to display 512 sample points at 100 ns per point and 12.3 μs is used for a horizontal synchronization pulse and blanking. The 8K buffer is partitioned into 2 banks called Bank A and Bank B. Alternate lines of data from the computer are routed to Bank A or Bank B so that Bank A contains up to 8 lines of data for one field of the interlaced frame while Bank B contains 8 lines of data for the alternate field. Consequently interlacing is performed by hardware and is transparent to the user. Data are obtained from the 1800 in 16 line slices at the rate of 1 byte/μs. The placement of the slice as well as the size of the slice is under program control. Thus a flexible method of analog signal synthesis is obtained using digital techniques capable of achieving significant gray scale resolution (8 bits and up) at TV rates.

D/A converter and slice gating output control

The digital slice stored in the 16 line buffer is read out under slice gating output control when the disk location corresponds to the desired slice location. Two output sequences are placed on the disk per revolution corresponding to the two interlaced fields. D/A conversion occurs at 100 ns rates using a 50 ns D/A converter.

Digital input control

Digital input and analog output from the MOS buffer occur at mutually exclusive times. The input is under the control of the digital input control logic. The IBM 1800 computer initiates the transfer of digital data to the VIBE. Subsequent control of data access is handled by digital input control on a cycle steal basis at a rate of 2 bytes/2 μs. The MOS buffer is shifted at a 2 μs rate to provide "essentially synchronous" transfer although the interface is designed for non-synchronous operation. Although channel priority assignments are made so that a cycle steal request should be honored within 2.5 ms, provisions are made to signal an overrun if a request is not acknowledged within 2.5 ms. The 2.5 ms service rate is a condition imposed by the dynamic MOS shift registers for data refresh. The digital control is complicated somewhat by this requirement, which is the price we paid for an "inexpensive" memory.

Line and word counter, interlace control

Referenced to the once-per-revolution clock on the disk, we partitioned the disk into 525 sections corresponding to the 525 horizontal lines. The partition is made in such a way so that EIA TV signal constraints are observed. The counting and interlace control logic is provided so that we may accurately synthesize a 512 line picture using 16 line slices. The entire picture construction process is expected to take 6 to 10 seconds.

TV sync generator and sync decode

A sync generator under crystal control is used to furnish vertical and horizontal sync pulses for overall system synchronization. The sync pulses are also furnished to the VIBE for proper data output synchronization. The sync decode logic generates an EIA sync and blanking signal which is added to the D/A output to form the ultimate video. Care is taken to avoid signal contamination from the sync pulses by logically disconnecting the sync signal from the video except during the blanking interval.

The construction phase of the VIBE is approximately completed.

Electromechanical Scanner

Some images that we will process will be already scanned and available on magnetic tape. However, in many cases it will be desirable to work with images that other workers have been experimenting with and which are available only as photographic slides. For this reason, it is essential that our digital processing facility be capable of scanning such images and reading the scanned image into the computer for storage on disk or magnetic tape. Consequently, we have constructed an electromechanical scanner. This scanner has a pair of horizontal rails and a ball-nut lead screw; on these rails are mounted a pair of vertical rails and a ball-nut lead screw, with a small rigid aluminum platform running on the vertical rails. The lead screws are turned by digital stepping motors which can position the platform in steps of 1/500", to an accuracy of a fraction of a step. The scanning mode of the platform is as follows:

accelerate downward up to terminal speed

run N steps downward at terminal speed

decelerate vertically to rest step M steps horizontally

accelerate vertically upward to terminal speed

run vertically upward at terminal speed

decelerate vertically to rest

step M steps horizontally etc.

By carefully choosing the acceleration and terminal speed, it is possible to scan 1500 steps per vertical line at a rate of slightly more than one vertical line per second.

Attached to the moving platform is a lens barrel, PIN photodiode, and battery operated FET preamplifier. The photodiode chip is 1/50" square. Thus with a lens barrel giving magnification of α, the scanning resolution is $(1/50\alpha)$ inches.

A program has been written that enables the IBM 1800 computer to:

1. move the scanner according to the above scan mode

2. take the output of the preamplifier, sample, and quantize to a digital number and

3. store the digital samples in a core until several lines have been collected, then read onto a disk, reordering the lines that are scanned upward.

The hardware and program were completed in August, 1971. With only minor electronic errors, which have been corrected, the scanner functions exactly as had been hoped for. With only modest lighting, the electronic noise is negligible. To date the scanner has only been tested with 1 to 1 optics, giving a resolution of 1/50". However, lens barrels with 5 to 1 and 10 to 1 optics have been completed in the past week and should be tested soon. When this is done, we will scan a fine line grating to see if we can obtain the hoped for resolution (1000 element scan lines on a 2" high negative).

Display Monitors

We have acquired a good quality 14" Conrac black-and-white monitor. Although our intention is to make use of a high quality color monitor we are making use for the present of an inexpensive 12" Sony Trinitron Television Receiver. We have modified the set to have access directly to the video color signals. This simple approach provides us with an inexpensive color monitor for check-out of programs and algorithms.

High Speed Data Link, IBM 1800 - CDC 6400 (H.SIC)

The design philosophy behind the high-speed communication link is an attempt to combine the high speed multi-precision computational power and large core memory of the CDC 6400 with the graphic output facilities of the IBM 1800.

The CDC 6400 'A' machine is primarily a batch oriented computer system. This system's main resource is its ability to perform rapid multi-precision computations on large amounts of data that are stored entirely in its fast memory. The CDC 6400 system, however, lacks the provision for user-program interaction on a real time basis and lacks sufficient real time picture display equipment.

On the other hand, the IBM 1800 system is ideally suited for interactive real time picture displaying, but lacks the computational power of the CDC 6400.

A combination of the IBM 1800 process controller with the CDC 6400 computer system will create a more versatile computer system.

The communication link is to be the primary data transmission path between the IBM 1800 and the CDC 6400. In normal operation, a picture file will be sent from the IBM 1800 to the CDC 6400 where it will be processed and then sent back to the IBM 1800. Here the file might undergo auxiliary IBM 1800 processing and then be placed on the display screen for a closer visual examination. At this point the person who is directing the processing might choose to try the same set of CDC 6400 processing programs with a different set of data or try another set of CDC 6400 processing programs with the same data. In both cases, the data transfer procedure will start again and the processing sequence will be repeated. Using this type of interaction, rapid turn around can be achieved and the user's train of thought is not broken. Real time decisions such as this might take as little time as a few minutes or as long as an hour. In any event, it is necessary to make the data transmission rate as fast as possible to minimize the computer time needed to transmit the large picture file (for instance a 512 × 512 word) and also to minimize the time that input and output buffer space needs to be available in the IBM 1800 and CDC 6400.

The data buffers in the CDC 6400 may be as large as 100,000 (OCTAL) 60 bit words. If four IBM 1800 words are packed to one CDC 6400 word, this space is more than enough to store a complete 512 × 512 picture file.

In the IBM 1800, the memory is only 20,000 (OCTAL) words of which about 6000 (OCTAL) words are taken up by the TSX Executive. This leaves 12,000 (OCTAL) words for both the user program space and buffer area. Therefore, the absolute maximum data buffer space available in the IBM 1800 is less than 10,000 (DECIMAL) words.

Data are originally stored in a slow speed bulk storage device and must be made readily accessible before they can be transmitted between processors. The number of data words that can be manipulated in an IBM 1800 record is at most 10,000 (160,000 bits). This amount of data can be stored or fetched in an average of 320 milliseconds. Assume that we want an order of magnitude difference between bulk data retrieval time and data transmission time. It is necessary to transmit 160,000 bits in 32 milliseconds: a transfer rate of 5000 bits/millisecond. Data transfers which are made to and from the CDC 6400 are done in multiples of 12 bits because the CDC 6400 peripheral processors are 12-bit machines. Therefore, the transfer rate must be on the order of 5000/12 = 417 words/millisecond or 0.42×10^6, 12-bit, words/second. An upper bound is placed on the transmission speed due to the limitations on the speed at which the CDC 6400 peripheral processor can shuffle data (a maximum rate of one 12-bit word every microsecond). Cable delays of 1.5 nanoseconds per foot further reduce the maximum transmission speed. In this case, the transmission cable is 1,000 feet long and introduces a 1.5 microsecond delay per direction. For reliability and simplicity of construction a data transmission method was chosen which requires a confirmation signal from the receiving end. Therefore a cable delay of $2 \times 1.5 = 3$ microseconds is introduced into the communication link. A rather conservative transmission speed of one 12-bit word every 3 microseconds (a transmission rate of

333,000, 12-bit words per second) seems to be a practical upper bound for the data transmission rate of the communication link. This speed would allow a record to be transmitted in under 40 milliseconds. A complete picture file consisting of 512 × 512, 16-bit words is composed of twenty-five 10,000 word records. The total data transfer time would be $25 \times 40 \times 10^{-3} = 1.0$ seconds. The total data seek and fetch time would be $25 \times 320 \times 10^{-3} = 8.0$ seconds. Based on these calculations a complete file could be moved from one computer system to another in less than 10 seconds.

System specifications must include the form in which the data are to be transferred between processors. The IBM 1800 has 16-bit words; the CDC 6400 has 60-bit words. This difference in word size introduces a number of problems. First, in the IBM 1800, fixed point numbers are represented with 16, 32, or 48 bits of precision; in the CDC 6400, fixed point numbers are always 60-bits long. Second, in the IBM 1800, floating point numbers are represented with 32 or 48 bits of precision and the exponent follows or precedes the mantissa; in the CDC 6400, floating point numbers are 60 bits long with a preceding exponent.

A useful interface must have the provision for easily converting from one computer system's number representation to the other's. To minimize the IBM 1800 and the CDC 6400 computer time associated with reformating the transmitted data, a design choice was made to supply the interface controller with enough computational power to perform data conversion. This choice proved to be beneficial because it greatly increased the flexibility and growth potential of the commucation link. To achieve the potential speed and advantages of such a communication link, a sophisticated electronic device, under control of the IBM 1800, is being designed and built. The major part of the construction, which is at the IBM 1800 end of the link, has been completed and will be checked out in the near future. Some software development and possibly some minor hardware procurement will be needed at the CDC 6400 end of the link and will be undertaken during the summer and fall 1972.

8.2.2 Developing of a Picture Processing Programming System

Due to the large number of specific operations of interest in our work it is necessary to provide a framework for the organization of user oriented image processing programs. To this end an image processing system is being developed.

That system consists of four components:

1. Monitor
2. Processing subroutines
3. User program
4. Disc update program

The components have the following functions:

The processing subroutines perform the actual picture processing, including such tasks as filtering and display. The user program consists of a sequence of statements used to cause the execution of a sequence of processing subroutines. The monitor interprets the user program, stores the information contained in the user program, allocates appropriate storage space for data files, and initiates execution of processing subroutines. The disc update program adds to the monitor portion of the discs all required information about a processing subroutine newly added to the system.

It is intended that the picture processing system will be a useful tool for studying a broad range of specific topics. Since it is always difficult to foresee in which direction the research will proceed as new methods are devised and tested, it is of paramount importance that the system be sufficiently flexible to change and grow as needed. In order to make the processing system as useful and flexible as possible, a number of desirable properties had to be weighed and put in their proper place. The major considerations are listed here together with the reasons for their importance.

1. The system will be useful as a tool both for implementing working methods and algorithms and for interactively studying new approaches. Once a reasonable algorithm is obtained, it will be necessary to test it in detail. The non-interactive mode will be convenient for this testing. Until a reasonable algorithm is obtained, however, it will be very helpful to be able to study new ideas interactively.

2. System users will be required to have minimal familiarity with computers. Requiring less specific computer knowledge for use of the system will increase the number of potential contributors to the task of developing useful processing algorithms. Particularly the system's intended use as an interactive tool would be severely hampered by placing a programmer between the system and the user.

3. A wide variety of processing options will be available to the system user. These options will include for example, various displays, filters, and transforms. Such options will provide the user with a great deal of freedom to assemble algorithms and test his theories.

4. It will be possible to add new processing options by following a set of simple and straightforward steps. This will facilitate increasing the system processing option repertoire while minimizing time wasted by the writer of an option in learning the system's inner workings.

5. There will be a file management system that assigns and keeps track of the storage of data files. Because pictures of interest will often have many sample points (a quarter million is not unusual), massive amounts of data will be stored in such files on disks and tapes. The file management system will perform two functions: convenient manipulation of data files by the system, and easy access by the user to the files.

6. The user will not be able to alter the system monitor accidentally. The reason for this consideration is obvious.

7. It will be necessary to limit the time required for performance of the system. This is important because a user may be interested in an algorithm which consists of a large number of rapidly performed processing options. Then monitor functions could require a significant percentage of the overall processing time and thus severely restrict the system's usefulness as an interactive tool.

8. The programming language with which the system user will implement his algorithms will be sufficiently flexible to grow and

change as new needs develop. This flexibility will limit time wasted in rewriting the programming language to meet unforseen needs.

9. The system software itself will be written in such a way as to minimize the time required for making changes in the software when the original programmer has left the project. This is essential for our own use of the equipment since turnover among students is necessarily high while at the same time new developments may require changes in the system.

10. The system will have to be sufficiently simple that it can be implemented within a period of a few months. Research is already taking place in a number of areas, and it is desirable that the system be a useful tool for these ongoing investigations.

The need for such a system is already quite apparent from the difficulty we now encounter in using the large number of small programs which are already written. The constants on the individual programs which will allow their incorporation into a system are currently being specified. After this initial step all new programs will normally be incorporated into the system and a revision of non-compatible programs will also be carried out.

8.2.3 Programs for Data Acquisition and Handling and for Image Enhancement and Display

A number of programs of general interest in the acquisition, reformating, analysis, enhancement, and display of images have been written. Since they form at this time an heterogeneous collection we shall not report on them in detail but describe them in the context of reports on specific applications. We shall point out at this time the broad areas into which these programs can be grouped.

Data Acquisition and Reformating

Images and data available to us in digital form require some processing to facilitate their use in our digital processing facility. Some specific problems are (a) images recorded in seven track tape, (b) number of points per line and number of lines not convenient for our mass storage devices, and (c) gray scale not suitable for analysis or display. Flexible programs are required to handle some of these problems, including the problem of different file sizes and the reformating of large files for ease of access.

General Utility Subroutines

These programs are necessary building blocks in the design of user-oriented programs. A listing of some of the programs now available will illustrate the type of operations these programs perform. In use, after the description has been given a set of parameters specifies completely the operation.

MOVE: Transfer picture files from one storage location to another for further processing or for permanent storage.

NLIN: Set up a table to map gray scale values into a distorted scale. Such a table is needed for instance, for slicing the range of gray values.

FFT: Produce a one-dimensional or two-dimensional Fourier Transform. Useful in texture analysis, edge enhancement, etc.

DISP: Display a picture file by outputting x,y coordinates and intensity values of all points in the image. The output display device may be a storage cathode ray tube (CRT), a precision CRT, the scan converter for video disk storage, etc. A number of options are available in this program according to the specific needs.

Specific Enhancement or Application Programs

Several such programs, which make use in part of the subroutines described in the "General Utility Subroutines" section are of ultimate interest. We shall describe only two of these programs.

A. Constant Intensity, Color Presentation of Gray Scale Values

This program converts gray scale values into colors for ease of interpretation. The mapping is easily described by referring to the diagram of Figure 8.5.

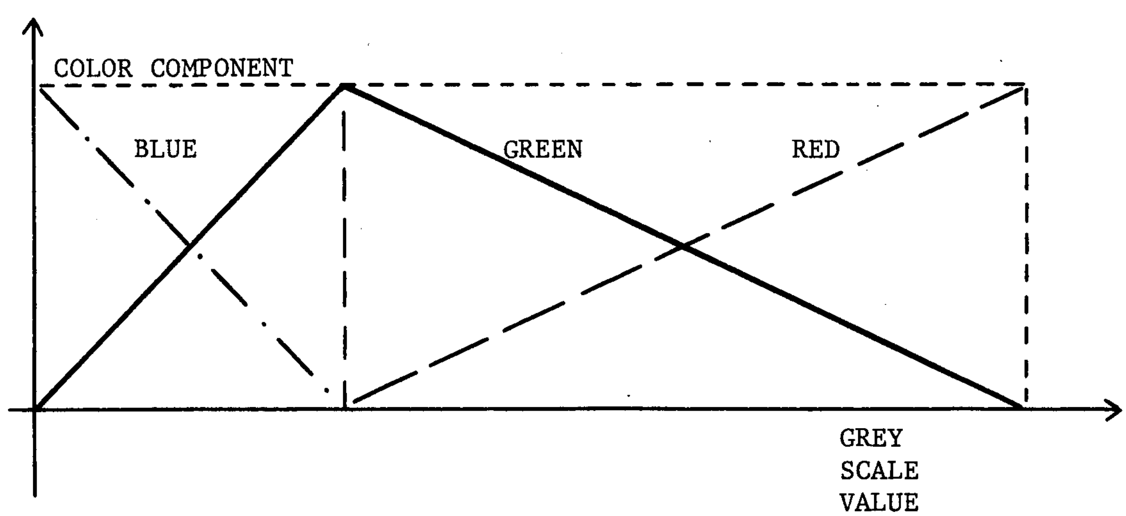

Figure 8.5 Diagrammatic representation of relation between gray scale values and corresponding colors.

Each gray scale value generates two color components, either blue and green or red and green. Thus for a complete black-and-white image three images are generated. The three images are stored one after another on three tracks of the video disk and displayed in color. Thus, intensity values will map into colors which range from blue for intensitites to red for high intensitites, going through all intermediate values. This is a common approach to color mapping of gray scale values which can be used for any type of feature enhancement. Arbitrary color coding of adjacent gray scale values can be obtained by predistortion or slicing of the gray scale before the color map.

B. Color Vividness Enhancement

We are now writing a program to enhance the vividness of colors. It is well known that in "high flight" photography the colors of objects on earth become desaturated and thus less vivid to a viewer than on low altitude photographs. An operation which is simple to carry out on a digital computer is to manipulate several components at once in such a way that eachof the colors of a color composite image becomes more saturated.

The programs just described are principally mentioned for illustrative purposes.

We have also undertaken a systematic approach to image enhancement in an interactive mode which makes use of most of the data available to a viewer. We describe one of the programs already written for this purpose and indicate the theoretical background for our approach to the analysis and enhancement of remote sensing data. Let us consider the problem of delineating the boundary between two vegetation types or two other features of interest. Let F_o and F_1 denote these two features. We have available N spectral components which may contain information relevant to the discrimination task. As we mentioned in the introduction two pertinent questions are: 1. Which spectral components do contain the relevant information? 2. How is this pertinent information to be used?

Let Z_k be the intensity of the spectral component S_k. For the feature F_o the intensity Z_k takes a range of possible values according to the conditional probability density function $P[Z_k/F_o]$. Similarly the distribution of Z_k for feature F_1 is characterized by $P[Z_k/F_1]$. According to statistical decision theory*, the optimum assignment** of an intensity value Z_k to one of the two features is done by a likelihood ratio decision rule:

$$\Lambda(Z_k) = \frac{P[Z_k/F_1]}{P[Z_k/F_o]}, \text{ compare to } \eta.$$

$\Lambda(Z_k)$, the likelihood ratio is compared to a threshold η. If the threshold is exceeded then the specific intensity value is assigned to F_1. If the threshold is not exceeded the intensity value is assigned to F_o. The threshold η depends on the optimality criterion used and on the *a priori* knowledge of the spectral characteristics of each of the two features.

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*C. Helstrom. "Statistical Theory of Signal Detection", Pergamon Press, 1960.

** Optimality is meant for any of several criteria, see Helstrom.

Figure 8.6 shows the probability densities of spectral intensity Z_k conditioned on features F_1 and F_o and also the logarithm of the likelihood ratio and the threshold log η. In the ranges of intensities Z_{k1} to Z_{k2} and Z_{k3} to Z_{k4} the likelihood ratio exceeds the threshold and these ranges of intensities are indicators of feature F_1. All other ranges of intensity should be assigned to F_o. If a threshold value η cannot be reasonably chosen, the likelihood ratio still indicates the relative merit of the value of a spectral intensity in a discrimination and enhancement task. Low values of the likelihood ratio for a specific spectral component indicate that the spectral component is irrelevant to the task at hand. Thus a considerable amount of information is conveyed by the likelihood ratio about the usefulness of a specific spectral component in the enhancement of specific features. A spectral analysis program has been written which computes empirically the three graphs of Figure 8.6 for each of three spectral components and for two small areas identified as belonging to features F_o and F_1 respectively. These computations are performed in approximately 15 minutes and are displayed for visual inspection on a storage cathode ray tube. An enhancement program which uses this information has also been run.

Other analysis programs have also been written which treat several spectral components jointly or analyze the texture of features instead of their spectral characteristics. The integration of these analysis programs into an interactive digital image enhancement program is also being studied and will be reported upon at a later date. This effort is just started and will be carried out in the coming several months.

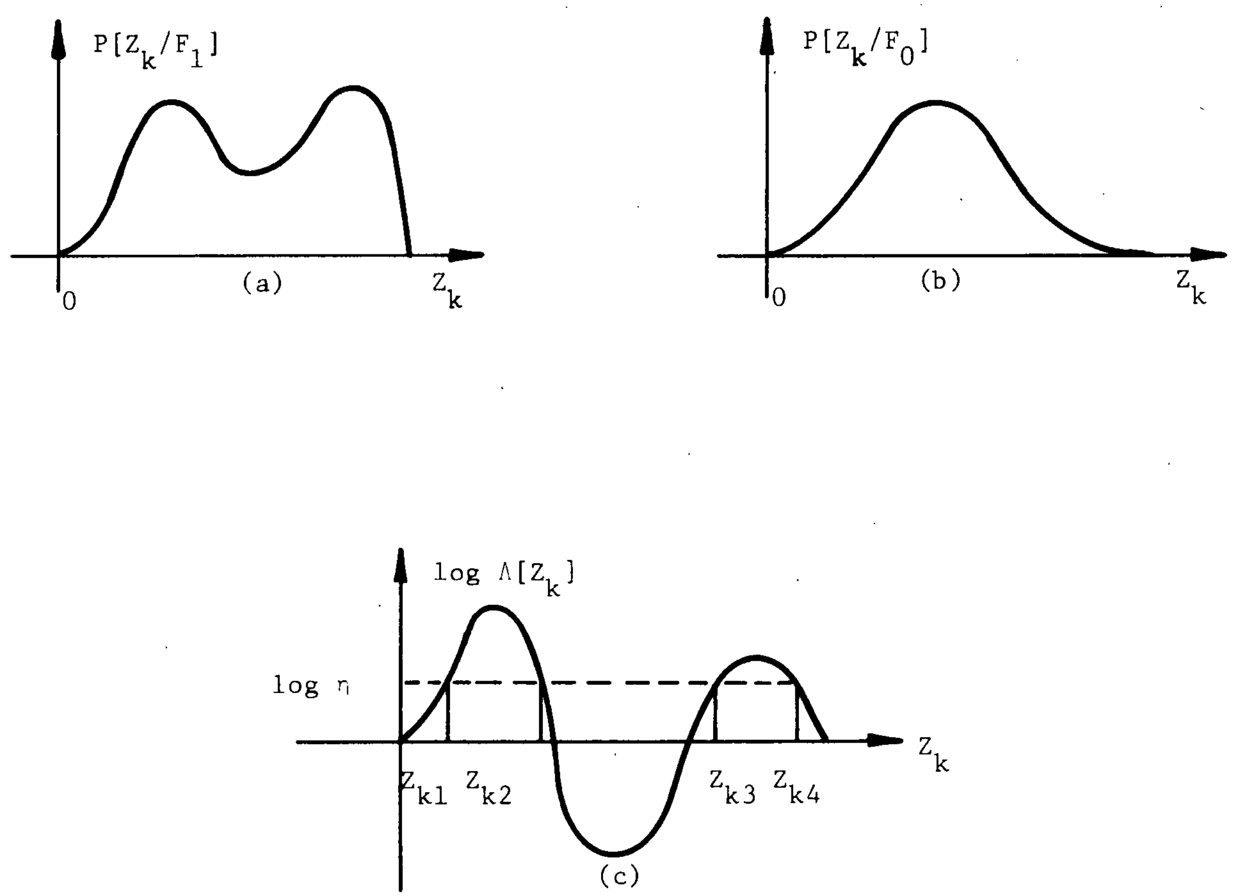

Figure 8.6 Diagrammatic representation of probability densities of spectral intensity Z_k conditioned on features F_1 and F_0, as discussed in the text

In October 1971, V. R. Algazi visited the Laboratory for Applications of Remote Sensing (LARS) at Purdue University and became acquainted with the activities and plans of the Laboratory in the areas of data handling and automatic feature classification. Care is being exercised to ensure that work described in this chapter is not duplicative of that being done at Purdue, Michigan and other univeristies funded under the NASA Earth Resources Survey Program, including that of our colleagues at the Forestry Remote Sensing Laboratory on the Berkeley Campus of the University of California.

Work relevant to our effort has been carried out by a Ph. D. student, Michael Ekstrom of the Lawrence Livermore Laboratory. His work is not supported by the grant. His work, on the numerical restoration of random images, is applicable to some aspects of our projects.

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Chapter 9

INVESTIGATION OF ATMOSPHERIC EFFECTS IN IMAGE TRANSFER

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9.1 INTRODUCTION

An understanding of the effect of the atmosphere on remote sensing images is fundamental to image interpretation and enhancement. Figure 9.1 shows schematically a typical remote sensing experiment. Not only is a remote image degraded in traveling from the ground through the atmosphere to the detector, but the image is also contaminated with radiation scattered into the detector by the atmosphere from other sources than the image of interest. Furthermore, the atmosphere may affect the quality of the image by changing the radiation pattern of the illumination. An understanding of the atmospheric effects in image transfer therefore not only requires an understanding of how radiation is transferred through the atmosphere but also how typical natural surfaces reflect radiation as a function of incident and reflected angles of the radiation.

A flow chart for the investigation of atmospheric effects in image transfer is shown in Figure 9.2. Indoor laboratory measurements of the reflection patterns of typical natural surfaces are being made with the dual-channel polarizing radiometer described in previous progress reports. The polarizing radiometer is capable of measuring intensity and the amplitude and direction of the linearly polarized component of radiation

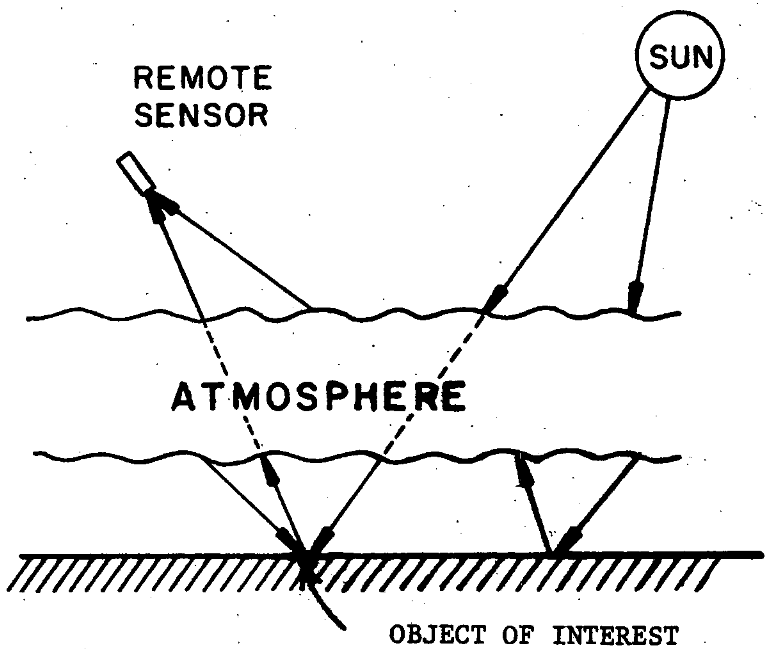

Figure 9.1 Schematic diagram of a remote sensing experiment

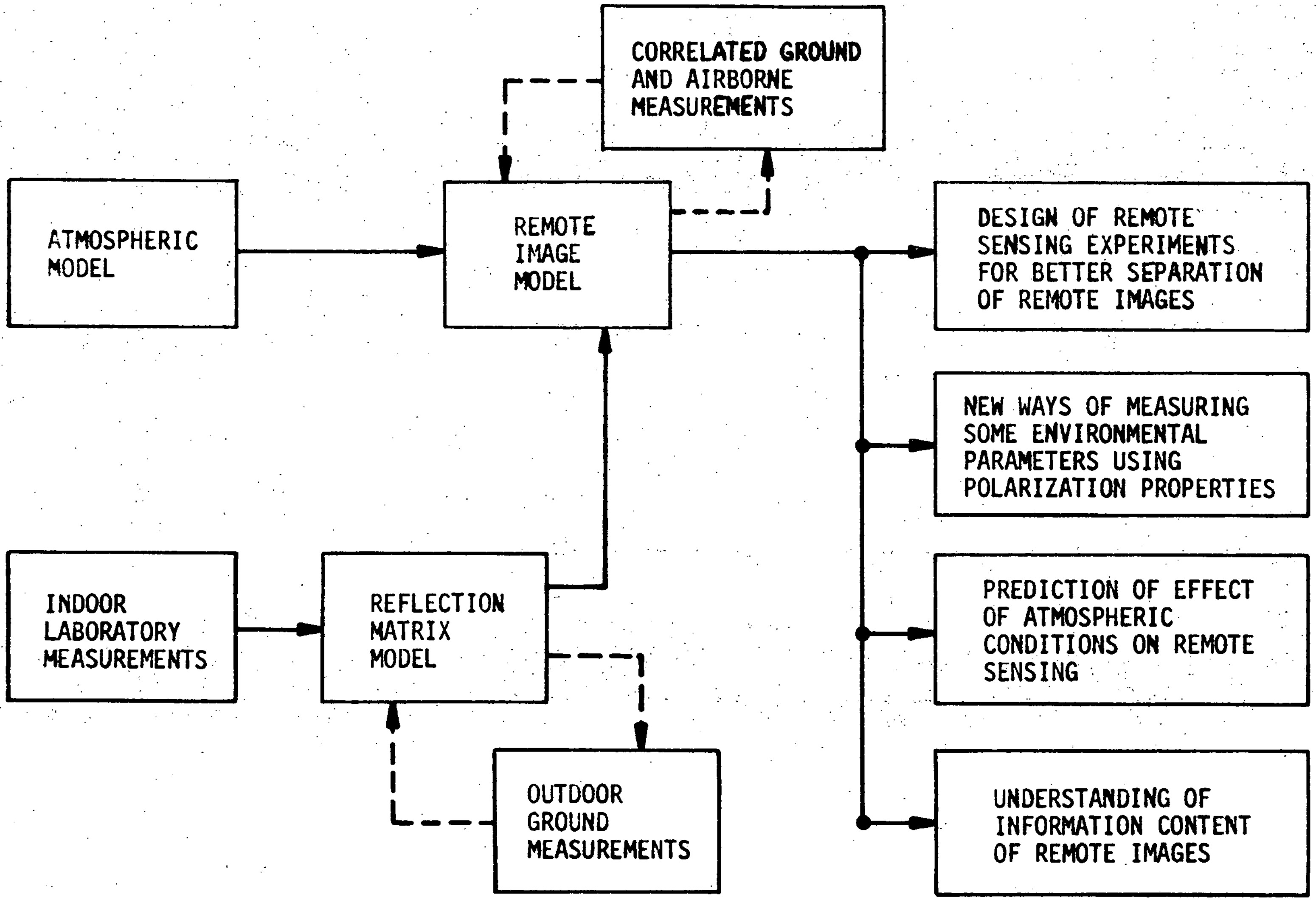

Figure 9.2 Flow chart for investigation of atmospheric effects in image transfer

in eight different narrow wavelength intervals from 3200 Å to 9000 Å. In addition, the instrument can measure the circularly polarized component of the radiation at 4000 and 7000 Å. The operation of the instrument is controlled completely by a PDP-11 computer, and the use of software operating at several levels of priority allows signals from the instrument to be reduced to the relevant physical quantities on a real-time basis. As far as is known, this is the most advanced design of any polarizing radiometer in existence. Data taken with the instrument will be used to construct a general model for describing the reflection or radiation from natural surfaces. Outdoor ground measurements of the reflection or radiation from the same natural surfaces combined with measurements of the incident radiation pattern will be used to test the validity of the reflection model. Concurrently, work is progressing on an atmospheric model which is practical for realistic simulations of clear, hazy, and cloudy planetary atmospheres. When both the atmospheric model and the reflection model are operational, they will be combined into a "remote image" model which hopefully will be capable of predicting the remote image seen by a particular sensor (which could use polarizing optics) given the spatial orientation of the sensor, the atmospheric conditions, the time of day, and the type of surface being viewed. In order to test the validity of the remote image model it will be necessary to make correlated ground and airborne measurements. The Convair 990 at NASA Ames will be used for this purpose. If such a remote image model can be constructed it will be an invaluable aid to the solution of remote sensing problems. Some of the ways in which such a model can contribute to remote sensing are indicated in Figure 9.2.

The remainder of this chapter will be concerned with discussing the technique to be used to model the reflection data and presenting the results of some preliminary measurements. Certain features of these preliminary data may have an important effect on remote imagery.

9.2 REFLECTION MATRIX MODEL

9.2.1 Basic Considerations

A beam of quasi-monochromatic light moving in the z-direction may be completely described by its electric vector in the xy plane

$$E_x = A_x e^{-i\omega_o t}$$

$$E_y = A_y e^{-i\omega_o t}$$

where A_x and A_y are complex quantities

$$A_x = a_x e^{i\theta_x} \qquad A_y = a_y e^{i\theta_y}$$

and the real quantities a_x, a_y, θ_x, θ_y may have some spatial and temporal dependence. Physically, not all information contained in the electric vector can be measured, since all real electromagnetic sensors have a sample time which is very long compared to one cycle of oscillation of the electric vector. In practice, all the physically measurable information about the light beam can be expressed in terms of a complete set of physical observables such as the Strokes parameters. In terms of the above definitions, the Stokes parameters are given by

$$S_0 = \langle a_x^2 \rangle + \langle a_y^2 \rangle$$

$$S_1 = \langle a^2 \rangle - \langle a^2 \rangle$$

$$S_2 = \langle 2a_x a_y \ \mathrm{Cos}\ (\theta_x - \theta_y) \rangle$$

$$S_3 = \langle 2a_x a_y \ \mathrm{Sin}\ (\theta_x - \theta_y) \rangle$$

where <...> represents a time average over many cycles. Thus, the radiation field at a point P and in a direction defined by a zenith angle θ and an azimuth angle ϕ is completely described by the Stokes vector

$$\underset{\sim}{S} = \underset{\sim}{S}\ (P,\theta,\phi) = \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix}$$

The reflection of light by an object may be interpreted as a transformation of incoming radiation described by a Stokes vector S (P,θ_i,ϕ_i) into outgoing radiation described by a new Stokes vector $\underset{\sim}{S}'\ (P,\theta_o,\phi_o)$. That is, the reflection from the object is characterized by a reflection matrix $\underset{\approx}{R}\ (\theta_o,\phi_o;\theta_i,\phi_i)$ such that

$$\underset{\sim}{S}'\ (P,\theta_o,\phi_o) = \iint d\phi_i\ d\ \mathrm{Cos}\ \theta_i\ \underset{\approx}{R}\ (\theta_o,\phi_o;\theta_i,\phi_i) \cdot \underset{\sim}{S}\ (P,\theta_i,\phi_i).$$

A suitable model for the reflection matrix is one which parameterizes its dependence on the incoming and outgoing angles. One such parameterization would be to expand the elements of the reflection matrix in terms of spherical harmonics

$$R_{ij}\ (\theta_o,\phi_o;\theta_i,\phi_i) = \sum_{\substack{\ell\ell' \\ mm'}} a(i,j;\ell,m,\ell',m')\ Y_{\ell m}\ (\theta_i,\phi_i)\ Y_{\ell' m'}\ (\theta_o,\phi_o).$$

This expansion is valid because the spherical harmonics $Y_{\ell m}$ are a complete orthonormal set of angular functions. Unfortunately, such a parameterization would require a very large number of coefficients $a(i,j;\ell,m,\ell',m')$ to adequately describe the reflection matrix for typical natural surfaces.

A simpler parameterization requiring fewer coefficients is apparent if we consider how the electric vector characterizing the radiation is transformed by a reflection. It was stated above that a beam of quasi-monochromatic light moving in the z-direction may be completely described by the components of the electric vector in a plane perpendicular to the z-direction:

$$E_x = A_x e^{-i\omega_o t}$$
$$E_y = A_y e^{-i\omega_o t}$$

After reflecting from a body the light will be moving in some new direction, and can be described by the components in a plane perpendicular to that new direction. Let ξ and η describe perpendicular coordinates in this new plane. The components of the electric vector are then

$$E_\xi = B_\xi e^{-i\omega_o t}$$
$$E_\eta = B_\eta e^{-i\omega_o t}$$

If it is assumed that the B's are linearly related to the A's, then the transfer matrix T is defined by

$$B_\xi = T_{\xi x} A_x + T_{\xi y} A_y$$
$$B_\eta = T_{\eta x} A_x + T_{\eta y} A_y$$

where the elements of the transfer matrix are complex quantities. It can be shown from this definition of the transfer matrix and the definition of Stokes parameters that the elements of the reflection matrix are related to elements of the transfer matrix as shown in Table 9.1. The angular dependence of the reflection matrix is now parameterized by expanding the elements of the transfer matrix in terms of spherical harmonics:

$$T_{ij}\ (\theta_o,\phi_o;\theta_i,\phi_i) = \sum_{\substack{\ell\ell \\ mm'}} t\ (i,j;\ell,m,\ell',m')\ Y_{\ell m}\ (\theta_i,\phi_i)\ Y_{\ell' m'}\ (\theta_o,\phi_o)$$

where $i = \xi$ or η and $j = x$ or y. The coefficients $t\ (i,j;\ell,m,\ell',m')$ are the parameters used to describe the reflection matrix.

Characterization of the reflection properties of a particular material is equivalent to specifying the values of a sufficient number of t-coefficients for that material to describe the dependence of its reflection matrix on the incoming and outgoing angles of the radiation. In order to determine the t-coefficients it is necessary to make laboratory measurements of the material of interest in a situation where the incident light is carefully controlled. This rules out outdoor daytime measurements for the determination of the t-coefficients. However, the t-coefficients for a natural surface in its native environment could be measured at night using a carefully controlled artificial light source. On the other hand, it is essential that daytime outdoor measurements of natural surfaces be made for verification of the model and the t-coefficients for those surfaces. Such measurements would require the complete angular distribution of incident radiation from the sky to be measured, since

TABLE 9.1. THE SIXTEEN REAL ELEMENTS OF THE REFLECTION MATRIX IN TERMS OF THE FOUR COMPLEX ELEMENTS OF THE TRANSFER MATRIX

$$R_{00} = \left(|T_{\xi x}|^2 + |T_{\eta x}|^2 + |T_{\xi y}|^2 + |T_{\eta y}|^2\right)/2$$

$$R_{01} = \left(|T_{\xi x}|^2 + |T_{\eta x}|^2 - |T_{\xi y}|^2 - |T_{\eta y}|^2\right)/2$$

$$R_{02} = Re\left(T_{\xi x}\, T_{\xi y}^* + T_{\eta x}\, T_{\eta y}^*\right)$$

$$R_{03} = Im\left(T_{\xi x}\, T_{\xi y}^* + T_{\eta x}\, T_{\eta y}^*\right)$$

$$R_{10} = \left(|T_{\xi x}|^2 - |T_{\eta x}|^2 + |T_{\xi y}|^2 - |T_{\eta y}|^2\right)/2$$

$$R_{11} = \left(|T_{\xi x}|^2 - |T_{\eta x}|^2 - |T_{\xi y}|^2 + |T_{\eta y}|^2\right)/2$$

$$R_{12} = Re\left(T_{\xi x}\, T_{\xi y}^* - T_{\eta x}\, T_{\eta y}^*\right)$$

$$R_{13} = Im\left(T_{\xi x}\, T_{\xi y}^* - T_{\eta x}\, T_{\eta y}^*\right)$$

$$R_{20} = Re\left(T_{\xi x}\, T_{\eta x}^* + T_{\xi y}\, T_{\eta y}^*\right)$$

$$R_{21} = Re\left(T_{\xi x}\, T_{\eta x}^* - T_{\xi y}\, T_{\eta y}^*\right)$$

$$R_{22} = Re\left(T_{\xi x}\, T_{\eta y}^* + T_{\xi y}\, T_{\eta x}^*\right)$$

$$R_{23} = Im\left(T_{\xi x}\, T_{\eta y}^* - T_{\xi y}\, T_{\eta x}^*\right)$$

$$R_{30} = -Im\left(T_{\xi x}\, T_{\eta x}^* + T_{\xi y}\, T_{\eta y}^*\right)$$

$$R_{31} = -Im\left(T_{\xi x}\, T_{\eta x}^* - T_{\xi y}\, T_{\eta y}^*\right)$$

$$R_{32} = -Im\left(T_{\xi x}\, T_{\eta y}^* + T_{\xi y}\, T_{\eta x}^*\right)$$

$$R_{33} = Re\left(T_{\xi x}\, T_{\eta y}^* - T_{\xi y}\, T_{\eta x}^*\right)$$

this information is necessary in order to calculate the radiation reflected at any particular angle.

9.2.2 Preliminary Data from Indoor Measurements

Before proceeding to a study of the complete angular and wavelength dependence of the reflection matrix, special cases will be studied. The special case currently being studied is for smooth sand and soil surfaces at 6000 Å with $\theta_o = 0°$. The reflection matrix simplifies for this case since the surfaces exhibit rotational symmetry so that the measurements are independent of ϕ_i and ϕ_o. Thus, the elements of the transfer matrix become

$$T_{ij} = \sum_{\ell} T(i,j;\ell)\, P_{\ell}\,(\cos\theta)$$

where the P_{ℓ} are Legendre polynomials. The symmetry of this special case also requires R_{20} and R_{21} to vanish, so that from Table 9.1,

$$T^{r}_{\xi x}\, T^{r}_{\eta x} + T^{i}_{\xi x}\, T^{i}_{\eta x} = 0$$

$$T^{r}_{\xi y}\, T^{r}_{\eta y} + T^{i}_{\xi y}\, T^{i}_{\eta y} = 0 .$$

Furthermore, R_{10} must vanish for $\theta_i = 0$.

The primary optical analyzing element of the polarizing radiometer is a linear polarizer. For a given measurement of the polarizer is at an angle α, and it can be shown that the output of the instrument (after dead time and dark count corrections) is

$$I = (S_0 + S_1 \,\mathrm{Cos}\, 2\alpha + S_2 \,\mathrm{Sin}\, 2\alpha)/2$$

where S_0, S_1, and S_2 are the first three elements of the incoming Stokes vector. By taking measurements with different orientations of the polarizer, the values of S_0, S_1, and S_2 can be determined.

Consider the effect of an unpolarized point source on the measurements. The incoming Stokes vector for unpolarized light is given by

$$S_i = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Multiplying by the reflection matrix gives

$$S_o = \begin{pmatrix} R_{00} \\ R_{10} \\ R_{20} \\ R_{30} \end{pmatrix}$$

This is just the outgoing Stokes vector, since no integration over incident angles is necessary for a point source. Therefore the elements R_{00}, R_{10} and R_{20} can be measured with an unpolarized point source.

In a similar manner the effect of a completely linearly polarized point source can be determined. For the plane of polarization horizontal (+) or vertical (-) the outgoing Stokes vector is

$$S_o = \begin{pmatrix} R_{00} \pm R_{01} \\ R_{10} \pm R_{11} \\ R_{20} \pm R_{21} \\ R_{30} \pm R_{31} \end{pmatrix}$$

Thus, with horizontally or vertically polarized light the quantities $R_{00} \pm R_{01}$, $R_{10} \pm R_{11}$, and $R_{20} \pm R_{21}$ can be measured. Comparing these results with the measurements using unpolarized light allows R_{01}, R_{11}, and R_{21} to be determined. Similar experiments can be devised to determine the other elements of the reflection matrix.

Laboratory measurements of R_{00}, R_{01}, R_{10}, and R_{11} were made for the following samples:

I.D.	SAMPLE
1	Flat White Paint
2	Silica Sand
3	Daytona Beach Sand
4	Atlantic City Beach Sand
5	Black Loam, Iowa
6	Glass Beads
7	White Gypsum Sand
8	Crushed Feldspar
9	Hematite Powder
10	Fresh Basalt Lava Chips
11	Limonite, Yellow Ochre
12	Small Black Pebbles
13	Yolo Loam

These particular samples were used simply because they were already available. The angular dependence of R_{00} and R_{11} is shown in Figures 9.3 and 9.4 respectively. The angular dependence is plotted versus Cos θ_i rather than θ_i because the Legendre polynomials are functions of Cos θ. It is interesting that R_{11} for two man-made surfaces, flat white paint (1) and glass beads (6), are much higher than for the natural surfaces. From the relationship between the reflection matrix and the transfer matrix shown in Table 9.1 it is seen that the values of $|T_{\xi x}|^2$, $|T_{\xi y}|^2$, $|T_{\eta x}|^2$, and $|T_{\eta y}|^2$ can be calculated from R_{00}, R_{01}, R_{10}, and R_{11}. These calculations were done for the thirteen samples, and

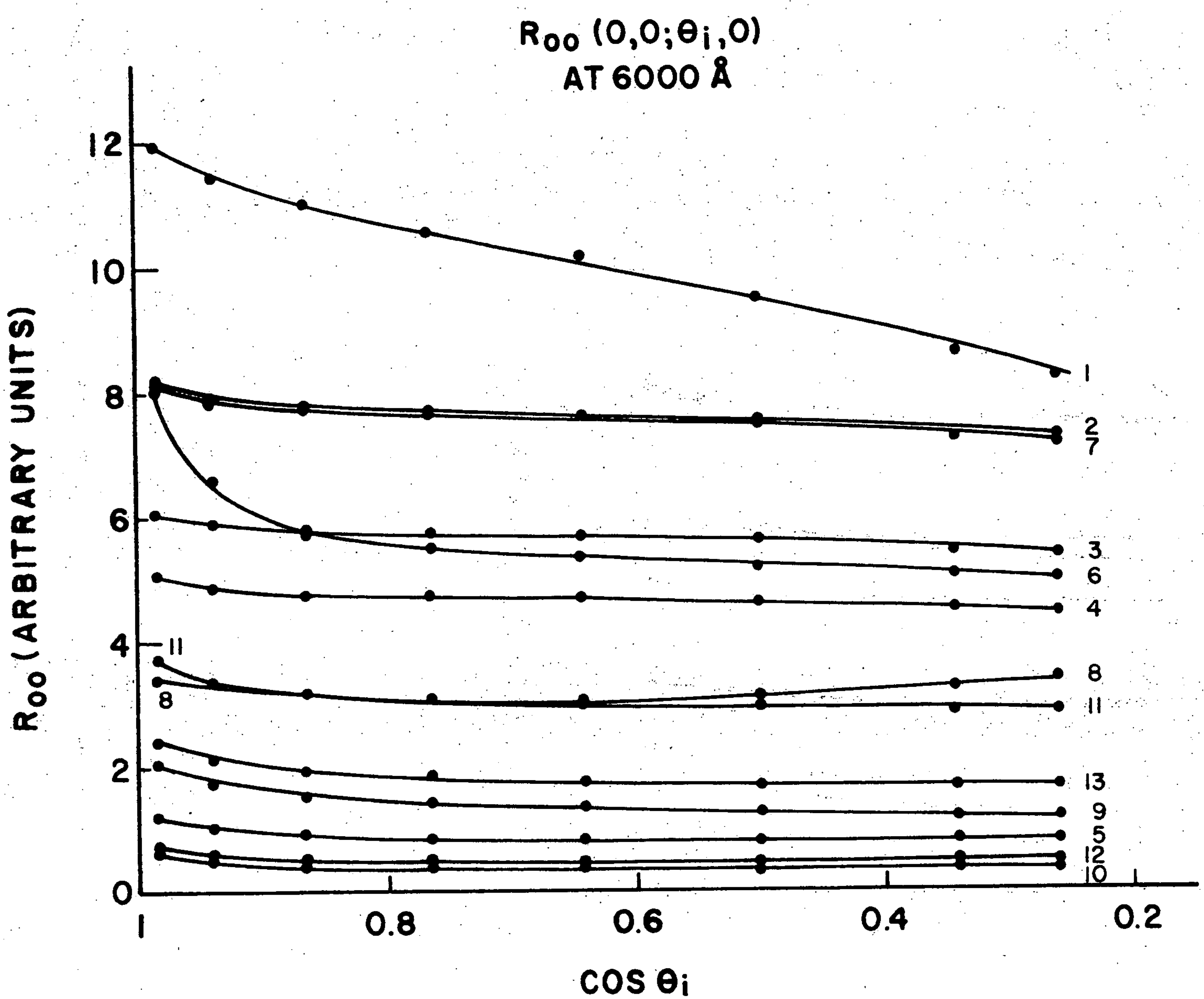

Figure 9.3 Angular dependence of R_{00} on Cos θ_i

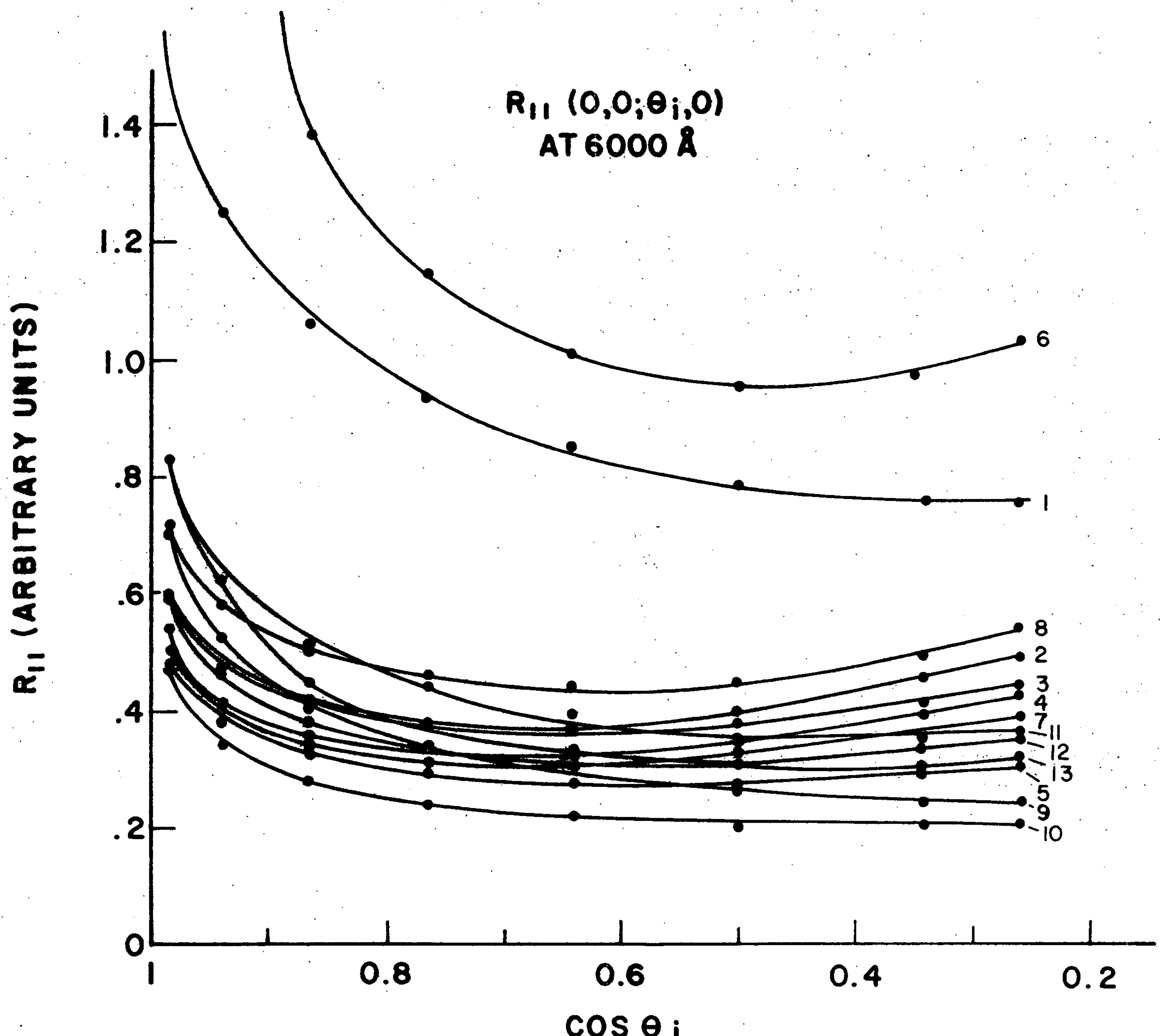

Figure 9.4 Angular dependence of R_{11} on Cos θ_i

the results are shown in Figures 9.5 through 9.8. It is apparent that the elements of the transfer matrix do not have a complicated angular dependence for the special case $\theta_o \neq 0$, but can be described by expansions in terms of a few low order Legendre polynomials.

If the form of the transfer matrix elements is assumed to be

$$T_{ij} = \sum_{L=0}^{L_{max}} \mathcal{T}(i,j;L)\ P_L\ (\cos\ \theta)$$

where the coefficients $\mathcal{T}(i,j;L)$ are complex, then it can be shown that

$$|T_{ij}|^2 = \sum_{L=0}^{2L_{max}} t(i,j;L)\ P_L\ (\cos\ \theta)$$

where the real coefficients $t(i,j;L)$ are complex bilinear products of the $\mathcal{T}(i,j;L)$. When the data are fit with a particular assumed value of L_{max} the quantity χ^2/d.f., where χ^2 is the chi-square for the fit and d.f. = degrees of freedom = number of data points - number of fitting parameters, is a measure of the significance of that value of L_{max}. That is, starting with $L_{max} = 0$, χ^2/d.f. will decrease as L_{max} is increased (and hence more fitting parameters added) until the additional parameters added by increasing L_{max} do not significantly improve the fit (even though χ^2 is decreased). The "most significant" value of L_{max}, i.e., the minimum value of L_{max} which adequately describes the data, is thus defined as that value of L_{max} for which χ^2/d.f. is smallest. For all thirteen samples it was found that the most significant value of L_{max} was 2 for all elements of the transfer matrix except for flat white paint (2) and glass beads (1). The $T_{\xi x}$ element for flat white paint required $L_{max} = 3$ and the $T_{\xi x}$ and $T_{\eta x}$ elements

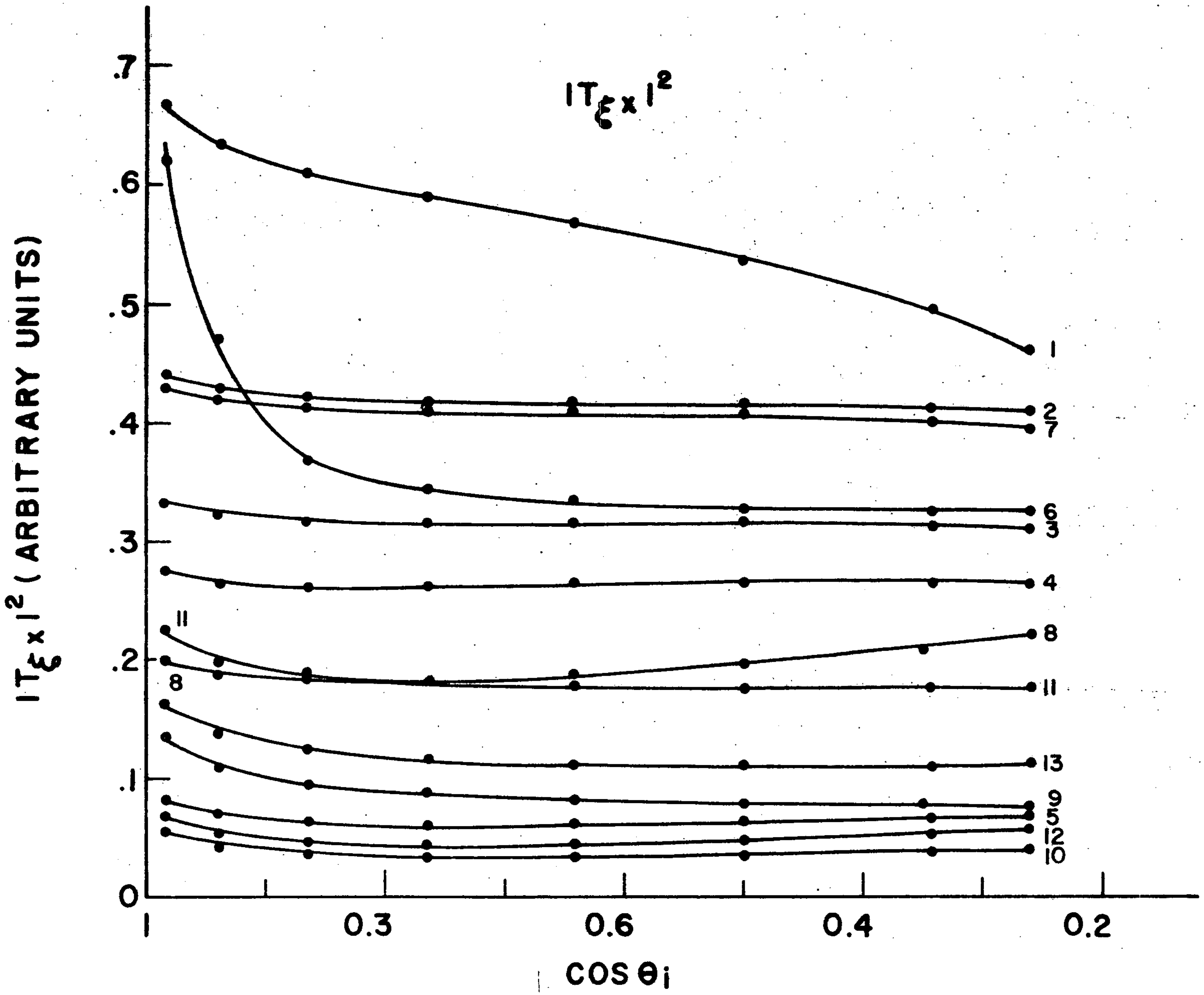

Figure 9.5 Angular dependence of $|T_{\xi x}|^2$ on Cos θ_i.

[redacted]

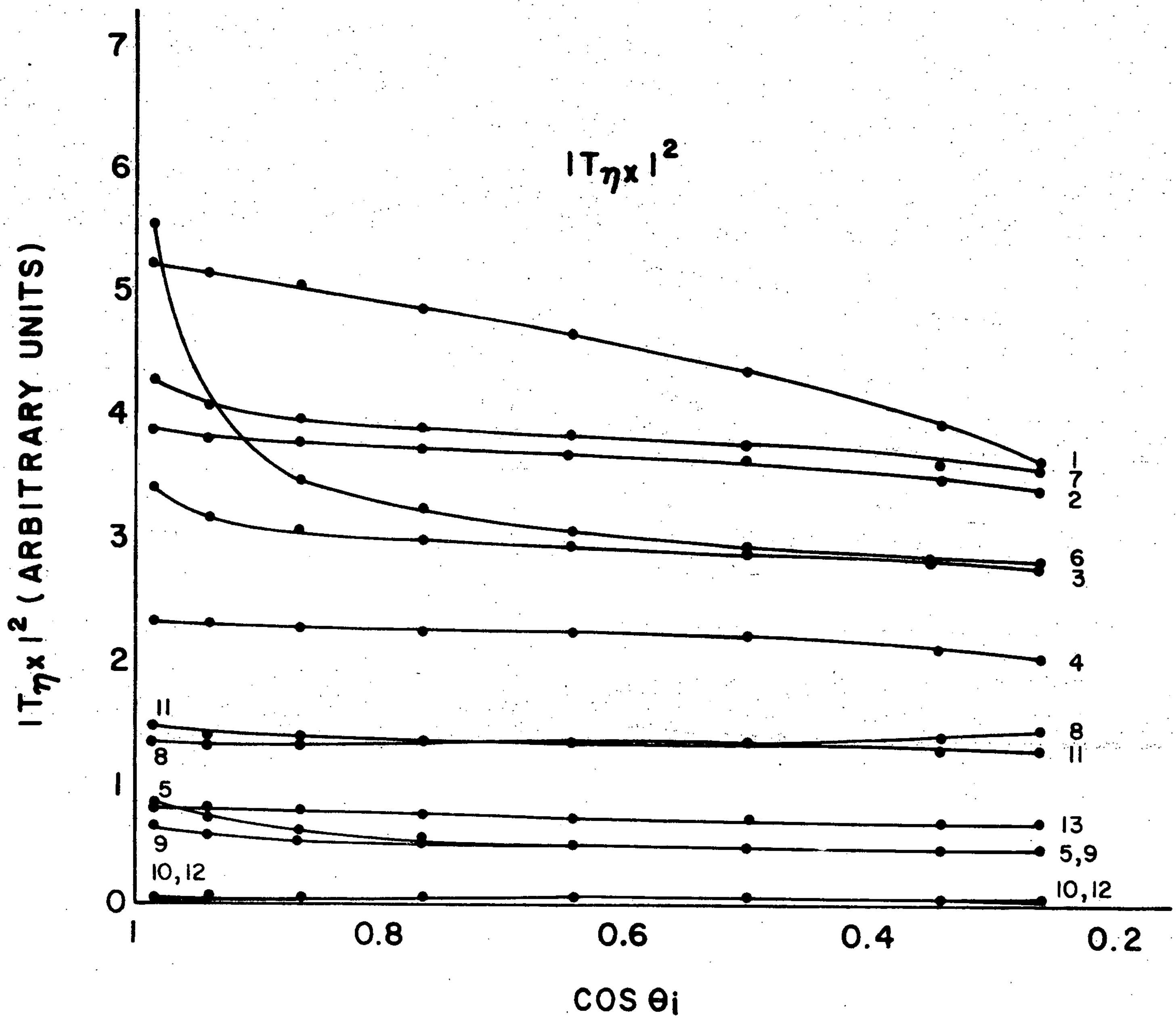

Figure 9.6 Angular dependence of $|T_{\eta x}|^2$ on Cos θ_i

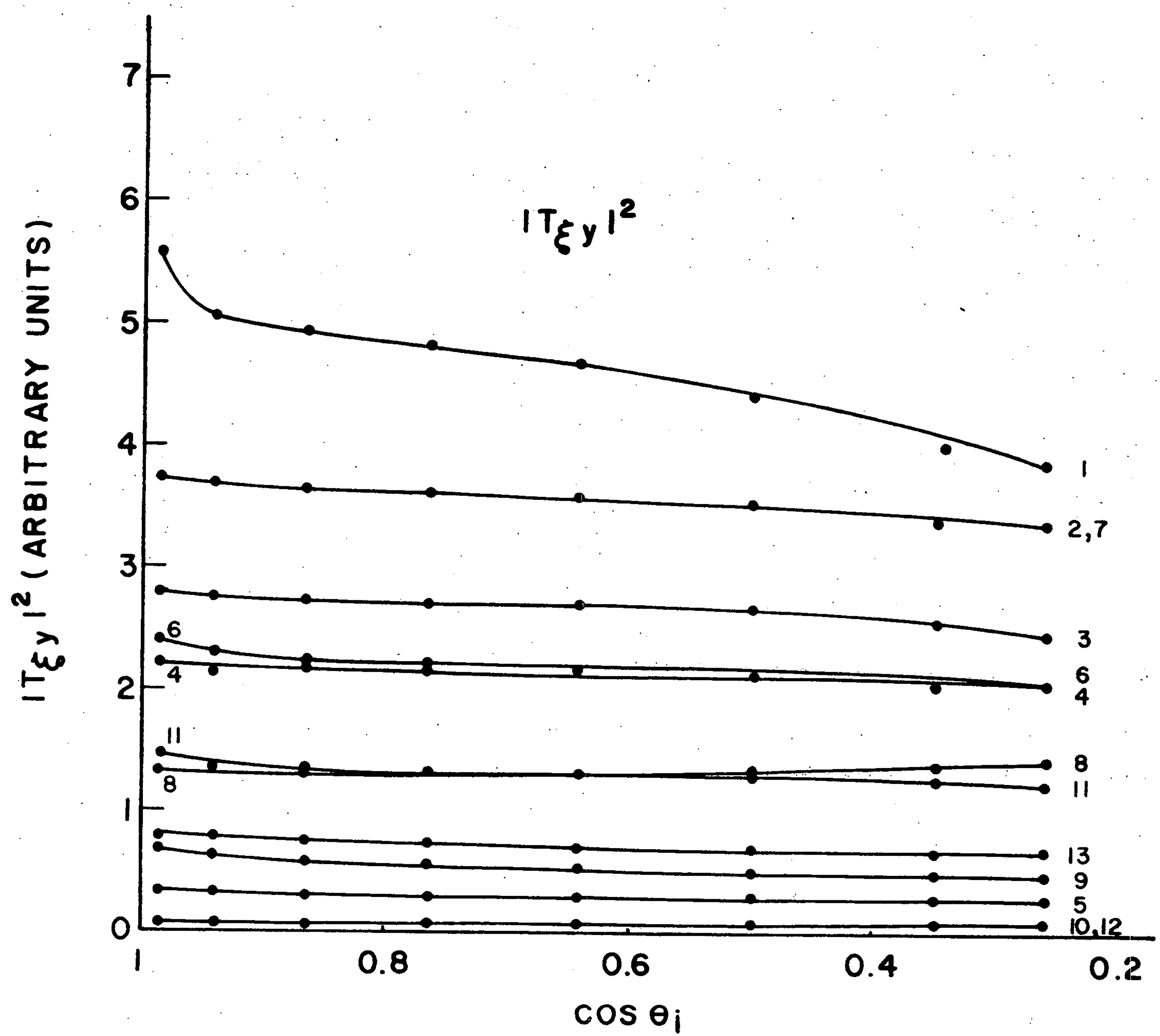

Figure 9.7 Angular dependence of $|T_{[redacted]}|^2$ on Cos θ_i

[redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted]

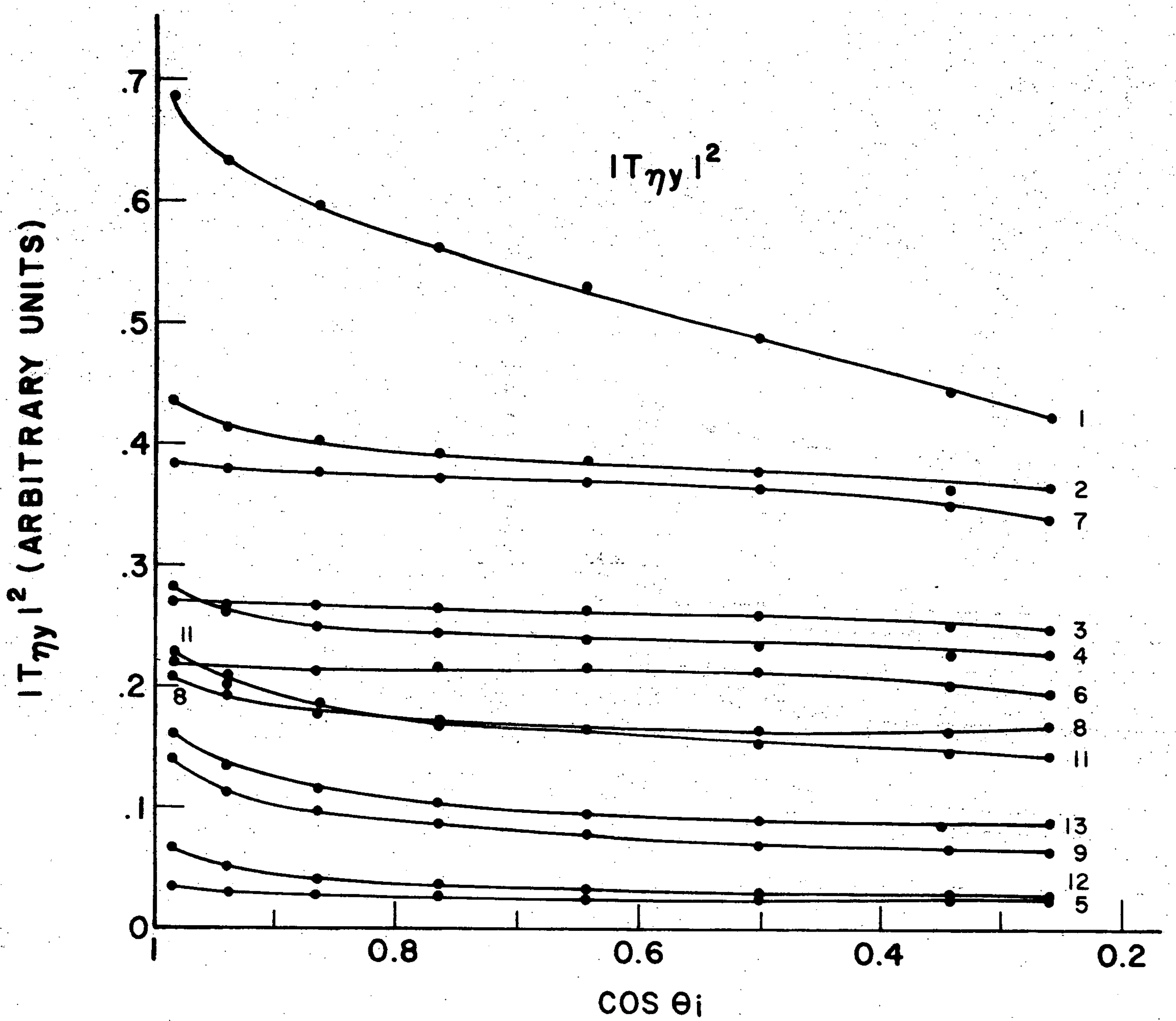

Figure 9.8 Angular dependence of $|T_{\eta y}|^2$ on Cos θi

for glass beads required $L_{max} > 3$. Figure 9.9 shows the silica sand data (2) fit with $L_{max} = 2$. Figure 9.10 shows the fits to the flat white paint data (1) for $L_{max} = 2$ and $L_{max} = 3$.

It is encouraging that most of the data for the special case $\theta_o = 0$ can be parameterized by the complex coefficients $t(i,j;L)$ with $L < 2$ or by the real coefficients $T(i,j;L)$ with $L < 4$. However, if only data for the reflection matrix elements R_{00}, R_{01}, R_{10}, and R_{11} are used, the values of the coefficients determined by fitting the data are not well defined. This is because R_{00}, R_{01}, R_{10}, and R_{11} do not contain enough information to uniquely (to within an arbitrary overall phase factor) determine the elements of the transfer matrix. Therefore it is necessary to measure additional elements of the reflection matrix in order to properly determine the transfer matrix.

9.3 WORK CURRENTLY IN PROGRESS

Work is now progressing on the complete determination of the transfer matrix for the special case $\theta_o = 0$ for the thirteen samples. After this is accomplished, other special cases will be studied and other types of natural surfaces will be studied. Before proceeding to a study of the complete reflection matrix, outdoor measurements will be made for the special cases to verify the correctness of the model for these special cases.

While it is too early to discuss the role of polarization in remote sensing, it is possible to illustrate the potential power of polarization as an analyzing tool in remote sensing. Consider the following situation: a satellite mounted sensor looking straight down at the surface of the earth must be designed to distinguish two particular surfaces. Suppose,

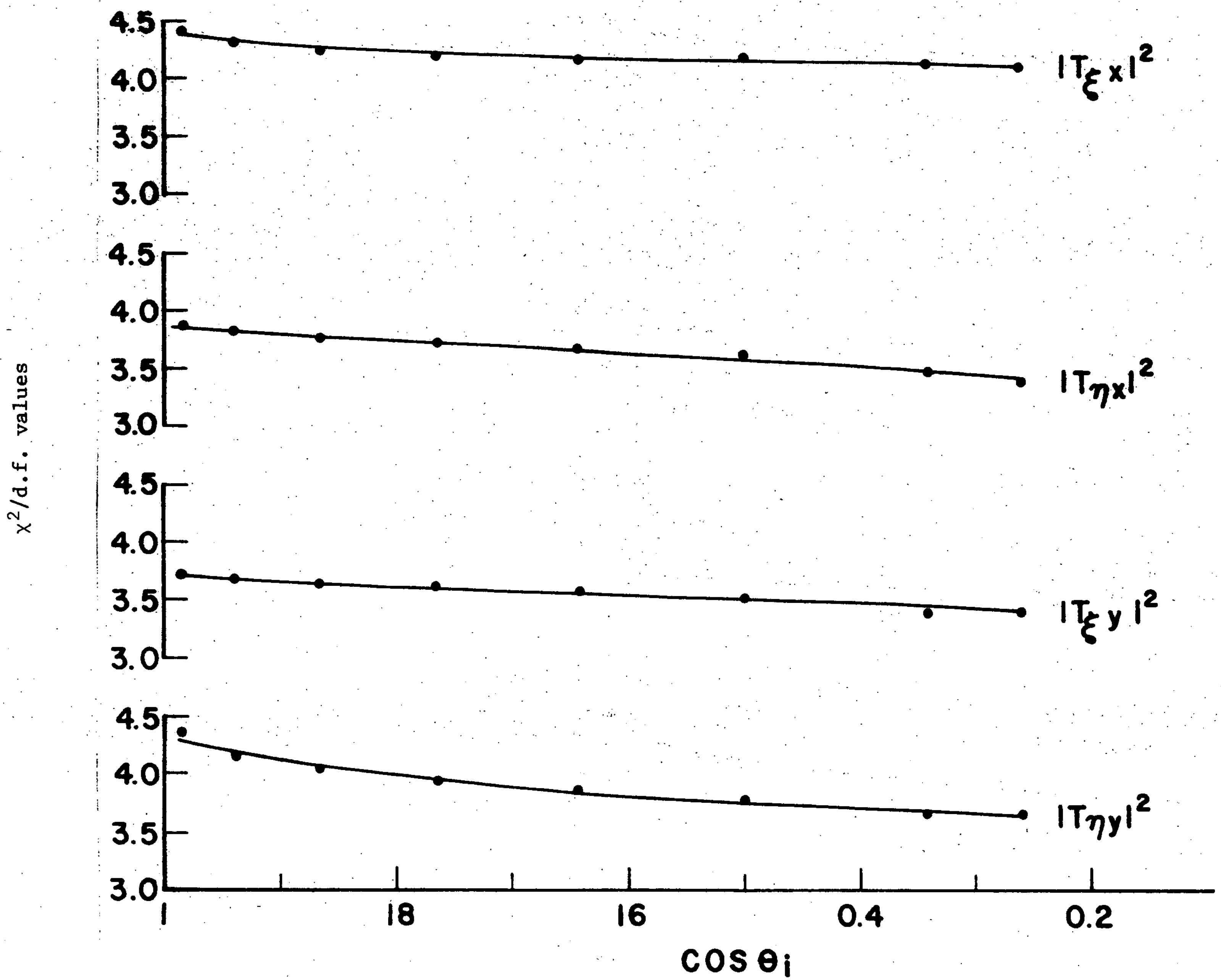

Figure 9.9 Angular dependence of χ^2/d.f. values for silica sand to Cos θ_1 for L_{max} = 2

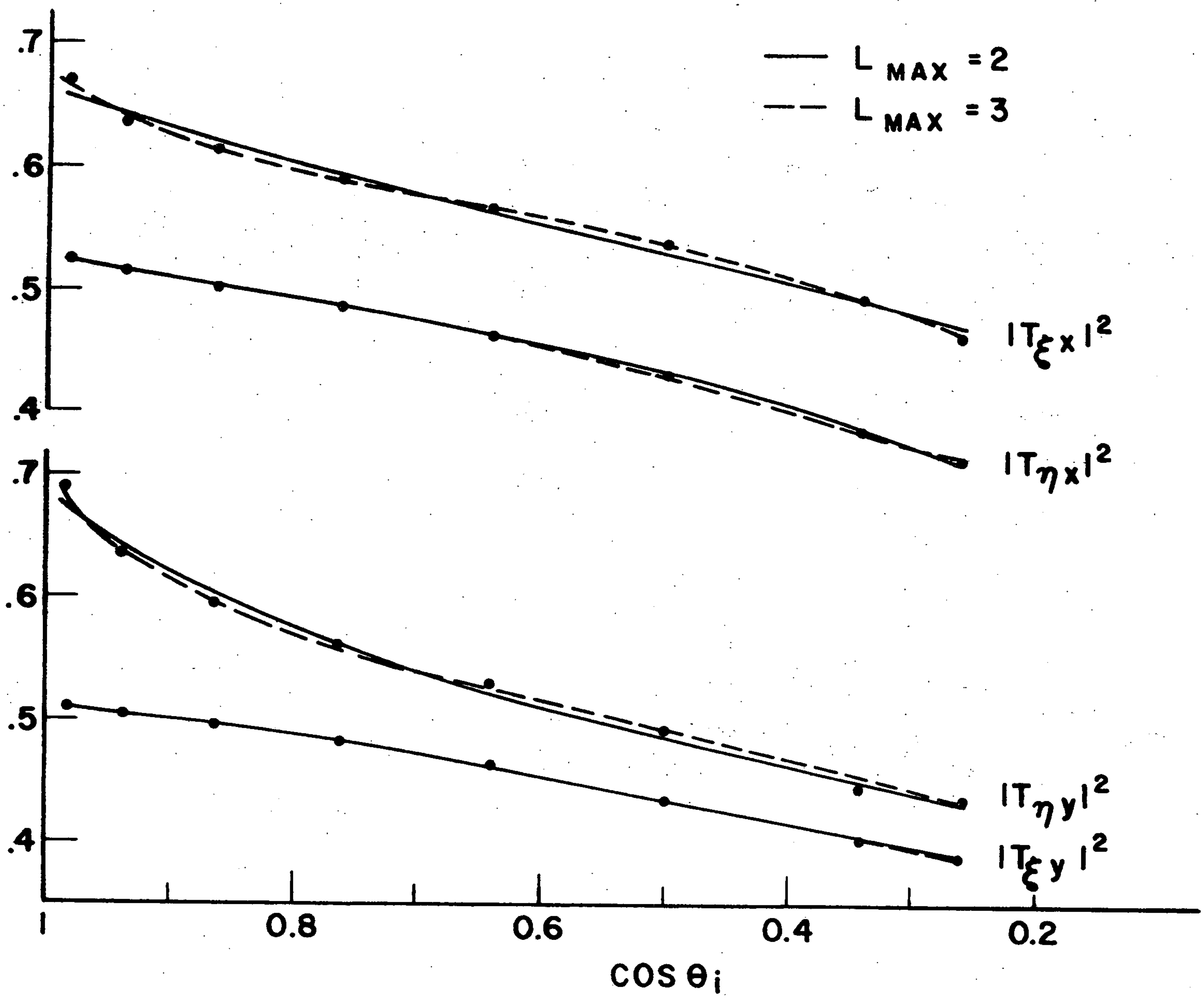

Figure 9.10 Angular dependence of χ^2/d.f. values for white paint to Cos θ_1 for L_{max} = 2

for the sake of illustration, that the two surfaces are beach sand and glass beads and the sensor has a narrow band pass at 6000 Å. (The unusual case was chosen because we have taken data for it.) Figure 9.11 shows the ratio of the intensity and polarization for Daytona Beach sand versus glass beads. The angle θ_i represents the angle the sun makes with the zenith. Using only the intensity information the two surfaces would be almost indistinguishable except at high noon. Notice also that the galss beads appear brighter at noon, but the Daytona Beach sand appears brighter late in the day. The polarization ratio is therefore a much better measure for separating these two surfaces. In fact, as the sun approaches the zenith the polarization of the glass beads becomes very large compared to the polarization of the sand.

While it might be argued that the comparison of glass beads and beach sand is an unusual case, it does illustrate the point that there are some specific cases where the use of polarization information in remote sensing will improve the image. It is hoped that other classes of surfaces (i.e., wet soils, dry fields, trees, wet plants, etc.) will show distinctive polarization patterns that will aid in their classification.

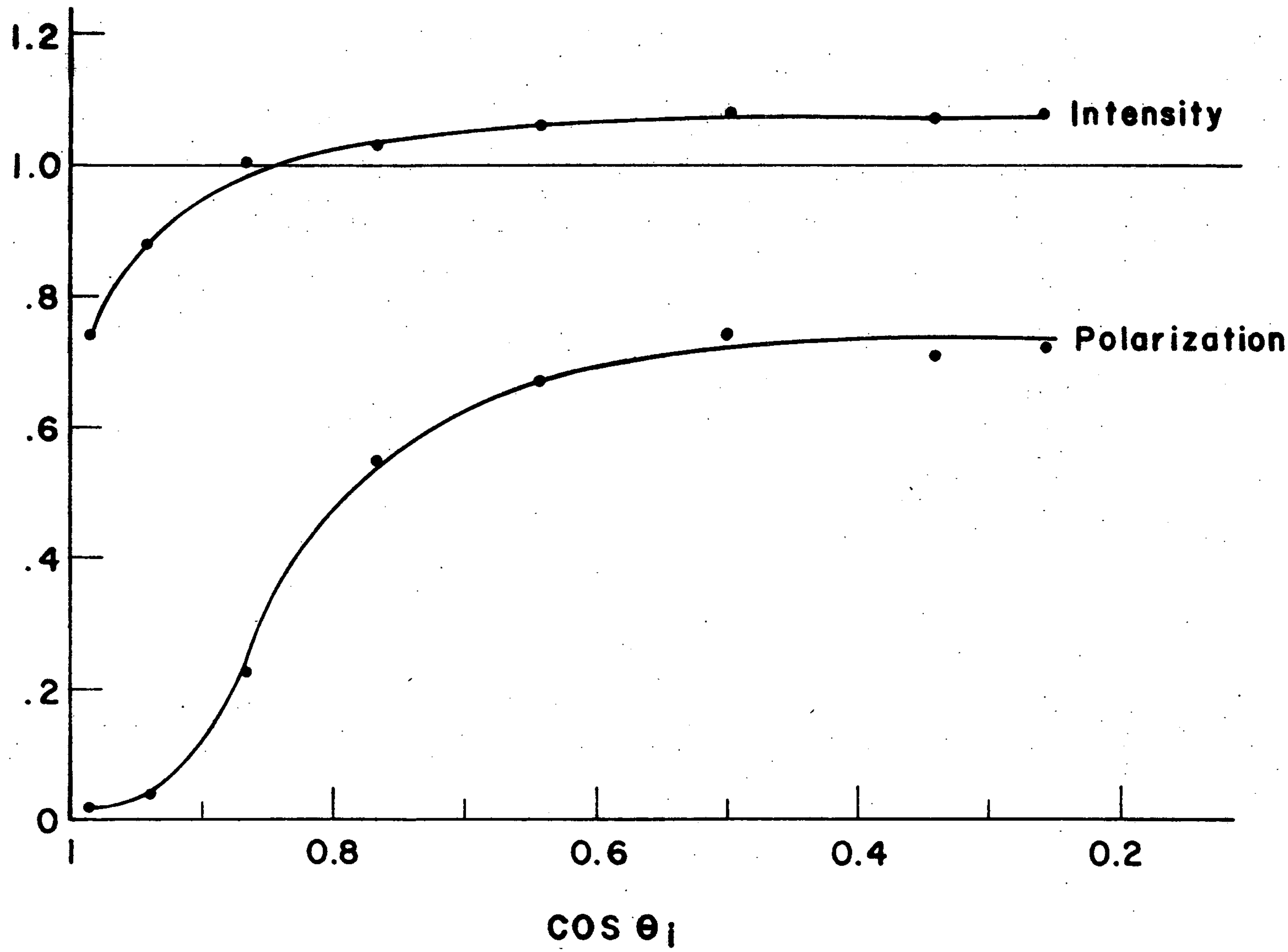

Figure 9.11 Ratio of intensity and polarization for Daytona Beach sand vs. glass beads

Chapter 10

SUMMARY AND CONCLUSIONS

A reading of the preceding chapters will document the fact that there is a mix of many kinds of problems relating to proper resource management in California, ranging from ecological and technological, through political and social, and including several economic, legal and enforcement aspects. Adding to the complexity of this multifaceted problem is the fact that many of California's resources are in a dynamic, rapidly changing state. All of these factors contribute to the need for resource inventories in California to be made with increased frequency and accuracy. As the preceding chapters have indicated, remote sensing from high altitude aircraft (and eventually from such spacecraft as ERTS-A) can do much to facilitate the management of California's earth resources by improving our ability to make the necessary resource inventories.

In the sections which follow, a brief summary is given of work done and conclusions arrived at during the period covered by this report by the various University of California groups who are participating in our NASA-funded integrated study. In each case a much fuller treatment will be found in the pertinent preceding chapter.

10.1 DEFINITION OF EARTH RESOURCE POLICY AND MANAGEMENT PROBLEMS IN CALIFORNIA

Virtually all of this type of work has been done, under our integrated study, by personnel of the Social Sciences Group on the Berkeley and Los Angeles campuses of the University of California. The prime objective of that group is to combine scholarly research with empirical observation and to translate the results into a form that may be useful to government officials who are responsible for making the ERTS program viable in socially relevant terms. To this end the Social Sciences Group has attempted to identify potential users of ERTS data, ascertain their needs, and assay the organizational impacts of new and technologically advanced sources of information. Consideration has been given to developing a large-scale linear programming model which would be useful in decision-making with respect to the resources which are to be observed by ERTS and other remote sensing vehicles. The California Department of Agriculture is greatly interested in the possibility of using such a model and is currently making arrangements to work closely with our group in the development of it, using San Joaquin County as the focal point for such a study. Already several specific areas have been identified in which ERTS-derived information could be highly useful, particularly if the information were to be regularly obtained (e.g., at 18-day intervals) and promptly disseminated. Since California is the nation's leading farm state, with its agriculture considered the most diversified in the world, it provides an ideal proving ground and demonstration site for the reception, application, and utilization of ERTS and similar data for agricultural purposes.

The case study which our Social Sciences Group will be making in cooperation with the California Department of Agriculture will provide the basis for a decision-making model useful not only for that agency but also for several others at the state level. It may also prove valuable to policy-makers in NASA as a guideline for the meaningful utilization of its advanced technological capability.

The Social Sciences Group recognizes the value of cost/benefit studies in relation to their work, e.g., in measuring the usefulness of ERTS data collection with respect to other forms. However, it is aware of limitations to this as the only approach to planning and is in the process of documenting the fact that broader social aspects and impacts are likely to become of ever-increasing importance in public decision-making.

A major part of the effort of the Social Sciences Group is discussed in the present report under the heading "ERTS and Environmental Management". There it is emphasized that a determination as to the quality of environment that should be maintained or achieved is a complex task which has important social overtones. By means of specific examples it is demonstrated that there is a web of interrelationships affecting decisions about resource utilization. Additional factors also are included in the studies currently being conducted by the Social Sciences Group. One such factor deals with the possible need for reorganizing official mechanisms for making and implementing policy with respect to natural resources. Another deals with the various ways in which advancing technology (as represented by ERTS) might enter into the public decision-making process. Among the factors which in this report, are subjected to detailed consideration in relation to ERTS and environmental management are (1) air pollution, as affected by the automobile, by industry and by electric plants; (2) water quality, with particular reference to the California Water Project; and (3) land use planning including the monitoring of changes in land use.

One topic to which our Social Sciences group has given major consideration during the period covered by this report is that of converting ERTS capabilities into an operational system. In this regard it is recognized that the potential impact on society of vast quantities of ERTS-type data is likely to be very substantial. Therefore the Social Sciences group considers it imperative that the design of an appropriate information dissemination system begin now and that the design be developed in an organized and systematic manner. Special consideration should be given in this regard to the question where, in the system, data interpretation will take place, to whom the resulting information will be made available, and on what schedule.

Our integrated project's Social Sciences group also has addressed itself during the past year to specific examples of Benefit-Cost analysis as applied to the prospective ERTS-A data collection system. Furthermore it has responded to the important, but rarely asked question, of whether ERTS or some successor to it will significantly change certain important social conditions and social balances. If so, then it probably will not be possible to fully evaluate the system merely by Benefit-Cost analysis. Based on such considerations the group concludes that the system of which ERTS-A will be a progenitor is destined to be a socio-cultural as well as a technical-economic phenomenon. This leads to a thought-provoking section of our report (Section 2.4) entitled "Beyond Benefit-Cost Analysis". In that section it is recognized that eventually an ERTS-type of data collection system may be of very significant benefit to all mankind, but that it may benefit some groups more than others, thus disturbing a certain accepted "equity" which now exists among these groups. This disturbance of equity can assume considerable significance in a society such as ours, where much of a person's perceived benefit resides in his comparative well being. If the eventual ERTS system preferentially benefits some groups, then it leads, in effect, to a redistribution of wealth and a consequent change in each individual's comparative well being. In fact, such a system may be, for this very reason, a "non-benefit" or even a "negative benefit" to some groups of society. It is this type of consideration that will complicate any eventual attempt to evaluate ERTS solely on a Benefit-Cost basis. Means for dealing with these intangibles when evaluating the potential significance of ERTS are then considered.

The next major topic considered by the Social Sciences group is that of computers in relation to management and planning problems. Special emphasis is given in this section to the use of computer technology for the analysis of ERTS-type data, the better to solve problems of the earth resource manager. These considerations lead, in turn, to "An Earth Resource Debate" which sets forth opposing views as to the benefits of an ERTS-based information system.

The experience derived from nearly a decade of functioning of our NASA-funded Social Sciences Group is reviewed in a section of Chapter 2 of this report that bears the title "An Interdisciplinary Approach to Science and Society". This section purposely takes the broad view of space technology, of which ERTS is only a part. In so doing it is highly responsive to the mandate that was set forth in the 1962 Memorandum of Understanding between NASA and the University of California whereby the university-based program was to seek ways in which the benefits of space-derived and related research could be applied to the social, business and economic structure of the United States.

10.2 DEFINITION OF THE INFORMATIONAL REQUIREMENTS OF HYDROLOGIC RESOURCE MANAGERS

The research dealt with in this section of our integrated study seeks to (1) analyze hydrologic and water resource systems, (2) establish the major parameters needed to meet the informational requirements of water resource managers, (3) specify when and where relevant data are needed, and (4) suggest possible remote sensing applications for acquisition of the required data.

The fundamental framework within which the analyses are being made consists of a model of the hydrological and water resource systems and their discrete subsystems including such components as evaporation, vegetation, precipitation, streams and estuaries, reservoirs and lakes, and the saturated and unsaturated soil zones. A series of tables is being developed for these various components in which a listing is provided, component-by-component as to the accuracy and frequency with which that component should be measured, the feasibility of using ERTS or other remote sensing data in deriving the necessary measurements, and the exact use likely to be made of such information by the resource manager.

In this way the analysis is attempting to relate hydrologic system and subsystem models to user applications and remote sensing technology with a view to assisting the water resource manager both in short term hydrologic forecasting and in the longer term planning and management of water resource subsystems.

10.3 REMOTE SENSING DATA AS AN AID TO RESOURCE MANAGEMENT IN NORTHERN CALIFORNIA

Much of the work that is performed under this portion of our integrated study by personnel of the Forestry Remote Sensing Laboratory is in direct response to the findings of Professor Robert H. Burgy et al who seek to establish the informational requirements of hydrologic resource managers (see previous section).

During the period covered by this report, personnel of the Forestry Remote Sensing Laboratory were engaged in two major remote sensing studies, namely (1) measurement of hydrologic parameters in the Feather River Headwaters area, and (2) analysis of the Northern Coastal Zone Environment.

10.3.1 Feather River Watershed

Within the Feather River Watershed the major effort has been expended in learning how to detect, identify and delineate each of the nine important vegetation/terrain types which previous phases of the study have found to be significant in relation to water yield in this area. A dichotomous photo interpretation key for the identification of these nine types has been prepared and currently is in the process of being tested. Techniques for delineating snowpack boundaries on sequential photography and relating these to potential water yield also are being developed. In the process of doing so, the investigators have found that there are four factors which greatly influence the appearance of a snow boundary, viz., elevation, slope, aspect and vegetation/terrain type, all of which show promise of being determinable through the detailed interpretation of remote sensing data. It has been found that snow boundaries are easily detectable in meadows and areas of bare ground, sometimes detectable in sparsely forested areas, and rarely detectable in densely forested areas of the type found in the Feather River Watershed where coniferous trees rather than deciduous hardwoods predominate. Training aids, including photo interpretation keys, are being developed to assist photo interpreters in the sometimes difficult task of mapping the areal extent of snow. Close cooperation in all phases of this study is being maintained with personnel of the Snow Surveys and Water Supply Forecasting Section of California's Department of Water Resources.

10.3.2 North Coast Zone

Within the North Coastal Zone it is expected that intensive use of earth resources will soon be brought about through increasing population. Hence land use planning should be undertaken as soon as possible to determine where and to what extent urban and industrial development should be permitted and also to determine the types and locations of various kinds of earth resource development and the regulations that should be imposed governing such development. As prime timberland is converted to other uses of lower economic return, alternate sources of income must be found for those presently gaining their livelihood from the timber industry. A first step is that of refining the existing maps of present land use in the North Coastal Area, and it is being demonstrated that remote sensing can be quite useful for this purpose. It is anticipated, based on work just completed by Forestry Remote Sensing Laboratory personnel, that ERTS data will be most useful for fairly gross land use delineations and as the initial stage in making regional resource inventories which will require supplemental aircraft imagery or ground data for their completion.

A land use classification scheme is being developed and tested based on remote sensing. As components of it are found to be both feasible and useful, photo interpretation keys are being developed to facilitate the training of individuals in the recognition of the pertinent land use components. Image enhancement and automatic data processing techniques also are being developed and various human-machine interactions are being studied to ensure the best mix of these two components in very sizable projects, such as this, requiring the analysis of vast amounts of remote sensing data. Up to the present time this work has been done, in the Northern Coastal Zone area, on rather small but representative calibration sites. However, with the advent of ERTS and Skylab an opportunity will be afforded to extend these techniques to adjacent, analogous and much larger areas.

10.3.3 Range Studies

Concurrent with the above, personnel of the Forestry Remote Sensing Laboratory are seeking to maximize the usefulness of remote sensing data for the inventory of rangeland resources and the monitoring of range plant development, particularly in areas where annual grasses predominate. Because of the seasonal variations in plant production and the length of the growing season at different sites through the annual grassland, a rancher at present cannot accurately predict how many cattle or sheep he should graze on his range, how much feed will be produced, how long it will provide an adequate feed source, and how soon he must move his animals to other pastures, ranges or feedlots. Research currently being performed by Forestry Remote Sensing Laboratory personnel is demonstrating that, when photography of these rangelands is obtained sequentially from aircraft and spacecraft, an experienced photo interpreter can monitor changes in range condition, predict "range readiness", and make improved estimates of forage production and "animal-carrying capacity" both locally and regionally. As in other phases of the study, simulated space photography currently being obtained sequentially by NASA's high altitude aircraft is proving very useful in developing a capability that soon can best be exploited through the use of remote sensing data acquired from ERTS and Skylab.

10.3.4 Automatic Data Processing

Both the hardware and the software required for effective operation of the Forestry Remote Sensing Laboratory "Terminal/Display" system underwent substantial improvement at only modest expenditure of funds during the period covered by this report. This improved capability is now being employed primarily to define and test various procedures which show promise of making the combined human-machine capability for analyzing remote sensing data as effective as possible. Among the machine capabilities that are being perfected are those which employ multichannel pattern recognition routines and also those based upon texture analysis routines. Data storage and retrieval techniques being developed under this study at the Forestry Remote Sensing Laboratory center around a concept known as MAPIT. The objective of MAPIT is to provide a package of computer subroutines which will permit the efficient storage, retrieval and updating of one or more profiles of resource data. A major test of the capability of MAPIT was conducted during this reporting period in the NASA Bucks Lake Forestry Test Site. The objective was to select those brushfields most suitable for artificial reforestation and eventual conversion to timberlands. In solving the problem of how best to achieve this objective, it was necessary for the investigators to manipulate the MAPIT system so that it would give due consideration to elevation, slope, aspect, soil type, and vegetation type. The end product consisted of (1) a delineation of those areas which satisfied all of these constraints and (2) a map on which the various portions of the landscape were stratified into good, medium and poor categories relative to the conversion of brushfields to timberlands.

10.3.5 Spectral Characteristics Studies

Work also was carried forward during this reporting period in defining (1) the spectral characteristics of earth resource features and (2) the procedures for specifying and calibrating multispectral remote sensing data acquired of those features. Field measurements of reflected radiation in the 375-1200 nanometer wavelength region were made for several brush species within the Feather River Watershed and an analysis of the data from a brushfield representative of thousands of acres of that watershed was made. This work is expected to greatly facilitate our eventual analysis of ERTS and Skylab data for the same geographic area. Field measurements also were made of changes in the spectral characteristics of several California annual grassland types as they progressed through their growth cycle. This work was done in preparation for monitoring both the fall-to-winter "green wave" and the spring-to-summer "brown wave" changes which are exhibited each year by these grasslands. Forestry Remote Sensing Laboratory personnel anticipate being able to perform such monitoring in the near future using ERTS and Skylab data.

10.3.6 Training Activities

Training activities of the Forestry Remote Sensing Laboratory during the period covered by this report included the presentation of a comprehensive 5-week course to thirty resource managers and inventory specialists of the U.S. Department of Interior. Numerous shorter courses also were given to personnel from a large number of government agencies. In addition several visiting scientists from many parts of the world made short inspection tours of the Forestry Remote Sensing Laboratory facilities and received briefings on remote sensing activities being conducted there. Furthermore, several agencies and groups were supplied with Forestry Remote Sensing Laboratory syllabi and other publications for use in their own remote sensing training programs.

10.4 RIVER MEANDER STUDIES

Considerable progress was made during the period covered by this report in using remote sensing techniques to measure those characteristics of river meander patterns which indicate meander stability and stream discharge rate. It is recognized that such information can be very useful in developing and maintaining river control systems that are based on levees, check dams and diversion areas. In those parts of the world known as "developing areas" such information also can be valuable at the time when preliminary regional plans are being formulated.

Investigation has recently been concentrated on establishing a possible correlation between the stream power spectrum (based primarily on an analysis of river meander directions and radii of curvature) and the stream discharge frequency distribution. As a result of this work the investigators have now completed their analysis of the Feather River test areas and have established the procedures for generating the "stream discharge probability density functions" and the "meander power spectra" for other rivers.

The approach being used involves the digitization of river meander patterns from aerial photography by means of photoelectric optical scanning. A continuous digitized record of the meander pattern for each bank of the river is thus obtained. As a result a set of data points (each having known X and Y coordinates) is developed at equally spaced intervals along the course of the river. For example a 23-mile stretch of the Feather River has been so digitized during the present reporting period and subsequently analyzed to determine the wavelengths and spectral peaks of the meanders.

Having developed the procedures for generating the meander power spectra and the discharge probability density functions for rivers, these investigators are now seeking to establish a correlation between these two functions as they conduct similar studies on a large number of rivers. They have obtained the hydrologic data on thirty river reaches from the Water Resources Division of the U.S. Department of Interior and the corresponding aerial photography and radar imagery from NASA and other sources. They currently are engaged in processing the data for these reaches in order to demonstrate quantitatively both the potential uses and limitations of their correlation study.

10.5 ASSESSMENT OF THE IMPACT OF THE CALIFORNIA WATER PROJECT ON THE WEST SIDE OF THE SAN JOAQUIN VALLEY

These studies, as conducted by personnel of the Department of Geography on the Santa Barbara campus, seek to characterize from remote sensing data the nature of the "area transformations" that are taking place primarily as a result of the fact that Feather River water recently has been made available to this developing region. Information is currently being extracted from NASA's remote sensing mission No. 164 and from ERTS-simulation high flight remote sensing imagery relative to: (1) land use, both general and urban-oriented; (2) vegetation, both general and problem-oriented (e.g., problems associated with boron and salinity affected areas); (3) irrigation systems; and (4) identification of crops. Since the West Side of the San Joaquin Valley is a large area, these studies are regional to sub-regional in scope.

10.5.1 Land Use Mapping

In the case of land use mapping, results already achieved substantiate the claim that maps of good quality based on general land use categories can be produced from an analysis of simulated ERTS photography. As soon as the present land use studies are completed, the interpretability of other regional parameters will be tested, the better to understand the land use transformation that is occurring on on the West Side. Among the categories on which the most recent tests have been conducted by these investigators are the following: (1) cropland; (2) new cropland; (3) grazing land; (4) land in which oil extraction is the primary use; (5) non-productive land; (6) settlements; and (7) transportation. A comparison of the percent of land occupied by each of these categories in 1957 vs. 1971 (based primarily on an interpretation of USDA photo mosaics and NASA photography for the two dates, respectively) showed the following: The 1957 period was characterized by grazing and cropland, with grazing (51 percent) clearly dominating cropland (38 percent) in areal extent. Oil extraction (4 percent) and non-productive land (7 percent) occupied significantly less area. By 1971 the pattern showed definite changes, with cropland (43 percent) almost on a parity with grazing (47 percent) in areal extent. Oil extraction (6 percent) had grown significantly, while non-productive land (4 percent) had declined to little more than half its previous extent. In total, about 19 percent of the area underwent a change from one land use category to another during this brief time interval. In evaluating these changes in relation to the emphasis currently being given to our "integrated study" it is important to note that the 1971 date is 3 years after water from the California Water Project first became available for use in this area. Hence the comparative figures provide some opportunity for analyzing Aqueduct-induced changes in land use patterns within this region.

10.5.2 Crop Identification

With reference to crop identification, the problem of accomplishing this task from a study of remote sensing imagery in the West Side of the San Joaquin Valley has been complicated as a direct result of the increased availability of water to the area. Since many new crops can now be grown in the area, there is a great deal of experimentation going on there that involves an unusually large number of crops.

Furthermore, no fixed crop rotation schemes have as yet emerged. The fact that cotton occupies almost 50 percent of the cultivated land makes half of the total problem (on an area basis) somewhat simpler especially because of the tendency for cotton to display a unique "temporal signature" as discerned on multidate remote sensing data of the type soon to be acquired by ERTS-A. It is with respect to the remaining half of the cultivated land that the problems alluded to above are decidedly complex and as yet unsolved. Work, however, is continuing which seeks to exploit, as aids to crop identification, both the multiband and multidate capabilities that will be incorporated in ERTS.

10.5.3 Irrigation Systems

Over 90 percent of the newly cultivated land in the West Side of the San Joaquin Valley is being irrigated by some form of sprinkler system because the rate of water application can be controlled much better and the water can be spread much more evenly by such means than with row flooding. In addition there is a minimal loss of water through runoff and the need for land levelling is minimized. From an analysis of remote sensing imagery of the types previously described, these investigators are in the process of determining the extent to which sprinkler-irrigated cropland can be differentiated from other cropland and, within the sprinkler-irrigated areas the particular type of sprinkler system being used (e.g., stationary and side-wheel line sprinklers, "trimatic" sprinklers in which a series of secondary sprinkler pipes are dragged behind the main pipe, and "hose pull" sprinklers).

Examination of photography obtained on NASA remote sensing mission No. 164 showed that these various kinds of irrigation systems usually could be identified by such means because of their tendency to produce a unique soil-moisture pattern related to the manner in which the water was applied to the soil. To the extent that crop type is related to sprinkler type, this developing capability soon should permit the image analyst to recognize one additional element in each crop's signature, from a study of remote sensing data.

10.5.4 Urban Change Detection

Indicators of change within urban sites are proving to be primarily morphological ones (e.g., commercial buildings, processing plants, residential expansion and improved transportation networks). Acquisition of ERTS imagery will provide an opportunity to test the hypothesis that frequent monitoring of important morphological characteristics of urban communities from orbital platforms is possible. With this possibility in mind, the investigators studied two kinds of imagery of urban areas in the West Side of the San Joaquin Valley during the present reporting period: (1) Apollo 9 (S065) multispectral photography of the Coachella Valley, an area which is further south than the primary test area but in many respects analogous to it, and (2) ERTS-simulation high flight photography of the West Side area, itself. It was found that the red band was more informative than either the green or near-infrared band for detecting cultural detail, although the green band was best for monitoring urban areal extent and certain intra-urban phenomena. In addition, it was tentatively concluded that an imaging interval of about 6 months should constitute an adequate frequency for monitoring changes in the urban areas being studied.

10.5.5 Vegetation Patterns

A primary objective of this study is to produce, through an analysis of remote sensing data, a vegetation map of the perennial species encountered in the West Side of the San Joaquin Valley. Principal among these are desert saltbush, spiny saltbush, seep weed, mesquite and samphire, each of which serves to one extent or another as an "indicator species" of soil conditions that affect the suitability of land for agriculture.

From a study of the previously-mentioned types of imagery, these investigators determined that: (1) infrared ektachrome is the most useful for differentiating among the above-listed species; (2) conventional ektachrome is occasionally helpful to clarify the nature of the vegetation cover in areas that are especially difficult of interpretation; and (3) of the two photographic scales available (1:60,000 and 1:120,000) the former yielded significantly more detail than the latter, although the latter showed virtually the same gross patterns as were visible at the larger scale.

Further investigations, based on the vegetation map that has now been constructed, will be concerned with the characteristics of the soils on which each identifiable vegetation type occurs, the better to determine where "problem areas" of various types occur in relation to the production of agricultural crops.

10.5.6 Boron Problems

In times past virtually all investigations of potentially toxic levels of boron in soils prior to cropping have been restricted to costly and time-consuming laboratory analyses of soil samples taken at varying depths from point locations. During the period covered by this report, the present investigators studied boron-problem areas on various kinds of remote sensing imagery including thermal infrared imagery and photographs taken with conventional ektachrome, infrared ektachrome and panchromatic films. Infrared ektachrome was found to be the most interpretable, especially in areas where boron toxicity was creating significant plant stress. It is anticipated that late summer or early fall will be the optimum season for acquiring photography to detect such stress, since these are the time periods when boron concentrations in the leaves are the greatest.

Future research by these investigators is to be directed toward each of the major fields of endeavor discussed above.

10.6 ASSESSMENT OF THE IMPACT OF THE CALIFORNIA WATER PROJECT IN SOUTHERN CALIFORNIA

These studies are being conducted primarily by personnel of the

Department of Geography on the Riverside campus of the University of California. The primary objective of these studies is to use remote sensing techniques as an aid to understanding both the resource complex and the environmental complex of representative areas in Southern California. During the present reporting period much of the study has been based on an examination of imagery that was obtained of these areas on NASA's "high flight" remote sensing mission No. 164 during the period March 31-April 5, 1971. In addition photography obtained by NASA of the Los Angeles earthquake area on Mission No. 157 on February 9, 1971, as well as photography obtained locally at much larger scales, has proved to be very useful.

Among the studies currently being made by the Riverside investigators are (1) an inventory of rural land use and a monitoring of land use change related to the construction of Lake Perris in the Perris Valley; (2) the use of computer graphics technology in updating the USGS Atlas of Urban and Regional Change, especially in the Riverside-San Bernardino region; (3) the use of remote sensing to study areas in which important rural-to-urban transitions are occurring, such as the Walnut Valley area; (4) the mapping of montane vegetation by remote sensing as an aid to assessing microclimatic and weather conditions associated with forest fires in Southern California; (5) the regional monitoring by remote sensing of significant resource-related changes that are occurring in San Diego County; (6) the development of models and methodologies for using remotely sensed data for regional information systems; (7) the evaluation of present computer mapping capabilities based on the analysis of remote sensing data of the various above-mentioned geographic areas; and (8) determining the usefulness of remote sensing techniques for assessing environmental quality in Southern California. A brief statement as to the status of each of these phases of work appears in the following paragraphs.

10.6.1 Rural Land Use Inventory and Change in Perris Valley

Earlier studies by the present investigators had established the feasibility of using remote sensing data for making detailed studies of the types indicated. Present studies are concentrating on the elimination of unnecessary detail in order to increase the usefulness of such inventories on a broader regional basis.

10.6.2 Urban-Regional Land Use Studies

The central cities of Riverside, San Bernardino and Ontario, as well as many adjoining non-urban areas are being mapped in this phase of the study with the aid of remote sensing imagery. The work is being integrated with that of Dr. James Wray of the U.S. Geological Survey, who also is funded under the NASA Earth Resources Survey Program. A primary objective of this study is to develop improved techniques for analyzing urban area features as imaged by remote sensing and to present the findings in suitable graphic and tabular forms. At the time of this writing an initial interpretation of the previously mentioned photography flown by NASA is nearing completion.

10.6.3 Monitoring Rural-Urban Transitions

One aspect of this work seeks to predict the land use successional steps that are likely to occur as a rural area is converted into one urban form or another. In some instances our investigators have found, partly from a comparative analysis of sequentially-flown aerial photographs, that a decreased amount of expenditure is being devoted to certain kinds of lands instead of an increased amount -- a phenomenon known as "disinvestment". An excellent site within which to study disinvested agriculture is the route of the Pomona Freeway between downtown Los Angeles and eastern Los Angeles County through the Walnut Valley, which was basically rural in 1955 when freeway plans were first announced. From aerial photo interpretation the various types and amounts of land use inputs and outputs associated with the rural-urban conversion process have been estimated and three conclusions have been drawn: (1) a disinvested agricultural zone does, indeed, exist in this area; (2) the zone has become wider because of a widening of the freeway, and (3) a somewhat predictable sequence of events has taken place in the conversion of this land from rural to urban uses. Urban and regional planners need to recognize the ways in which urbanized landscapes evolve and these studies show great promise of helping them to achieve that objective through the proper use of remote sensing techniques.

10.6.4 Mapping Montane Vegetation

A previously-developed classification of the montane vegetation of southern California was tested during the period covered by this report in terms of its interpretability on simulated space photography that had been obtained on NASA high flight missions using infrared ektachrome film. The chief problem encountered was in finding photographs which exhibited the proper combinations of infrared enhancement and spatial resolution. Nevertheless, it was possible to establish that the plant classification which previously had been developed was adequate and usable, with the result that the mapping of montane vegetation from such photography of southern California is now proceeding.

This work is being supplemented by an effort to evaluate damage to brush and forest vegetation caused by fires which recently have occurred in the San Bernardino Mountains. For this purpose small scale infrared ektachrome imagery, obtained during the NASA remote sensing mission No. 164, is proving to be highly useful, particularly when employed as one element in a multistage sampling scheme.

10.6.5 Preparations for ERTS-A Data

Our proposed investigations using ERTS data fall into four general categories. The organization of these objectives in terms of site location is controlled by the fact that these are areas of specific geographic interest and by the fact that certain of these areas have been the focus of on-going research for the past several years.

The general research objectives include: (1) the mapping of land use patterns including an assessment of environmental impact of various uses; (2) the detection and analysis of land use change including the spread of urban areas, and the transformation of wild desert areas into urban and agricultural land use; (3) attempts to map and monitor environmental pollution in selected areas; and (4) the development and construction of models to explain "synoptic patterns" which are visible in the imagery.

Some sites for these investigations have already been chosen and under observation for two years in conjunction with the NASA California Project. Pre-ERTS and ERTS oriented research is already under way for the high desert, urban Riverside-San Bernardino, and Perris Valley sites. Information has been gathered, land use and thematic mapping is complete, and methodologies and techniques for computerized data mapping and presentation have been developed.

10.6.6 The Development of Regional Information Systems

For the past several years the development of equipment and methodologies for geographical information systems has been a major study area for this group, using other than NASA funds. It is anticipated that large quantities of regional data will need to be handled in connection with the forthcoming ERTS-A experiments. Hence some of the NASA-funded work of the Riverside group during the past year has been directed toward that end. Among the regional factors which are being investigated are topography, geology, vegetation, transportation and land use. The spatial resolution that is required when using remote sensing techniques to map these regional characteristics now is being determined. Results achieved to date indicate that a very useful classification scheme for the regional mapping of these characteristics from ERTS-type data can soon be developed.

10.6.7 Computer Prepared Thematic Maps

Mapping requirements of the forthcoming Earth Resources Satellite experiments are already placing a great burden on many cartographic services. Preparation of initial base maps of Southern California test site areas and experimental updating of thematic changes detected from current underflight imagery prove the need for an automatic thematic mapping system. Several systems for computer mapping are available to the Riverside campus and are being modified to our needs. Perhaps the most promising of these is a cartographic line type thematic map program known as CALFORM. Although it is less flexible than some other systems, CALFORM has been found to produce a much clearer line drawing with the result that it looks much like a map that has been drawn by a human cartographer. In addition, this system permits very rapid updating of information to be accomplished once the base map has been prepared. Furthermore the CALFORM system has the ability to quickly produce a new map to show a single category of information. Testing of this system during the past year has been based primarily on the previously described Perris Valley area.

10.6.8 Remote Sensing of Environmental Quality

All too often our capability for the remote sensing of environmental quality is used only to detect effluents and evaluate blighted areas. These are only two of the many important and inter-related environmental factors that need to be monitored. Unfortunately, many newly formed political and popular fronts for the assessment and improvement of environmental quality base their actions on incomplete information about the overall environmental "complex". Consequently they run the risk of using ill-informed and ill-considered popular action that may alleviate some problems while aggravating others. What is needed is a broader regional perspective of all of the major factors contributing to environmental quality together with "predictive models" and "preventive models" based on accurate periodic inventories of these factors. Much of the NASA-funded remote sensing research that has been conducted by the Riverside group during the past year has been pursuant of that objective, as detailed in Chapter 7.

10.7 DIGITAL HANDLING AND PROCESSING OF REMOTE SENSING DATA

The vast quantities of data soon to be collected by ERTS-A in each of several bands, and on each of several dates, will need to be analyzed in each of several ways. The fact that the original ERTS-A data will be available in electronic format and that photo-like images can be constructed from such data is of particular importance. Realization of this fact has prompted our investigators in the Department of Electrical Engineering and Computer Sciences on the Davis and Berkeley campuses to employ three approaches to the analysis of simulated ERTS data. These are (1) Human Photo Interpretation (2) Electronic Image Enhancement, and (3) Automatic Data Processing.

10.7.1 Digital Processing Facility

A major activity during the past year has been that of developing a digital processing facility. This facility is based on an IBM 1800 computer which has been modified by the addition of an array processor designed and built for the specific task of digital signal processing. This array processor permits a 20-fold increase in the speed with which several signal processing operations can be performed. The IBM 1800 will soon be connected by a high rate data link to the CDC 4600 of the Computer Center at Berkeley. This will permit simple data processing and image display to be done in a dedicated facility on the Davis campus for real time and interactive work, while larger computations and more elaborate processing can be accomplished on the Berkeley campus.

10.7.2 Image Processing Facility

An image processing system also is being developed which consists of (1) a monitor, (2) processing subroutines, (3) user programs, and (4) disc update programs.

10.7.3 Computer Program Testing

Several programs of general interest in the acquisition, reformating, analysis, enhancement, and display of images have been written and these currently are being tested in order to increase the state of readiness for analyzing data anticipated from the forthcoming ERTS-A experiment. As with other phases engaged in by this group, close liaison is being maintained with other participants in the integrated study, especially those in the Forestry Remote Sensing Laboratory on the Berkeley campus

10.8 INVESTIGATION OF ATMOSPHERIC EFFECTS IN IMAGE TRANSFER

The investigations summarized in this section have been performed by personnel of the Department of Agricultural Engineering on the Davis campus of the University of California. Their work is founded on the premise that an understanding of the effect of the atmosphere on remote sensing images is fundamental to image interpretation and enhancement. Not only is remote sensing imagery degraded as radiant energy from the distant feature travels through the atmosphere to the sensor, but also the image is contaminated with radiation scattered into the detector via the atmosphere from other sources than the feature of interest. Furthermore the atmosphere may change the radiation pattern as, for example, through polarization effects and spectrally selective absorption, transmission and scattering.

In addition the manner in which various earth resource features reflect radiation as a function of the incident and reflected angles of radiation needs to be better understood. To this end the investigators have made many indoor laboratory measurements during the past year of the reflection patterns of typical natural surfaces at various incident and reflected angles. These measurements have been made with the dual-channel polarizing radiometer which has been described in their portion of our previous progress reports. Outdoor ground measurements of the reflection of these same natural surfaces will soon be compared with the corresponding indoor measurements in order to test the validity of a "model" which these investigators are developing that will account for various atmospheric effects in image transfer.

When both the atmospheric model and the reflection model are operational, they will be combined into a "remote image" model which hopefully will be capable of predicting the spectral intensity characteristics of the remote image, as seen by a particular sensor, given the spatial orientation of the sensor, the atmospheric conditions, the time of day, and the type of surface being viewed.

In order to test the validity of the remote image model it will be necessary to make correlated ground and airborne measurements. Plans have been made to use the Convair 990 aircraft at NASA-Ames for this purpose.

Two major accomplishments of these investigators during the past year, as detailed in Chapter 9, have been (1) to develop the technique to be used to model the reflection data and (2) to test various aspects of this technqiue using some preliminary reflectance measurements which they have made on thirteen kinds of materials. The materials tested include Yolo loam (which characterizes much of our NASA Agricultural Test Site at Davis, California), fresh basalt lava, and four kinds of sand. A comparison of the reflectance from glass beads and beach sand has shown that there are some instances where the use of polarization information in remote sensing will improve the interpretability of the imagery. Work currently in progress seeks to determine, among other things, whether other classes of surfaces (e.g., wet soils, dry fields, trees, wet plants, and moisture stressed plants) also will show distinctive polarization patterns that will facilitate their identification.

10.9 STATUS AND PROSPECTUS

As indicated by the foregoing summary of progress which we have made during the past year relative to this "integrated study", our group has developed a high degree of readiness to interpret space photographs and other remote sensing data of the types that soon will be acquired of California both by the unmanned Earth Resources Technology Satellite (ERTS-A) and by the manned Skylab satellite.

Two major conclusions that might be drawn from our work to date are these:

1. Even an expert who is well versed in both remote sensing and resource management usually cannot make an adequate resource inventory of a given area from merely a single "frame" of remote sensing imagery covering that area.

2. The ease, accuracy and completeness with which the desired information can be derived is likely to be greatly improved through what might be termed the "multi" approach to remote sensing in which

several frames of imagery, all covering the same general geographic area of interest, are variously enhanced and analyzed. Specifically, just as multiband imagery is likely to provide more of the desired information than is obtainable from any one band, essentially the same can be said for multidate, multistage, multistation and multi-polarization imagery, especially if that imagery is then multi-enhanced, analyzed by a multidisciplinary team of experts and presented to potential users in various multipurpose formats (e.g., as a series of "thematic maps"). The gain made by using any one of these "multi" concepts may be either great or small, but the sum of the gains made by using several or all of them can be much greater than the mere sum of the individual gains. It is, perhaps, in this respect that the "integrated" aspect of our study assumes its greatest potential significance.

Thus our group remains poised and in a state of readiness on the very "eve" of what appears to us to be the two most significant photographic experiments in history, viz., those which will be ushered in with the successful launching of the ERTS-A and Skylab satellites, respectively.