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SECTION 40

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

by

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ABSTRACT

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 component of the earth resource "complex", 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. During the past two years remote sensing 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 resource 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. 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 these resources to be inventoried frequently and rapidly -- frequently so that resource trends can be followed -- rapidly 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 photography, are giving major emphasis to such considerations. These studies give particular consideration to the opportunities that will soon be afforded for satisfying these requirements through a combination of human and machine processing of ERTS-A data acquired (weather permitting) every 18 days. However, the wise management of earth resources in an area such as the state of California depends on far more than the mere acquiring of timely, accurate resource inventories. Even when given such information,

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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 paper, due consideration is being given to each of the foregoing factors in this "integrated" study.

INTRODUCTION

Most university faculty members cherish the privilege of working on research projects which are of their own choosing. In the university atmosphere a research scientist usually is permitted and even encouraged to devise his own research program, obtaining financial support for it as necessary through his own vigorous efforts. In fact, a major factor governing his rate of promotion within the university is his "creativity" as evidenced by his ability to perform such tasks.

The antithesis of such a project might seem to be embodied in the NASA-funded "integrated" study, which is the subject of my paper. That study is being undertaken by more than 20 senior scientists and approximately 40 graduate and undergraduate students on 6 campuses of the University of California. Each scientist participating in the study (details of which are about to be described) has found it necessary to sacrifice some of the research autonomy to which he has grown accustomed, in order to improve the degree of integration that might be achieved, and hence the overall effectiveness of the study. In addition he has had to demonstrate an unusual amount of adaptability in the reporting of his research results since there frequently has been a need for his contribution to be integrated into the overall progress report in a way that did not recognize his individual contribution as clearly as it would have been in more conventional studies. In view of these facts I would be remiss, in my capacity as principal investigator for our integrated study, if I did not take this opportunity at the outset to commend these participating scientists, eminent experts as they are in their own right, for the very high degree of adaptability and cooperativeness which they have demonstrated.

It is my privilege today, speaking on behalf of the many competent individuals who have been participating in the project, to do the following: (1) describe briefly the rather untraditional way in which our project got started, (2) indicate the specific nature of the project, (3) describe some of our research accomplishments to date, and (4) state what we hope to accomplish in the future.

ORIGIN OF THE INTEGRATED PROJECT

Early in 1969 the Director of NASA made a proposal somewhat along the following lines to the Director of the NASA-funded Space Sciences Laboratory of the University of California: "In addition to the research which your laboratory is already doing for NASA in such fields as planetary physics and systems analysis, it would seem desirable for you to consider doing work which is related to NASA's Earth Resources Survey Program".

These words of encouragement led to a series of planning sessions, most of which were participated in by faculty representatives from all of the major campuses of the University of California, together with one or two NASA representatives. The university scientists prepared various remote sensing proposals dealing with a large number of topics which ranged from the global monitoring of volcanic eruptions to the study of aerosols in the atmosphere. Among these was a proposal to conduct an integrated study of California's entire "resource complex" through remote sensing from aircraft and spacecraft.

Of these various proposals, only the latter led to funding by NASA, the first allocation of funds having been made in May, 1970. From the outset, half of these funds have been contributed by the NASA Earth Resources Survey Program and half by the NASA Office of University Affairs, but with a substantial amount of matching support by the University of California.

Since its inception this study 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 selecting the state of California for the test site included the following:

1. It exhibits a great variety of earth resources, landforms and climatic factors.

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

3. With respect to earth resource management, various social and environmental stresses already are being felt strongly, making California a model of things to come, both nationally and globally.

4. Many competent physical and social scientists now residing in California could be, and want to be, assigned to such integrated studies.

5. Appropriate NASA-funded facilities and associated administrative capabilities for the conduct of such studies already exist in California.

NATURE OF THE STUDY

It was recognized in our proposal to NASA that little would be accomplished under this integrated study if we attempted to investigate, at the outset, all components of California's entire earth resource complex, statewide. Ideally we would begin our study by investigating some phase of this complex which was both discrete and limited, but which nevertheless required a consideration of both the resource interrelationships and the attitudes of the people in a very sizable part of the state. Given these constraints and ambitions we tentatively selected the "California Water Project" as the focal point for this initial phase of our study. The word "tentatively" is used advisedly because it was recognized that resource managers and administrators, particularly within the Administrative Branch of the state of California, would need to be consulted in order to determine (1) whether such a study would meet with their favor or disfavor and (2) whether, in the event that we were authorized and funded to conduct such a study, mutually beneficial working relationships with resource managers in the Administrative Branch might be developed.

Initially there were some serious reservations expressed by personnel in the California Resources Agency, and elsewhere in the Administrative Branch, as to the advisability of our conducting those aspects of our study that related specifically to the California Water Project. They 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 recognized that it would be prohibitively costly and time consuming for us to attempt to acquire this same kind of "input" independently. However it was our belief, as expressed in our proposal, that this situation enhanced the usefulness of the state of California as a "calibration" test site, and of the California Water Project as a "calibration" project, so that our research findings could be 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. By the time these discussions had been concluded, an amicable relationship with the Administrative Branch had been developed and this fact was made known to the appropriate NASA authorities at the time when final consideration was being given to our proposal.

During the period in which we have been conducting this NASA-funded study, we have given numerous briefings to the appropriate individuals in the California Administrative Branch. In recent months this procedure has been responsible, in part, for the development of complementary rather than competitive ERTS-A and SKYLAB proposals by the Administrative Branch and the University of California, respectively. Evidence of the success that has thus been achieved, despite the fact that initially there were many formidable diplomatic difficulties, can be found in the following quotes from a letter to NASA from California's Lt. Governor Reinecke, dated April 13, 1971, the purpose of which was to comment upon the University's ERTS-SKYLAB proposal as viewed by the Administrative Branch: "On behalf of the State of California, I wish to take this opportunity to strongly endorse this proposal . . . Mr. Norman B. Livermore, Secretary-Resource Agency, and Mr. Earl Coke, Secretary-Agriculture and Services Agency, who represent the largest segments of state government utilizing this data, and who have contributed guidance and impetus to the proposed program, will provide further leadership and assistance as required".

The emphasis already given in this paper to matters of "protocol" is a highly purposeful one. For herein may lie the greatest determinant of future successes for the entire NASA-sponsored Earth Resources Survey Program. The skeptics are finally becoming convinced that meaningful resource surveys and related information of a highly detailed nature can be acquired primarily by means of remote sensing from aircraft and spacecraft. Therefore, many of them are becoming quite sensitive about the kinds of surveys that should be permitted. To ignore this fact in future studies conducted under the NASA Earth Resources Survey Program may be to ensure at the outset the ultimate failure of such studies. So important is this development, in the view of the present writer, that it will be referred to again in a concluding section of his paper, but with reference there primarily to its international implications.

FRAMEWORK WITHIN WHICH TO VIEW THE STUDY

A key word in the title of this study, which serves to differentiate it from other earth resource survey studies that have been funded to date by NASA, is the word "integrated". According to the dictionary, the term "integrate" means "to form into a whole; to unite with something else; or to incorporate into a larger unit". In order to appreciate how such a concept might best apply to the individual and collective efforts under this multi-campus project, let us consider the desires of two groups that are certain to be interested in this project and its findings.

On the one hand, there are those already referred to who need to make major policy decisions with respect to the earth resources in a particular geographic area and then to develop management plans that will permit those decisions to be implemented in an efficient manner.

On the other hand, there are data acquisition and data processing specialists who are interested in knowing (a) what package of remote sensing devices (and the associated aircraft and spacecraft for transporting these devices) might best be used to collect meaningful earth resource data on a global basis, and (b) what techniques and equipment should be used in extracting useful information from the acquired data.

The interest of both groups in having research done in the state of California results primarily from the fact that the findings made there by a competent group of scientists might be applied, with only slight modification, to vast parts of the globe which are, to varying degrees, analogous to the state of California in terms of the complex of earth resources exhibited and earth resource management decisions to be made.

The links of a chain which might serve to tie these two groups together are indicated in the diagram in Figure 1. Areas of research emphasis of the different campuses responsive to these different links are illustrated in Figure 2.

An additional way in which to view the links by means of which remote sensing techniques can be used to satisfy the informational requirements of various resource management groups appears in Figure 3. It is to be emphasized that our initial efforts, as suggested by the central portion of this diagram, have dealt with one resource -- the water resource -- and furthermore have been quite specific in dealing almost entirely with one example of that resource and the management problems associated with it, viz. the California Water Project. Even within this limited context, however, we are making a sizable 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 useful 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 employing these various "multi" concepts, as appropriate. 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 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.

NATURE OF THE CALIFORNIA WATER PROJECT

Because of the initial emphasis being placed in our study on the California Water Project, it is deemed appropriate to provide here a brief historical review and synopsis of that project.

The California Water Project is the first major water resource development under the California Water Plan. The masterplan was published by the Department of Water Resources (Bulletin 3) and approved by the State Legislature in 1959. It is the outgrowth of studies in the 1950's of the ultimate potential use of the land and water resources of the state as per Bulletins 1 and 2 of the DWR.

The State Water Project (see Figure 4) will deliver 4,320,000 acre feet of water annually to Central and Southern California. The major supply of water comes from the Feather River and is impounded by the Oroville Dam for subsequent release through the Sacramento River and the Delta pool to pumps on the south side of the Delta. Water is pump lifted to the South Bay Aqueduct and the California Aqueduct (244 feet).

The California Aqueduct, which will deliver the water to Southern California, carries the flow to the joint federal-state utility, San Luis Reservoir, the second major storage reservoir of the Project. Deliveries are made from the San Luis Reservoir to the federal Central Valley Project in the California Aqueduct for delivery to the southern San Joaquin Valley and Southern California. At the south end of the Central Valley, Project water is pump lifted nearly two thousand feet through the Tehachapi Mountains. South of the Tehachapi's the system divides into a West Branch for delivery to the MWD and a number of smaller contractors, and an East Branch for delivery to Antelope Valley-Mojave Desert water agencies and the balance of the MWD commitments. The terminal reservoirs for the project are Castaic in the East and Lake Perris in the southeast. The Project is the largest single water resource development undertaken in the United States. In addition to the transfer of 4,230,000 acre feet annually through 684 miles of aqueducts it provides a storage capacity of nearly 7 million acre feet. The project facilities will generate 5.3 million kilo-watt hours of electricity annually and consume 13.4 million kilo-watt hours annually at full development.

A number of essential features of the California Water Project are still in various stages of study and litigation. Future water supplies to augment the California Aqueduct and the Delta Pool may be needed before the project can operate at full capacity. A Peripheral Canal around the Delta has been proposed to protect the ecology of the San Francisco Bay and Delta areas as well as to provide for an adequate flow of fresh water. The Central Valley Master Drain to prevent soil salts from accumulating is still in abeyance until agreement is reached on repayment of its cost.

In total, the State Water Project is over 95% completed or under construction. As of late 1969 it was operational to northern Kern County. The tunnels through the Tehachapi Mountains are completed and most of the construction on the pumping plants has been completed, with the result that the first water from this project was delivered to Southern California in October, 1971. The aqueducts of both the West and East Branches of the system are under construction as well as the four major reservoirs, Pyramid Lake, Castaic Lake, Silverwood Lake and Lake Perris. The delivery of water to Los Angeles County is soon to be followed by delivery of water to both San Bernardino and Riverside Counties.

Water deliveries from Castaic Lake will be made to three water contractors. The principal user, Metropolitan Water District of Southern California, will receive more than 1.4 million acre feet per year from that facility after 1990. Water delivery at the Devil Canyon Powerplant near San Bernardino will include service to all the San Bernardino-Riverside area. When the terminus reservoir, Lake Perris, is completed, it will serve this area as well as the extensive water market which includes San Diego and Orange Counties. Water delivery from the Perris Reservoir is expected in the early months of 1973.

Financing for the State Water Project has been a problem area almost from its inception. At the time of its authorization in 1960 the cost was estimated at 1.75 billion dollars. Today the conservative costs estimates of the DWR amount to 2.8 billion dollars, while more liberal estimates project a cost of 4.0 billion dollars. Project customers will repay those amounts allocated to water supply, hydroelectric power and agricultural waste disposal amounting to 90%. The remaining 10% will be repaid by federal flood control funds and state tideland oil and gas revenues.

The California Water Project is only one of a number of large inputs into the Southern Coastal Hydrographic Unit. The local safe yield supplies and the imported water from Owens Valley and the Colorado River exceed the projected import of Project waters. The problems associated with water resources and water importation are numerous. The Project will alleviate such situations as sporadic water runoff, maldistribution of water supply, ground water overdraft and the intrusion of sea water. On the other hand, it raises and contributes to still other problems such as inadequate drainage, disputed water rights, water pricing policies of agencies such as the MWD and the general efficacy of water redistribution and the efficiency of water use.

UNIVERSITY PARTICIPANTS AND THEIR FIELDS OF STUDY

Figure 4 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 the probability of participation by scientists from that campus and from others whose research activities on our integrated project are of such a nature that they are not logically directed toward any one of the study areas shown in Figure 5.

A summary of the co-investigators on the various campuses and of the specific phases with which they are concerned is as follows:

1. Definition of earth resource policy and management problems in California

   C. West Churchman and Alexander Mood
   (Berkeley and Irvine campuses)

2. Definition of the information requirements of hydrologic resource managers

   Robert Burgy and David Storm (Davis campus)

3. Measurement of hydrologic resource parameters through remote sensing in the Feather River headwaters area

   Gene Thorley, et al (Berkeley campus)

4. Studies of river meanders

   Gerald Schubert and Richard Lingenfelter (Los Angeles campus)

5. Assessment of the impact of the California Water Project, the westside of the San Joaquin Valley

   John Estes, et al (Santa Barbara campus)

6. Assessment of the impact of the California Water Project, southern California

   Leonard Bowden, et al (Riverside campus)

7. Digital handling and processing of remote sensing data

   Vidal Algazi and Dave Sakrison (Davis and Berkeley campuses)

8. Investigation of atmospheric effects in image transfer

   Kinsell Coulson and Robert Wolraven (Davis campus)

The above listing of the various phases of our integrated study serves to indicate its unusually great breadth as compared with other studies that have been funded to date under the NASA Earth Resources Survey Program. Because of this breadth it has been necessary to give a considerable amount of thought to the question of how one might best report, in a brief paper such as this, the most significant results of our integrated study. As recently as 6 or 8 years ago the most effective report on such a project probably would have been one in which great emphasis was placed on the inclusion of highly colorful infrared Ektachrome photos of various portions of our test site, together with the inclusion of suitable annotations and captions indicating their usefulness in resource inventory. At that time most of the present participants in the nationwide NASA Earth Resources Survey Program had seen few, if any, infrared Ektachrome photos, even though others in the program have been working on such photography for nearly 30 years. The situation has changed dramatically in the last few years, however, to the point where most of us probably are weary of seeing the other fellow's latest infrared Ektachrome photos, however enthusiastic we may be about our own! *

Similarly, any such report, if given as recently as two or three years ago, might appropriately have placed its major emphasis on quantitative expressions of the extent to which certain important earth resource features can be identified on various kinds of imagery taken from aircraft and spacecraft. At that time there was a crying need for such quantitative information -- a fact that was vigorously pointed out by the NASA convenors of one of our annual reviews. This situation, likewise, has been dramatically rectified in the interim to the point that many of our present-day reports to NASA seem to be literally clogged with confessions about our "errors of omission", "errors of commission" and "probable levels of significance".

Many apsects of our 6-campus integrated study have, indeed, entailed the use of beautiful infrared Ektachrome photos. Furthermore, some of our findings are, indeed, highly significant to umpteen places and several degrees of confidence, if not overconfidence. These facts will be apparent to anyone who reads our periodic reports. However, there are other aspects of this study which would seem to merit even greater emphasis now that the concept of inventorying earth resources by remote sensing has come of age. These are aspects resulting from the attention which is being given in our integrated study to certain broad questions which pertain, not to resource inventory, but to resource management. Such questions are arising at this particular time in relation to the Earth Resources Survey Program primarily because of the following reason: The studies which many investigators, nationwide, have been conducting under that program are at last convincing the skeptics that it soon will indeed be possible to make meaningful earth resource surveys primarily by remote sensing from aircraft and spacecraft. Now that they are beginning to take us seriously, they also are beginning to raise some hard questions about the impact which such surveys may have, directly or indirectly, upon man and his environment.

But first let us provide a brief summary of some of our findings to date relative to the inventory of relevant components of the resource complex with which the California Water Project is concerned. Consistent with our previous description of this project we will report findings separately for the "source", "central" and "sink" areas.

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*In this regard a fellow scientist said recently, "Sometimes I think the whole world must be turning red".

REMOTE SENSING ACTIVITIES AND ACCOMPLISHMENTS IN THE SOURCE AREA FOR THE CALIFORNIA WATER PROJECT

The headwaters of the Feather River, principal source of water for the California Water Project, includes the NASA Bucks Lake Forestry Test Site. Under sponsorship of the NASA Earth Resources Survey Program, that test site had already been under study by University of California scientists for approximately 5 years before the start of the present integrated study. During this prior period, emphasis had been placed on determining the extent to which various kinds of earth resources (timber, forage, soils and water, as well as geologic and recreational resources) could be inventoried through the use of modern remote sensing techniques. Consequently, much was known at the start of the present study that was at least indirectly related to the problem of determining the volume of surface and subsurface flow of water by means of remote sensing. This is true because the volume of water which a watershed will yield during any given season obviously depends not only on the nature, amount and distribution of precipitation during that season, but also on the geologic, soil and vegetation characteristics of each portion of the watershed. Furthermore, since the remote sensing imagery used in these earlier studies had been flown to various specifications in terms of spectral regions, time of day, season of year and flight altitude, much also had been learned about the optimum specifications for remote sensing imagery used in estimating certain of the parameters which are known to affect water yield.

Our present studies in the source area are building on the base which was established by this previous work. Specifically, our investigators who presently are working in the Feather River Watershed area are concentrating on: (1) defining the parameters which are both pertinent to a determination of water yeild and discernible through the use of remote sensing techniques; (2) determining the accuracy with which the parameters can be measured and mapped using remote sensing data flown to various specifications; and (3) relating the water yield predictions thus made to actual water yield; both for the entire Feather River drainage and for various components of it.

In performing this work our investigators are being given an excellent opportunity to demonstrate the validity of one of the most important concepts on which the NASA Earth Resources Survey Program is based. This is the 2-stage concept of (1) initially making the earth resource survey studies on a relatively small but highly representative "calibration area", in this case the Bucks Lake Forestry Test Site of approximately 100 square miles, for which ground truth is accurately known. (In so doing the investigators determine the optimum remote sensing specifications and data analysis techniques for the type of earth resource survey that eventually is to be made operational.); and (2) then making at least a semi-operational evaluation of these findings on a very large "extended area", in this case the entire Feather River Watershed of approximately 3,600 square miles. Ordinarily the establishment of "ground truth" for so vast an extended area would be a formidable task in itself. In this investigation, however, the ultimate measure is the volume of water, in any given period of time, which is yielded by the entire watershed. Fortunately for purposes of our study, water from the entire Feather River Watershed is impounded in the Oroville Reservoir, where an accurate measurement of the volume of water that is present at any given time can easily be made. Thus a suitable check is readily obtainable on the accuracy of the overall estimate, for any specified period of time, as made by remote sensing. Similarly, since there is a dam and associated reservoir at the lower end of each of several sub-units of this drainage system, an accuracy check also is available for these sub-units. Consequently, if large errors of estimate based on remote sensing are found in certain of these sub-units, but not in others, an opportunity is afforded for making more detailed studies of conditions in these areas in order to determine the exact cause of the errors and thus to devise means of minimizing them in future studies. Authorities who control the volume of water that is impounded at any given time behind Oroville Dam (the largest earth-filled dam in the world, and more than 700 feet high) have told us that they greatly need more accurate information about the volume of run-off that can be expected from the Feather River Watershed during various specified periods of time. In the absence of accurate information, they must incorporate a very large safety factor in deciding upon the volume of "draw-down" which they must effect at Oroville Reservoir, particularly just before heavy spring run-off from the vast Feather River Watershed. Without such a safety factor there would be no way of preventing disastrous floods in the event that the rate and amount of spring run-off greatly exceeded expectations; but through use of such a sizable safety factor, in most years large amounts of water must be discharged from the reservoir and allowed to flow out to sea, even though that water could have been used to great advantage during the summer months.

None of the foregoing is meant to imply that haphazard techniques are currently being used by those who control the flow of water from the Feather River Watershed. To the contrary they are using some of the most suitable techniques currently available, while readily agreeing that there is a great need for more suitable techniques of the type that we are seeking to devise through our remote sensing research.

An important aspect of the research which our investigators are conducting in the Feather River Watershed Area seeks to develop means for better monitoring the rate of snow accumulation in the late fall and winter and of snow melt in the spring and early summer. Prior to the start of our present integrated study we had made only a few preliminary attempts to do this with the aid of remote sensing data acquired at suitable time intervals. Consequently we are in the process of improving our capability in this regard using photography flown at 18-day intervals by NASA's U-2 aircraft. At the same time we are converting our previously-developed classification schemes for the mapping of vegetation, soils and other components of the earth resource complex into schemes which will be more indicative of water yield. Details as to our accomplishments to date in these various respects will be found in our forthcoming progress report to NASA which is scheduled for completion in May, 1972.

REMOTE SENSING ACTIVITIES AND ACCOMPLISHMENTS IN THE CENTRAL AREA OF THE CALIFORNIA WATER PROJECT

A major part of our interest in this Central area (consisting mainly of the West Side of the San Joaquin Valley) is in using remote sensing techniques to monitor an agricultural region in its initial stages of development. As stated by Senger (1972), who is one of the participants in our integrated study: "This initial phase is important because it is a time of experimentation. Different segments of the local community often will devise a variety of approaches for developing the land. The results of these efforts may eventually produce a defined pattern to the landscape that will serve as a basis for labelling the area as a distinctive agricultural region or an extension of one already existing." Consequently, if this area develops into a distinctive type of agricultural region, our study could make a contribution to investigations that seek to explain the evolution of an area and the processes that help to determine its outcome.

As early as 1957 agricultural cropland had expanded about as far as it could within the West Side of the San Joaquin Valley until such time as water could be transported to the area for use in irrigation. Of the 1,350,000 acre feet per year of water which will be delivered to this area by the California Water Project, the overwhelming majority of it will be used for agricultural purposes. At the present time farmers in the area are attempting to discover what kinds of crops can be grown at a reasonable cost under existing environmental conditions, are readily marketable, and can show a good profit. Up to the present time there has been very little specific plant breeding for this environment and farmers are obliged to experiment mainly with crops which were developed for adaptation to other areas. Yet cropping is about the only alternative to the present widely practicied grazing of the area. For example, the area is quite isolated from population centers of California so it is not realistic to consider the development of an industrial park. Because of the marginal value of the land for crop production (prior to the importation of water from the California Water Project) no sense of urgency had been inspired to conduct more than general surveys of the soils, geology, vegetation and climate of the area. Consequently the avilability of water from the California Aqueduct has come at a time when no one could say for sure whether the area is suitable for irrigated agricultural development. Hence we see here a case in which technology (the construction of the Aqueduct and the subsequent influx of water) has occurred before the local populous was ready for it. Hence farmers are now having to learn about their local environment while at the same time having to grow crops that will enable them to stay in business. In addition, various irrigation systems are still being experimented with, and the whole landscape conveys the appearance on remote sensing imagery of being in an "experimental" state, which indeed it is. There are very large areas, now used only for grazing, which are available for more intensive agricultural development, but not likely to be developed until the end of this experimental period.

In a somewhat broader context, Spencer and Horvath (1963) have stated that there are six major factors influencing the development and the cultural processes of a landscape. They are psychological, agronomic, political, historical, technologic and economic. It is believed, from the studies which we have conducted to date in this area, that a final decision as to whether or not to develop irrigated agriculture can be attributed primarily to a combination of economic and psychologic processes. Farmers do not want to leave the area, but can they afford to stay? Water is being made available to them at a cost ranging from $8.00 per acre foot for subsidized federal water to $15.00 per acre foot for unsubsidized state water. While this may still leave some margin for profit, the farmers are in an unfavorable competitive position with those only a short distance to the east (on the East Side of the San Joaquin Valley) who pay only $2 to $3 per acre foot for water.

The first few sets of U-2 photographs that are being flown of this area by NASA at 18-day intervals have now been made available for our use. By means of this photography and appropriate field checking we will be able to continue our monitoring of both the short term and long term changes that are occurring in this area, particularly with respect to land use. While so doing we will be able to develop photo interpretation keys which will facilitate land use mapping in areas similar to this one on simulated space photography.

REMOTE SENSING ACTIVITIES AND ACCOMPLISHMENTS IN THE SINK AREA OF THE CALIFORNIA WATER PROJECT

Studies to date in this area have been largely confined to two specific regions: (1) the Perris Valley surrounding the future Lake Perris; and (2) the Sheep Creek Fan-Mirage Basin area of the Mojave Desert. Progress in studying remote sensing imagery in only the first of these two areas will be reported here, as being representative of the types of investigation being conducted by those scientists on the Riverside Campus of the University of California who are participating in this integrated study.

To date studies by that group in the Perris Valley Area have taken three approaches: (1) a land use survey has been made in a sample study area using both ground observations and interpretation of high altitude color infrared photography; (2) a survey has been made, partly through the use of questionnaires, to determine the attitudes of residents relative to the proposed changes to be made in the area because of the California Water Project; and (3) estimates have been made of the potential population changes and land value changes likely to occur in various portions of the area. These latter studies have been carried out using conductive sheet analog models. Future simulations will add greater realism to the models and should provide valuable insights to social, economic, and land-use planning problems within the area of interest.

At the time of this writing, our land use survey in the Perris Valley area has been confined to a sample area of one census tract which is located centrally to Perris Valley and adjacent to the future Lake Perris. The photography which our group initially studied of this area consisted of high altitude (1:50,000 and 1:100,000 scale) color infrared metric imagery flown in May, 1970. Additional photography recently has been obtained at frequent intervals by the NASA U-2 aircraft. Consequently, an inventory of the remainder of the area, and a monitoring of changes throughout the entire area currently are being undertaken through use of this photography.

Recently, it has been found that land developers in this area have established a number of locations for the promotion of present agricultural land for non-agricultural purposes and at non-agricultural prices. This activity appears to be directly related to future potential uses of this land for recreational and other purposes as a result of the construciton of Lake Perris. It appears from our studies that land developers and speculators play a significant role in determining the future land use in this area, including immediate changes in the region's land use patterns and activities. Consequently, in additon to the completion by the Riverside group of a survey of present land use in the Perris Valley area, the group is also attempting to assess the role and activities of land developers in the area and the direction and rate of change in land use for various portions of the area.

As detailed in our periodic progress reports, similar studies are being undertaken by the Riverside scientists in other parts of the so-called "sink" area of the California Water Project.

OTHER ACCOMPLISHMENTS TO DATE UNDER THIS INTEGRATED STUDY

The social sciences group which is participating in this study is using a systems analysis approach which seeks to optimize 3 types of models: (1) the data-collection and information-extraction model, from the viewpoint of those engaged in earth resource inventory; (2) the decision-making model, from the viewpoint of those engaged in earth resource management; and (3) the ultimate beneficiary model, from the viewpoint of members of the public who may benefit or be harmed by such decisions.

Part of this work is fitted closely to that of other investigators and is being applied to the geographic areas within which the previously-described studies are being made. Additional aspects of the work take cognizance of the fact that what is done with one kind of resource in one part of the state has broad implications with respect to other components of the resource complex within that area and also in other parts of the state. Consequently, a somewhat broader approach both geographically and disciplinary-wise is being taken by the Social Sciences group.

As with previously-described phases of our integrated study, the interested reader is referred to our periodic progress reports for additional details with respect to the very broad scope of activities currently being undertaken by the Social Sciences group.

A LOOK TO THE FUTURE FOR THIS INTEGRATED STUDY

Briefly stated, the direction of our activities in the immediate future under this integrated study will be along three general lines, all of which will be oriented toward maximizing our ability to make meaningful interpretations of ERTS-A data which we anticipate will soon be acquired of vast portions of the state of California: (1) continuation of studies on the California Water Project in the "source", "central" and "sink" areas along lines indicated in earlier sections of this report. (It is planned that these future studies also will include investigations of the Sacramento River Delta area); (2) initiation of studies in the coastal zone of California, within which 80 percent of California's total population is reportedly localized and for which resource monitoring, beyond that presently being accomplished, is vitally needed; and (3) continuation of studies by the Social Sciences group, particularly with reference to the third of its three "models", the "user" model. In addition, it is probable that our proposed work involving the making of regional agricultural surveys will be initiated, using San Joaquin County, California as the focus for that study.

The providing of further details relative to our proposed future activities would not be fruitful at this time and might even be considered presumptuous until the exact scope and level of funding for our integrated study are more clearly defined in conferences soon to be held with our NASA monitors.

CONCLUSION

As I look for some highly relevant note to sound in ending this presentation, I can do no better than to echo the sentiments of NASA's Dr. Wernher von Braun, which were expressed by him several years ago when the overall space program in general, and the Earth Resource Survey Program in particular, had come under rather severe criticism. Paraphrased, here are the comments, as well as I can remember them, which Dr. von Braun made to several of us on that occasion: Critics of the NASA program are bemoaning the fact that so much of this country's scientific talent, and in so many different disciplines, is being diverted into a single effort -- the space program. These critics imply that much more could be accomplished that would be of potential benefit to mankind if each such scientist were left to pursue a research program of his own choosing.

Dr. von Braun said that he viewed the matter quite differently: What these scientists from so many disciplines have needed for years is a large, peace-oriented focal point for these many talents so that the result of their efforts would be something far greater than might be expected from the sum of their individual contributions. He pointed out that NASA's Space Program in general, and its Earth Resources Survey Program in particular, provided the best opportunity to date for mounting such a worthy integrated effort.

Having been deeply involved in such an integrated effort through the project which I have just described, I find myself in complete agreement with Dr. von Braun's observation.

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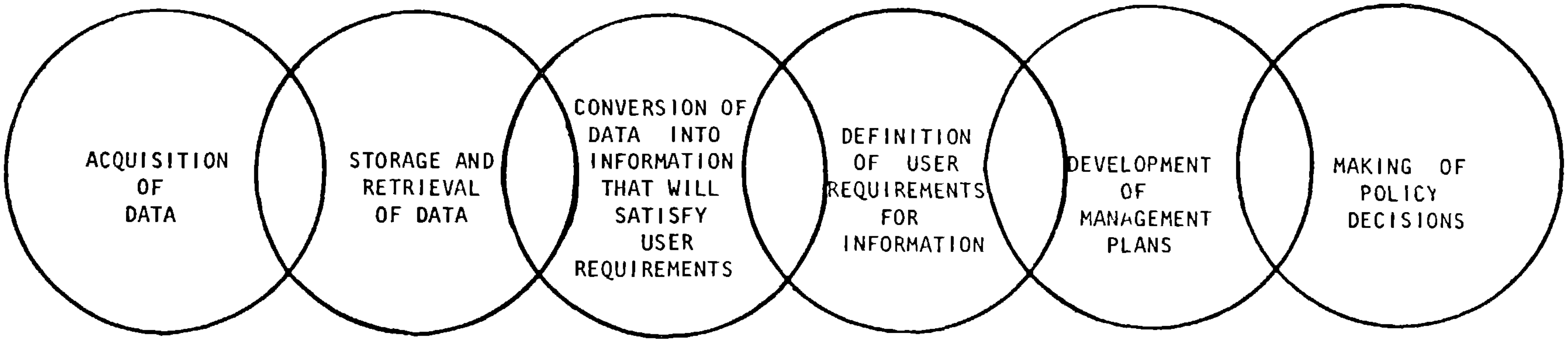
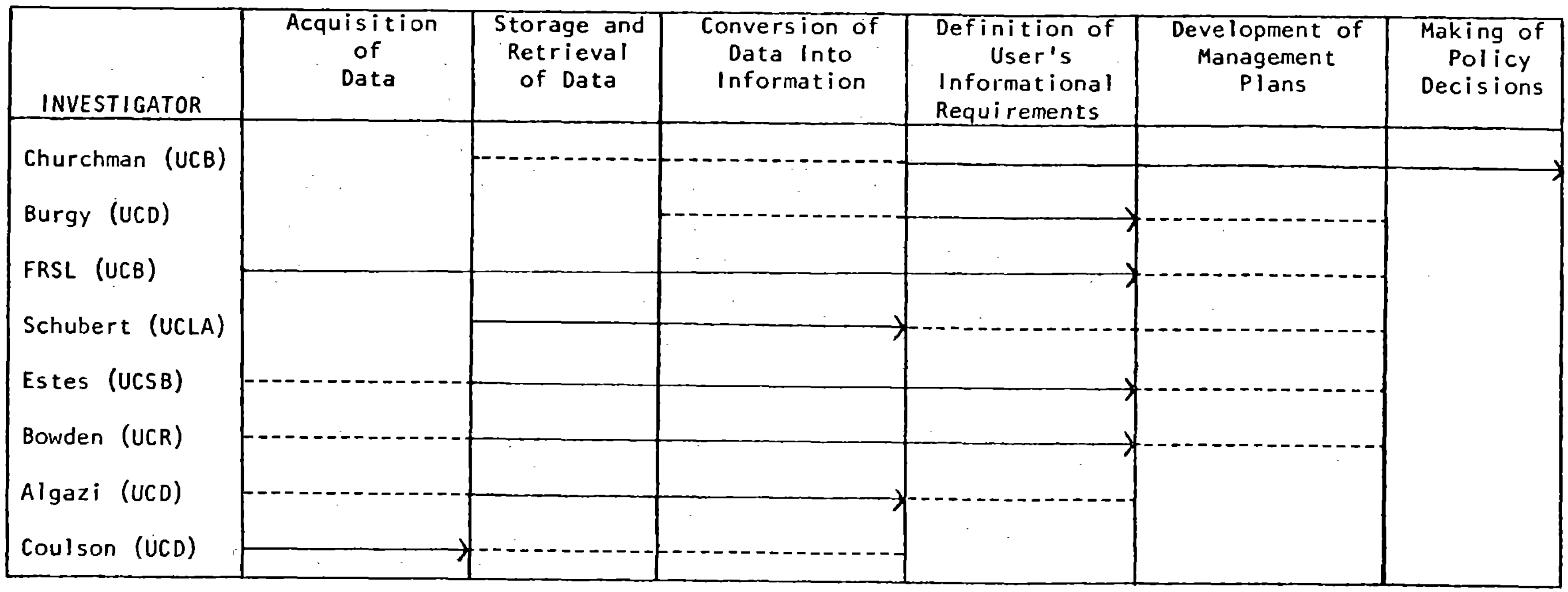


Acquisition of Data	Storage and Retrieval of Data	Conversion of Data into Information that will Satisfy User Requirements	Definition of User Requirements for Information	Development of Management Plans	Making of Policy Decisions
Specify spectral and spatial resolution characteristics of sensors, atmospheric constraints, target illumination and weight, power and volume requirements of the sensors. Specify performance characteristics of vehicles needed to transport sensors, including speed, attitude control, service ceiling, stay time and ability to satisfy weight, power and volume requirements of the sensor package.	Specify the "model" or "models" that will best facilitate the storage of data and its retrieval periodically by those who are to convert the data into information that will satisfy specific requirements of the various users.	Establish the "signature" for each type of earth resource feature that is to be identified, as a function of its spectral, spatial, goniometric and temporal characteristics. By proper use of humans and ADP machines, provide an "in-place" delineation, area-by-area, of each type of earth resource, including vegetation type, soil type, water quantity and quality, topography, culture, and multi-resource interrelationships.	Precisely define the kinds of earth resource information needed by those who must develop and implement management plans and policy decisions; also define the speed with which these types of information must be provided following acquisition of remote sensing data, and the frequency with which these kinds of resource information are likely to be needed by the various users.	Determine, for example, how best to manage the watershed with a view to multiple use management; also how and where to store water and to develop and distribute hydroelectric power from it. Also, how best to transport water to farmlands, urban areas and other places of water consumption.	Determine, for example, whether to encourage or discourage (1) the growth of a megalopolis in a particular area, (2) the intensification of agriculture in a second area, etc.

Figure 1. LINKS BY MEANS OF WHICH REMOTE SENSING TECHNIQUES CAN BE USED TO SATISFY THE INFORMATION REQUIREMENTS OF VARIOUS RESOURCE MANAGEMENT GROUPS



——— = primary emphasis by the investigator

- - - - = secondary emphasis by the investigator

Figure 2. AREAS OF RESEARCH EMPHASIS OF THE VARIOUS PARTICIPANTS IN THIS INTEGRATED STUDY OF EARTH RESOURCES

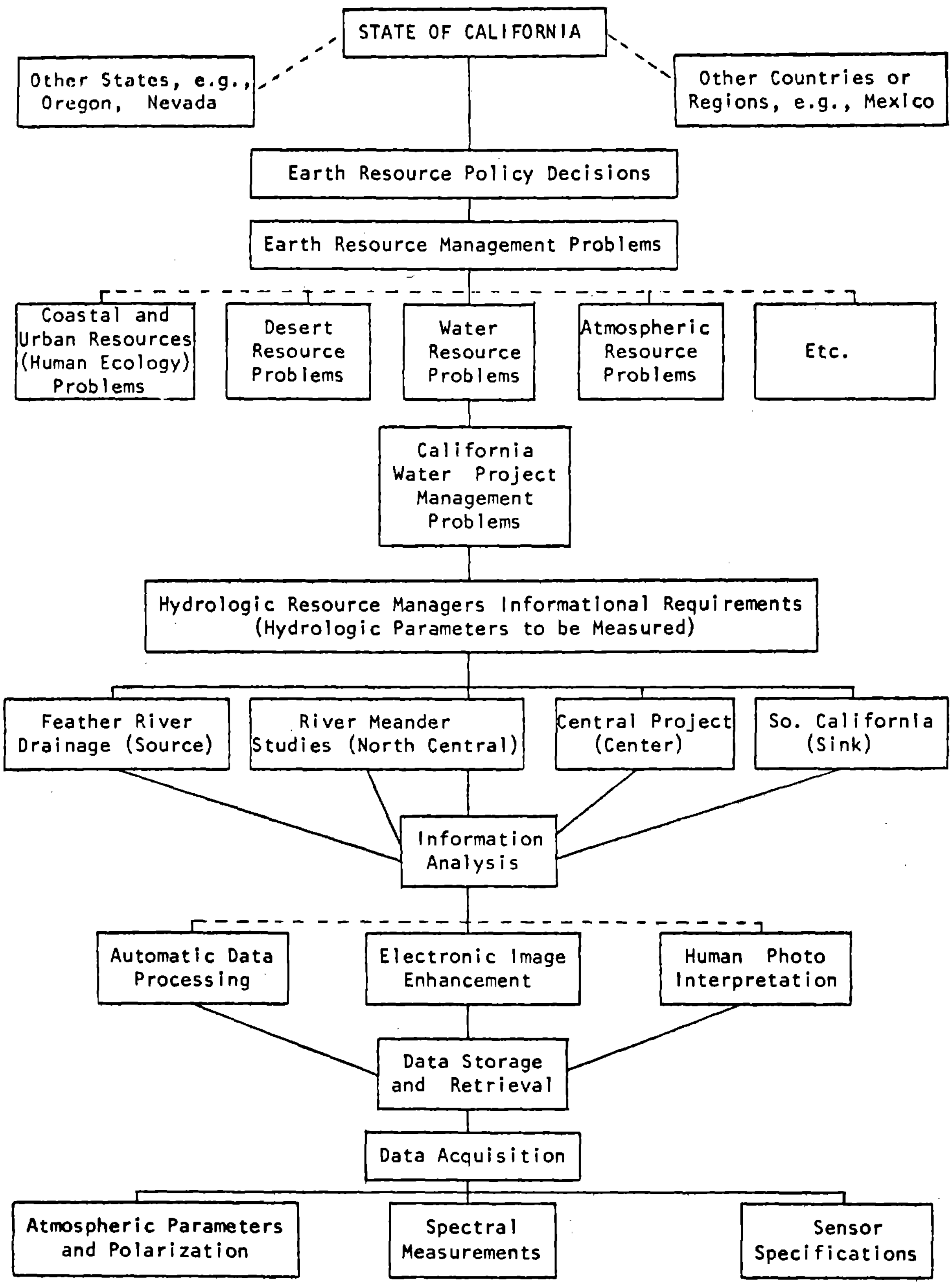


Figure 3. DIAGRAM ILLUSTRATING THE STRUCTURE OF THE INTEGRATED PROJECT AND ITS RELATION TO OTHER CRITICAL RESOURCE PROBLEMS IN CALIFORNIA

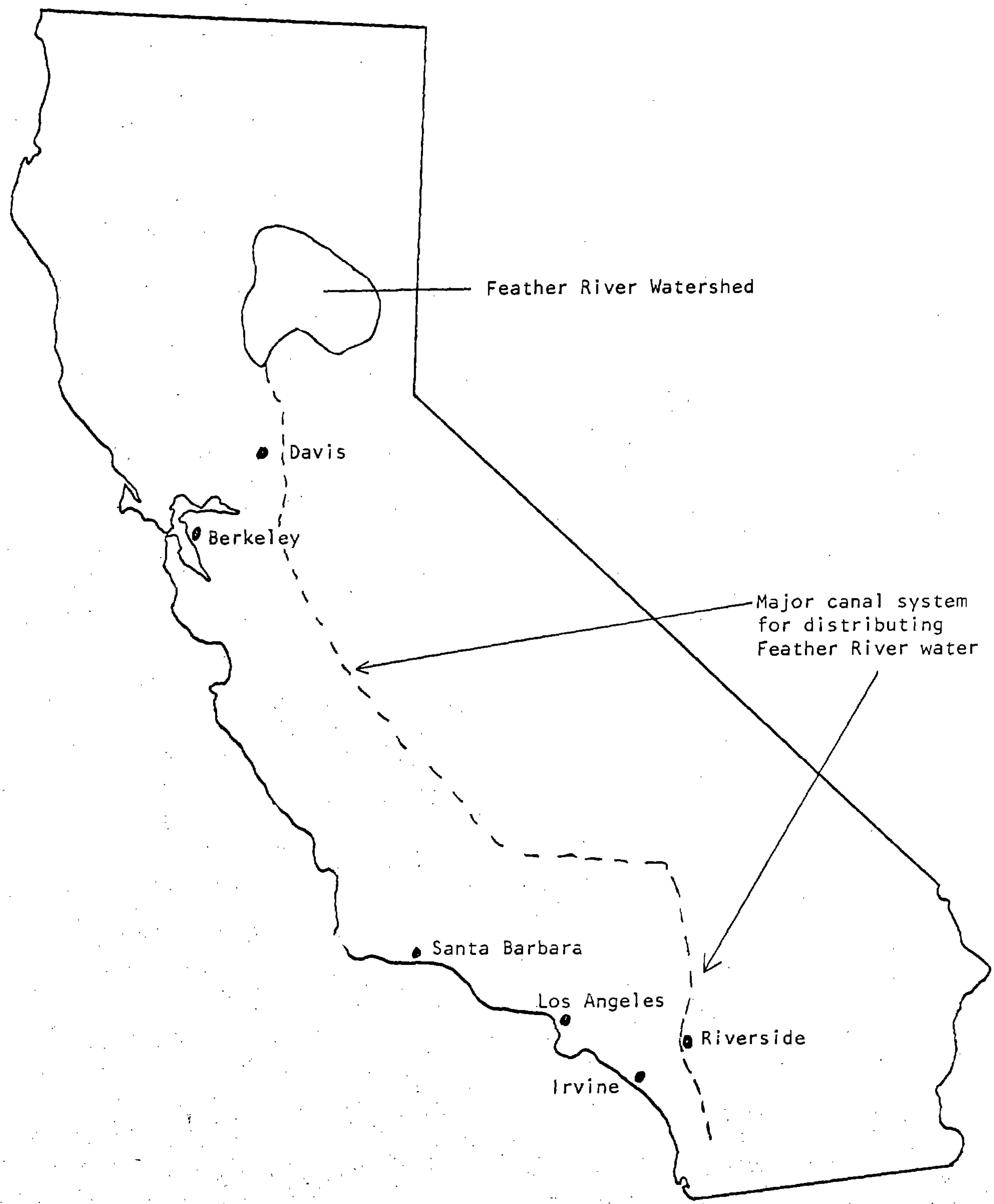


Figure 4. Location of participating campuses that are involved in the Integrated Study and their relation to the California Water Project.