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The Management Of Irrigation Systems For The Farm

AN INTERPRETIVE SUMMARY
OF
THE ADC/RTN IRRIGATION SEMINAR
HELD AT CORNELL UNIVERSITY, OCT. 16-18, 1972

GILBERT LEVINE, HAROLD CAPENER, AND PETER GORE

Acknowledgements

Special appreciation must be expressed to the preparers of the case studies which formed the focus of the seminar discussions: Mr. Kaya Bozkurt, Mr. Ko Hai-Sheng, Mr. J. Luis Mendez-Arocha, Dr. P. S. Ongkingco, and Mr. H. Shipley.

Introduction

Origin of the Agricultural Development Council Research and Training Network Irrigation Seminar

In February 1971 the Agricultural Development Council invited fifteen physical, biological and social scientists to meet in Logan, Utah, to explore potential areas of research on Water Resource Development Problems of Less Developed Nations. Three general areas of focus emerged from the Logan discussions:

1. Water control requirements associated with the "seed-fertilizer revolution"
2. Project feasibility analysis improvement
3. On-farm water management improvement.

Subcommittees were designated to consider the potential for continued interaction among RTN participants in each of the problem areas. Review of the literature and direct contacts with the International Research Institutes indicated that the scarcity of information concerning water requirements of new seed-fertilizer technology essentially precluded effective interaction at the present time. The feasibility analysis group decided to explore the role of the economist in providing effective inputs into the policy decision process.

The water management subcommittee decided to focus on the critical aspects of human and institutional factors associated with the interaction of farmer and system. Although the paucity of research concerning these factors was recognized, the consensus of the group was that generalized understanding and specific interests in this problem area were sufficient to make further collaboration fruitful. The mechanism for this interaction was to be the development of a research instrument, essentially a "profile for the evaluation of irrigation systems at the local level." This instrument would serve to identify the critical factors and interrelationships associated with successful irrigation management within a system context.

Both the "feasibility" and "water management" groups met at Colorado State University in August 1971. After two days of exploration, the feasibility analysis group, primarily economists, concluded that the uncertainties associated with the physical variables precluded any additional input of value by economists. Subsequent meetings of the group were not scheduled.

Each of the participants in the water management group, representing a range of disciplines, brought a "profile" to the meeting; these strongly reflected the disciplinary orientation of the individual preparing it. While spirited discussions established general areas of agreement, no specific instrument was developed. The need for both additional research and for input of system operators was cited. Participants generally agreed that the physical and biological science areas were more definitively defined than the social science areas, that a coordinated/integrated approach was necessary, and that lack of understanding between these areas inhibited effective interaction. At the conclusion of the meeting the subcommittee recommended that a seminar which would bring together a group of broader expertise and experience be designed.

A meeting at Tucson, Arizona in December 1971 resulted in the following agreements: (1) that an international seminar be held at Cornell University in October 1972; (2) that four or five case studies be commissioned by authors having first-hand acquaintance with the design and operation of irrigation systems; (3) that the case studies represent different developing regions of the world, i.e. the Philippines, Taiwan, Eastern Europe, Latin America and the United States; (4) that a profile or frame of reference be provided as a guide for each writer in the preparation of the case studies; (5) that the final participants in the program include a selected group of researchers, administrators and key officials concerned with the problems of design, operation and evaluation of irrigation systems and, (6) that a "conceptual" paper be prepared to serve as the initial basis for consideration of the case studies

Subsequently, five individuals with irrigation system experience joined in the seminar development, through the preparation of case studies representing a range of system types. The individuals, and their respective case studies, are listed as follows:

1. Mr. Ko Hai-Sheng—The Chia-Nan Irrigation Association, Taiwan
2. Mr. Henry Shipley—The Salt River Project, U.S.A.
3. Mr. Kaya Bozkurt—TOPRAKSU, Turkey
4. Mr. J. Luis Mendez-Arocha—The Las Majaguas Project, Venezuela
5. Dr. P. S. Ongkingco—The Laoag-Vintar and Nazereno-Gamutan Projects, The Philippines.

The Seminar, Cornell University, October 16-18, 1972

The Seminar was based on a set of assumptions established by the planners:

1. That a realistic and functional conceptual framework can be articulated and used as a framework for examining actual case studies of irrigation systems.
2. That a rough, profile frame of reference will enable writers from different regions of the world to prepare and document selected case studies in such a manner that the studies can be analyzed and compared against the framework and each other.
3. That the prior distribution of case studies allows participants to become familiar with the material before the formal seminar.
4. That the presentation at the beginning of the seminar of a theoretical and conceptual framework for a total interactive irrigation system design will facilitate:
   a. Analysis and dissection of the case studies.
   b. Insight into the interactive dependencies of physical, biological and social science variables in a system level analysis.

Under ADC sponsorship the seminar convened with forty participants representing eight universities, ADC, The Agency for International Development, the International Bank for Reconstruction and Development, the International Rice Research Institute, and the Rockefeller Foundation. (See Appendix 1 for list of participants.)

The basic assumption—that with the keynote paper as a base, the seminar participants could rapidly develop a conceptual framework of sufficient utility to guide the analysis of individual case studies—failed, but the reasons for failure are not entirely clear. Undoubtedly, the time necessary for effective interaction of individuals with different disciplinary backgrounds was a contributing factor. In addition, although conceptual understanding of *individual* aspects of the irrigation management problem exists, evidence indicated that a unified conceptual understanding for viewing real world irrigation systems in their entirety did not exist.

Furthermore, the case studies lacked the degree of interdisciplinary depth anticipated. First, the profile guide given the writers to prepare the cases lacked detailed specificity. Second, the depth of analysis desired seemed to require an interdisciplinary team rather than an individual author, even one with a broad professional background.

The case studies were prepared and distributed to seminar participants sufficiently far in advance for adequate study prior to the seminar.

Because the basic assumptions did not hold, the seminar committee has organized the summary according to a sequence other than the format of the seminar itself. We believe that the summary, as outlined in the table of contents, reflects the substantive *outcomes* of the seminar deliberations and presents them in a form more efficient than a more traditional summary.

This interpretive summary takes a more empirical approach which was effectively utilized by Dr. A. Mosher in his closing remarks (Part VIII). Specifically, the empirical approach deviated from both the broad conceptual view and from the individual farm viewpoint; the decision-action sequence associated with the design process forms the basis of the approach. The substantive material in the summary, therefore, represents the inputs from all seminar participants, but the authors are responsible for the organization of the material as well as for the interpretation placed upon it.

System Goals and Objectives

The fact that the identification of goals and objectives precedes the design of an irrigation project and its associated system was generally agreed upon by seminar participants; but the nature of appropriate goals was subject to extensive discussion, and no real consensus was reached. *Increased productivity* was a generally recognized goal, but whether this productivity was to be *primarily* economic *production* or *human development* was not resolved. Non-economic goals identified included political, social, cultural and aesthetic goals. Most of the larger projects were viewed as having *multiple* goals, and it was recognized that *all* could not be pursued with equal effectiveness. Thus, the importance of *priority* within a multiple goal context was cited. Both production and human productivity goals were in evidence, singly and in combination, in the project case studies. While production was emphasized in the U.S., the Philippine, and early Taiwan projects, greater emphasis was placed on human welfare aspects in the Venezuelan project. The later Chia-Nan system exhibited combined goals.

Recognition of differences between the *public* perspective and *personal* perspective in viewing the goals and the mechanisms for achieving the goals was less evident in the case studies. Even when stated goals of a project included a priority toward human development, problems occurred when the view taken by the planners and/or system operators was at variance with the perspective of the population to be served. The difficulties experienced in the Las Majaguas Project demonstrate this aspect. The seminar also raised the problems of identifying personal goals and the perspectives of groups and individuals to be served by the projects. Except for stressing the importance of greater sociological input at early stages in project development, however, these questions were not resolved. It was also recognized, however, that personal goals and perspectives need not be met in order for a system to achieve specified goals, provided the special requirements imposed by this duality are recognized. For example, the early Chia-Nan project, with a relatively narrow goal of increasing rice production for export to Japan, could achieve this goal through the use of police power, even though the goal was not necessarily a personal one among the farmers.

Another difficulty in developing stated goals is the problem of identifying the *implicit* goals that frequently exist or develop during project formulation. These implicit goals, often of a political character, may strongly influence project design. Their importance was stressed frequently during the discussions.

The second step in the initial stage of system planning is the translation of more general goals into specific project objectives which, when aggregated, lead to goal achievement. There was relatively little discussion of this phase, but certain evidence, for example, in the Las Majaguas project, indicated that major problems can result when specific objectives are not consonant with ultimate goals.

The major conclusions of discussions in this general area seem to be that in order to meet project goals, effective system design and operation requires: (1) an accurate recognition of these goals; (2) a reasonable congruence or compatibility among them; (3) translation of these goals into appropriate objectives; and (4) where conflicts between project goals and individual goals exist, the design must have adequate means for resolution.

The Design Process

Having established the objectives of a proposed irrigation project, the system design process can be classified into five stages: (1) initial inventory, (2) preliminary decisions, (3) detailed inventory, (4) specific decisions, and (5) evaluation and revision. Throughout this process, a concept of "relativity" is operative.

A Concept of Relativity

Basic to the design of an irrigation system is the classification of environmental elements as "absolute," "fixed," or "manipulable." Those components of the environment considered unchangeable, either by virtue of technical limitations or as a result of overwhelming considerations, are considered *absolute.* Components which can be changed exist on a continuum of facility and cost. At one end of this continuum are components for which technology is readily available for economic manipulation; these are typically identified as *manipulable.* At the other end of the continuum are aspects for which the available manipulative technology is uncertain and expensive; these components are typically classified as *fixed.** Between these two extremes any component can be considered either as manipulable or as fixed, depending upon relative benefits and costs. Frequently these decisions are made early in the design process. Subsequent design reflects an accommodation to the constraints of the absolute and fixed variables and a definition of the desired change in the manipulable variables together with the mechanism for effecting this change.

If an irrigation ssytem is "a complex interaction of physical, economic and social components" (the definition accepted by the seminar), the identification of absolute variables and the specification of fixed and manipulable variables must apply to all three areas. The case studies and the discussions suggest that this identification and specification is most explicit in the area of physical environment and least explicit in the social area.

Inventory

Physical environment aspects are more thoroughly recognized, studied, and incorporated into the design process than are the other components associated with irrigation systems. In addition to the generally recognized fact that irrigation is a direct manipulation of the physical environment, the seminar identified two fundamental reasons for the emphasis on the physical environment: first, relatively strong conceptual bases for understanding the physical environment exist; and, second, these conceptual bases have been simplified to make them operative for specific applications.

For example, the processes of soil formation are reasonably well understood. This understanding permits a *generally recognized* system of detailed soil classification. The classification provides the mechanism for communicating basic information about physical properties of soil. The hydrologic process associated with rainfall, runoff, and evaporation are sufficiently well known to indicate what data to collect to characterize the water phase of the environment. Similarly, other major aspects of the physical environment have conceptual bases to facilitate general understanding. Even their interrelationships have a conceptual base in physical ecology. Furthermore, understanding is not limited to concepts. Design consideration of the numerous individual components of the physical environment would be extremely difficult for a project of even moderate size. It would require major investments of skilled technical and professional manpower. Techniques have been developed, however, which permit the grouping of components with related characteristics from the standpoint of irrigation. This grouping, usually in the form of an irrigation capability classification, provides a basis both for selective collection of information (a complete inventory is not necessary) and for easier utilization of that information. At the same time these classifications reflect an identification of absolute, fixed and manipulable variables including implicit attitudes toward ecological change and assumptions about available technology. Hence, the classifications introduce errors to the extent that these attitudes or assumptions are in conflict with the objectives of the project or fail to reflect the state of the art.

A limited conceptual base also exists for understanding the economic environment, with some aspects more generally agreed upon than others.* The relevance of concepts based upon the experience ot developed countries is open to question when applied to low-income countries. Furthermore, the lack of concepts appropriate to non-capitalistic economies indicates an incomplete basis for understanding. Nevertheless, certain concepts and some specific tools, such as supply-demand-price surveys, are available as a means to incorporate economic information into the design process.

The inventory and subsequent recognition of social-institutional-organizational considerations in the design process are hindered by a number of factors. For example, the variables relevant to irrigation behavior are not as well identified and established as are the variables of the physical environment. It is recognized, however, that these variables are relational in character and therefore dynamic rather than static. Thus, measurement is relatively difficult. Measurement is further compounded by the fact that measurement instruments must be calibrated with reference to the site situation. Added to these problems is the significantly longer time scale to effect social change; by comparison to that for the engineering of physical change.

The reasons for the differences in degree of understanding and subsequent utility of different factors within the design process are related to differences in the character of the environments and to the extent of available expertise. The physical environment, governed by complex but relatively fixed relationships (at the level we are considering), is easier to comprehend than either the economic or social environment. Only a few social scientists other than economists are working on problems related to irrigation projects, and these few are confronted with a serious ethical problem. Ethical questions also arise among those evaluating the physical environment—for example directly through attitudes toward environmental impact—and among economists—in considering the impact on employment or income distribution—but not as sharply as among sociologists and anthropologists.

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* In this context, "fixed" does not imply "unchanging," but rather non-manipulable given the constraints applied.

* This understanding, however, appears to apply only to the economic environments of developed, capitalist nations.

The seminar discussion illustrating the problem developed three alternative approaches to the role of the social analyst in the planning of resource development projects: first the neutral approach, in which the social scientist simply reports on whether a given technical arrangement is compatible or not with particular social arrangements, leaving the decision to the technicians and administrators. Second, a "disciplined commitment" approach, in which the social scientist makes a kind of sociocultural benefit-cost analysis, points out particular damage that might result to the society from particular technical changes, and recommends alternative schemes to avoid these consequences. The third approach, called the "social advocate," may be followed when the social analyst comes down hard on any technical change which threatens the cultural or human rights component, and usually suggests that existing methods of resource development are probably less harmful ecologically and sociologically. A main point about these approaches is that none has become standard, and an individual social analyst may fluctuate between the three on one assignment, depending upon the magnitudes of impact, and personal values.

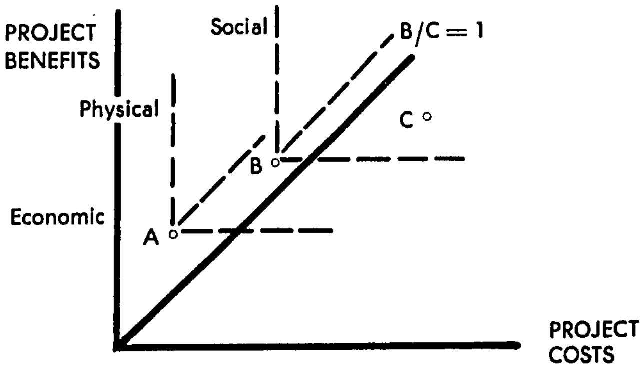
While acknowledging this problem, the seminar did not explore the extent to which this dilemma and the resulting lack of appropriate expertise cause the failure to incorporate social factors into the planning process. This was clearly revealed in the Las Majaguas Project case study, where major probems were associated with differences between anticipated and actual behavior. By contrast, in the Chia-Nan Project the Japanese, who vested strong authority over farmer behavior through system operating personnel, displayed recognition of social aspects of the environment, whether implicit or explicit. In the Philippine projects and in the Salt River Project, the "grass roots" type development automatically reflected prevailing social conditions, and relatively few social components were changed.

Preliminary Decisions

Once the environmental inventory is available, designers decide which components are manipulable and which are fixed. In the Las Majaguas Project major components of the total environment were considered manipulable: the land surface was to be leveled; new cropping patterns developed; economic relationships altered; and social relationships radically changed. In the Chia-Nan Project major differences in soils were accepted as fixed, but water distribution practice was to be changed. Furthermore, social relationships were to be altered. In the Philippine projects the major changes were confined to the water environment.

Within this decision-making context the seminar raised the question: "who makes the decisions?" Two particular concerns were raised in relation to major projects. First, international consulting firms or their domestic equivalents have design responsibility, and their designs reflect attitudes toward the environment which may vary significantly from those of the people to be "assisted." Second, the "distance" between the designers and "people" frequently is such that attempts to relate to the desires and attitudes of the prospective project participants fail because so little is actually known of the reality of the local situation. A comment during the seminar, "all designers should have to operate the systems they design," is a reflection of this problem.

Compounding the decision-making problem is the role of benefit-cost analysis. Both benefits and costs associated with proposed changes in the physical, economic, and social environments were generally recognized by the seminar. But the weight assigned to the *analysis* of benefits and costs as a basis for decision was a matter of disagreement. Figure 1 illustrates the problems raised.



Benefit-cost scales are illustrated for the economic, physical and social environments. For the case illustrated, consideration of only the economic benefits and costs, pt. A, would suggest a favorable situation. Adding consideration of a moderately adverse relative impact on the physical environment, e.g. some downstream effects of a large reservoir, shifts the overall benefit cost to pt. B, which still would suggest a favorable case. When the social benefits and costs (in this illustration very adverse) are added, pt. C is obtained. The project no longer appears as favorable as when only economic factors were considered. Thus, reliance on any one basic component can lead to erroneous conclusions about the viability of a project. However, major difficulties in applying these ideas exist.

The difficulties associated with B/C analysis in the economic area are well known, but application of this analysis to social and physical (non-conventional) environmental areas is much more difficult. Thus, during the seminar the contention was that reliance on B/C analysis tended to minimize consideration of social and physical environmental costs. Participants argued that greater emphasis should be placed upon *principles,* or philosophies, of approach to development. Counter arguments stressed the need for the use of some type of analysis independent of "fixed" ideas until something better than a benefit-cost analysis was developed.

Design Specifics

As indicated earlier, the fundamental basis for a detailed design is the accommodation to absolutes and fixed environmental variables, together with the definition of changes in the manipulable components.

General Approach

Following the initial decisions concerning the objectives of a project, the environmental inventory and the identification of variables, designers turn to preliminary considerations of the technical character of the project. For example, a basic approach of gravity irrigation rather than sprinkler irrigation might be made, or storage vs. run-of-the-river or groundwater. These decisions are based upon evaluation of the inventory, supplemented by assumptions (explicit and implicit) to fill in gaps in the data. All the previously raised questions about assumptions are applicable here. The case studies suggest that those projects considered successful had fewer assumptions, particularly in the area of human responses, than projects in which severe difficulties were encountered.[1]

To varying degrees, as gaps in information are identified, additional information is sought through experiments, field trials, and surveys. In most cases, the emphasis is on factors relating to the physical and directly associated economic environment. With yield discounts of 50 percent not uncommon, the question of the reliability of results obtained from experiments was raised. The approach of the Chia-Nan system, however, in which large numbers of directly applicable experiments were conducted by the Association, suggests that reliable results can be obtained. Field trials were recognized in the seminar as an appropriate technique for filling in gaps as well as for verifying assumptions and extrapolations. Some emphasis was given to the possibilities of using a field trial aproach in the social area. Examples such as the pilot irrigation associations in the Penaranda and Upper Pampanga River Projects in the Philippines were cited. The problems of transference and the need for conducting these trials in the project area were stressed; these problems were exemplified by the failure of large numbers of trainees studying rotational irrigation in Taiwan to initiate the practice in their home countries. Extrapolation is also a problem in the use of surveys, but primarily from a time point of view. The utilization of past experience in the identification of appropriate new practice has not been adequately explored.

Throughout this process of determining approaches, techniques, and specific activities, the effects of a change in one variable on other components of the environment must be recognized in order to minimize mistakes. Interaction effects were stressed repeatedly throughout the seminar.

Design of Physical Components

The specification of changes in physical components and in the mechanisms for achieving these changes typically constitute the major portion of system design. Water-supply development, water conveyance, and water distribution are the primary physical components. Secondary components such as roads and power may be included depending upon project size.

The case studies illustrate the range of physical components in irrigation system design. The Philippine communal systems were limited to improved water diversion and distribution structures. The Chia-Nan System included water storage, diversion and distribution structures, and components directly related to farming practice (e.g. crop suitability for different soils). The Majaguas system included the above mentioned components together with development of related physical infrastructure, such as individual homes, villages and towns. The Salt River Project dealt with all of the direct irrigation-related physical components, with the added element of power generation.

Within the context of physical component design, decisions made seem to be primarily technical, but in reality they have major implications and make major assumptions about behavior in the social-institutional-organizational and economic areas. The extent of these implications was explored through consideration of the *design diversion requirement* (the amount of water to be diverted from the water source per unit area served).

The water required to meet the physical environment demands (at maximum unit area production) can be estimated to a reasonably precise (±10%) degree for a variety of physical situations). The design diversion requirement is typically larger than this as a

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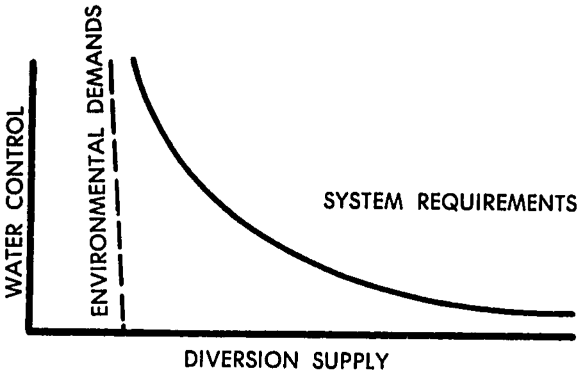
[1] (This is not to say that behavioral change was excluded from system development in the successful systems. For example, in the Chia-Nan system the Japanese anticipated the need for a relatively high degree of farmer cooperation in water distribution, and, provision was made for a high degree of control of farmers' action through the use of police forces. Subsequently, under the Chinese, modifications in the design to permit rotational irrigation were implemented with political support [including the arrest of obstructionists] as well as with the necessary physical structures. By contrast, in the Majaguas Project a relatively high degree of irrigation sophistication was expected, and the engineering specifications reflected this expectation. Farmer irrigation practice, however, was far from that anticipated. Adequate training and/or control of the farmers were not provided.)

result of incomplete control of the water as it moves through the system to the crop. The concept of efficiency is utilized to arrive at the diversion requirement. For example, water application efficiency is an indication of the degree of water control beyond the system *turnout;* similarly, the conveyance efficiency is a function of control between the *turnout* and the *diversion* point. The overall design *water use efficiency* (diversion to crop) for many systems is 50 percent, as in the Majaguas system.

With its implied values that high efficiency is good and low efficiency poor, this concept has a number of associated problems. From a primarily physical standpoint, it has questionable utility when the available water supply is substantially in excess of environmental needs. For example, in the Nazereno-Gamutan System in the Philippines where a flow of 3000 liters/second is readily available for 1200 hectares cropped and rainfall contribution is substantial, a design diversion based upon a relatively high water use efficiency would have little direct value (unless drainage was a problem). Yet it would be unusual to see a "modern" design that specified a 30 percent efficiency level (even though many systems are operated at this level or below). Generally, the efficiency concept has limited utility in situations where water storage is not provided. The problem is compounded in humid areas (as in the Taiwan and Philippine systems) by the contribution of rainfall.

The broader problem associated with this type of "technical" decision is illustrated by the paradigm below:



As the design diversion requirement is reduced, there are direct requirements for increased water control. This water control is effected through a combination of physical facilities (e.g. gates, measurement devices, lined canals, etc.), utilized in accordance with appropriate delivery plans. Generally, to achieve greater control, more skilled irrigation-system personnel at all levels including the farmer are needed, as well as an extension of control to smaller areas, and closer liaison between farmer needs and system operation. Unfortunately, while it is possible to put units on the abscissa of the paradigm and to identify systems with water diversions of different ratios, the units and composition of the ordinate variable are not clearly understood relative to the physical environment requirements. Thus, experience, usually that of the engineers, is relied upon. Examples of success in identifying the essential physical elements of the control infrastructure, as well as examples of the lack of success in identifying the essential social and organizational elements abound. The Majaguas case study explicitly made this point.

Another significant aspect of the design of physical components is the identification of anticipated cropping patterns, and the seminar raised questions about the validity of these projections. Particular concern was expressed over the use of projections radically different (in terms of type of crops) from existing patterns. To be successful, changes of this type usually require new information, new skills, and new marketing arrangements. Thus they require not only economic justification but also evidence of probable acceptance. The extent to which B/C analysis influenced a shift from the "more probable" cropping patterns (in terms of actual farmer practice) to more "possible" was not defined during the seminar. But the exertion of this influence, and the fact that influence was greater when other pressures for project implementation were strong, was the consensus of participants.

Seminar participants also generally agreed that interactions were inadequately understood, both in terms of their effects on system performance and in terms of requirements for success. Inadequate understanding of interactions exists *among* as well as *within* the physical, economic and social components. Examples within the physical area are the interactions among production inputs such as fertilizer, variety, and water.

In addition to easily recognized interactions the seminar raised the effect of interaction with *time.* Most time estimates associated with system design were seen as underestimates, particularly as they related to changes in the behavior of individuals and institutions. It was felt that in several instances, prospects for project success might be considerably enhanced by staged development. While staging is frequently included in project design, it is usually limited to the *rate* of implementation of specified elements. For example, the size of project area served might be staged, as in the Majaguas Project, to match projected extensions of channels or to match the rate of on-farm land levelling. Rarely is staging considered for the purpose of providing time to accumulate and feed back experience to the designers, or for farmer expertise to be developed. Often, even in projects where "pilot" areas are designated, real provision for incorporation of the results of "pilot" operation is not made.

The discussions of design specifics raised, again, the questions of design experience and the extent to which designs represent "a priori" decisions rather than accurate responses to actual conditions. For example, most projects incur substantial "unanticipated" requirements for drainage. Given the relatively high level of knowledge in this area, the consistency of the underestimation might be considered surprising. This underestimation, along with relatively consistent overestimation of expected production, can be viewed as the designers' response to political pressure for project development, where costs must be projected as low and benefits as high. The magnitude of potential improvement in a system design and operation caused by more accurate response to project conditions is not really known. But if significant benefits could be demonstrated, both the argument against reliance on Benefit/Cost analysis and the argument for more open recognition of the "real" reasons for project development would be strengthened.

The Design of Economic Components

While participants accepted implicitly the importance of factors such as credit, market opportunities, price policy, taxes, and water fees, there was relatively little discussion of the economic components associated with project design and operation, except in relation to the benefit-cost question. Evidence of attempts to plan for certain economic components varied, but emphasis in the design process was usually limited to the question of water fees and repayment policy, and more recently to provision for credit. Other economic factors are considered non-manipulable and represent constraints within which the design takes place.

The implications of the economic components in design are extremely important. In the Chia-Nan case, the price stabilization policy for rice encourages farmers to grow rice even though the market potential for crops with lower water requirements is good (though variable). Fee policies which do not recover the real operating and maintenance costs of the irrigation investment may also insure system deterioration, unless general fund appropriations are specified for the purpose. Tax policies which do not recognize land improvements associated with irrigation development may defeat goals to improve tenant tenure status.

Because of the limited consideration of these economic components, some stress was placed on more effective involvement of economists in the design process.

Design of Social Components

The design of the social components is made difficult by the variety of social situations which can be encountered within project areas as well as between projects. Furthermore, the limited number of social technologists and the complexity of factors involved in the mechanisms for achieving planned social change have inhibited the design of social components.

As indicated earlier, in certain cases social components have been changed as a result of planning and design. In most instances, however, changes have been unplanned and unanticipated. Frequently, implicit assumptions have been made that relationships among farmers are manipulable where, more logically, they might have been considered relatively fixed. Similarly, relationships between farmers and authorities have been viewed as relatively easily manipulable variables, when in fact they may be relatively fixed. In the case of the Chia-Nan Association, social changes were implemented to a major extent. In the Las Majaguas project they were realized only partially, and then not always in the ways anticipated.

While the value of a socio-cultural analysis was generally recognized, no consensus was reached on the detail necessary. As might be anticipated, social scientists tended toward very detailed analysis, while the physical scientists and engineers raised questions about the acquisition and direct utility of the detail.

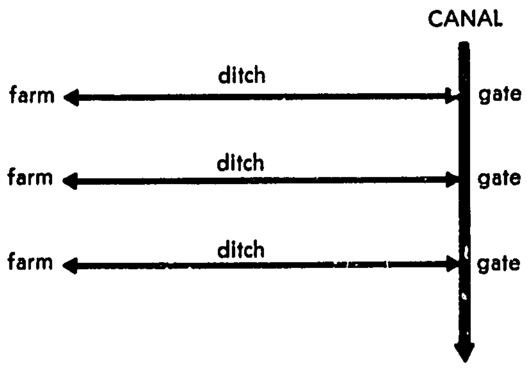
Aspects of the socio-economic milieu identified as directly relevant to the problem may provide clues to the depth of analysis required. Among these are:

1. styles of communication
2. role differentiation and interaction in formal and informal settings
3. leadership patterns and decision making
4. value orientations toward authority and government
5. goals and values of farmers and irrigation authorities relative to water—its utility and meaning.

In addition to the above factors of relatively direct influence, others—level of education, attitudes toward public property, the effectiveness of legal sanctions, relations with public officials—have varying degrees of impact on system operation and project success. These factors are incorporated in the design stage by either taking into account or planning to manipulate elements in such areas as: development of new leadership and leadership patterns, developing communication and information feedback mechanisms, and land tenure.

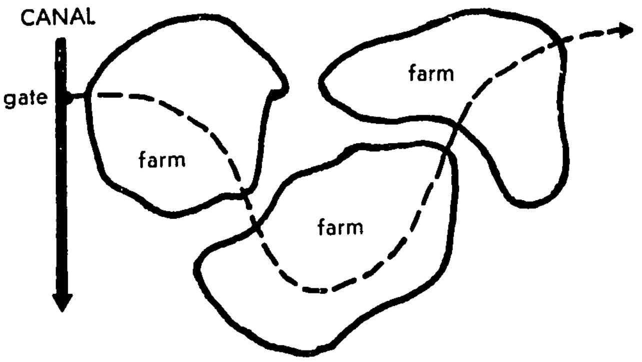
While the lack of definitive understanding in this general area prevents effective design, the importance of the social context can be exemplified by consideration of two characteristic views of water availability.

In many Western irrigation projects, such as the Salt River Project, each farm unit is served with an individual turnout. The primary relationship is between the farmer and the physical system, as illustrated:



This relationship can be defined in terms of water rights, delivery schedules, etc. Relationships among the farmers play a secondary (though frequently important role).

In many tropical areas, especially humid areas in which irrigation is frequently supplemental to rainfall, water is delivered to areas composed of a number of farmers. Distribution from the turnout flows from farm to farm, as illustrated. Thus successive farmers in the delivery sequence are increasingly dependent upon their relationships with the other farmers in the area, and more remote from the structural system.



This difference in relative dependence upon the irrigation organization and neighbors has major implications for appropriate distribution facilities organizational pattern, and other related considerations. To avoid major difficulties, these differences must be accounted for in program design.

One area of social consideration where participants felt an impact could be made, given the lack of design capability to effect planned change, would be the inclusion of *planned* opportunity for feedback and *project revision*. The value of this capacity for revision is exemplified by the Taiwan study, where except in the cases of the very largest rivers, irrigation association size has been modified over time to allow for individual association control over water resources.

Implementation

Because irrigation system design is based upon incomplete information and understanding, unanticipated developments are likely to occur during the process of project implementation. Given this recognition, the seminar suggested two basic principles: (1) to stage implementation to provide maximum opportunity for exposing unanticipated developments; and (2) to maintain sufficient flexibility in implementation to allow for the incorporation of information and understanding gained during the early stages of implementation.

The seminar discussion implied that application of these principles was limited in most projects. Even where staged development and "pilot" projects had taken place, the design of feedback and change components has most often focused on the physical aspects of the system, including both the water distribution and agronomic phases.

Operation

Understanding a system's operation is essential to an identification of gaps in our knowledge of a system's design and implementation. The seminar did not explore in detail the problems of system operation, but much of the discussion was relevant to four aspects of operation: (1) water scheduling; (2) feedback and response; (3) degree and location of control; and, (4) water charges.

Water Scheduling

The case studies illustrated the range of possible operational extremes. The Salt River and Majaguas projects operate with "demand" type scheduling, the Philippine systems with very limited scheduling, and the Chia-Nan system with very rigid scheduling. But this differentiation indicates very little about the degree to which farmer water needs are met, or about the requirements associated with different types of scheduling.

The Salt River Project and the Chia-Nan system represent opposites in terms of the freedom of the individual farmer in decision making about water delivery. Yet evidence suggests that both systems are successful in meeting water needs of the farmer while operating within the system constraints of water supply, maintenance requirements, and economics. By contrast, the Majaguas project, which has a scheduling system similar to the Salt River Project, met farmer "demands" for water but at the same time encountered major problems of "excess" water use.

These examples and the seminar discussion suggest that success in the *demand* system is dependent upon a combination of factors—*farmers* who are experienced and knowledgeable in irrigation and who will *effec-*

tively interact with water *controllers* in a situation where both farmer and system needs are reflected in a limited set of operational rules. Success in a rigidly controlled system is dependent upon a combination of water *controllers* who are experienced in farming and will *interact effectively* with the *farmers,* in a situation where farmer needs are accurately reflected in the operating schedule. The Philippine systems for supplemental irrigation of rice during the rainy season have little water scheduling during the rainy season; the water supply is adequate for continuous flow. During the dry season limited scheduling is practiced, generally through rotation by laterals once every week with delivery of 10 cm to the area served. This type of scheduling, while providing some equality of delivery to different areas, does not provide equality of service in meeting farmer needs. Areas with lighter textured soils would be less adequately served than areas with heavy textured soils. By contrast, in the rigidly controlled Chia-Nan system, water deliveries are based upon the needs of individual units from one to ten ha in size. The principle is equity of production capability rather than equality of water delivery.

With respect to water scheduling, the seminar generally agreed that as control was devolved to the farmer, the requirements for farmer education and training increased greatly.

Feedback and Response

The phrase "interacting effectively" masks many of the concerns about the problems anticipated in attempting to achieve effective interaction, discussed during the seminar. The three aspects of the system environment were included in these discussions, but the major problems were viewed as relating to the social relationships among farmers, between farmers and the system controllers, and between the system controllers and central government bureaucracy. In the operation of a system, mechanisms for feedback and response must exist and be used, if goals are to be achieved. The feedback from the farmers to the water controllers, and feedback to the farmers are essential if farmer needs are to be identified and met. In the case of "demand" scheduling of water, feedback from the farmers is a regular part of system operation. Feedback is essential, even in a rigidly specified system such as the Chia-Nan system, because it is impossible to identify all of the circumstances under which the water will be managed; the farmers must have some mechanism for bringing their special needs to the attention of the water controllers. These mechanisms may be a formal part of the organization of the system, an informal part, or a combination of both. In the Salt River Project and the Chia-Nan System both exist. Mechanisms are available for feedback directly to operating personnel; furthermore, direct input to an association of farmers who then have authority to effect changes aids a source of indirect feedback to operating personnel. In both systems, the operating personnel are directly responsible to the farmers' associations rather than to a central government bureau.

In the Laoag-Vintar system in the Philippines, the farmers' association meets periodically with the system operating staff to review problems, but operating personnel are responsible to the national government. In the Nazareno-Gamutan system the association has direct responsibility for system operation. The effectiveness of feedback in terms of control response is dependent upon the leadership within the associations.

In addition to providing mechanisms for feedback from farmers on their needs, the water controller must respond to that information. He must have both the *impetus* to respond and the *capability* to modify the water delivery or other phases of water management. Alternatively in those cases where this capability does not exist, water controllers must have sufficient rapport with the farmers to allow for the transmission of knowledge of system deficiencies *to* the farmers without loss of confidence in the system. For example, in both the Salt River and Chia-Nan systems "dry" years reduce the available water supply, and farmer needs cannot be met at optimum levels. Yet farmers accept this condition with minimum adverse reaction toward the system itself.

Major elements in the capability to respond are an appropriate physical system, and an effective system for internal communication. The highest level system requirements, from both physical delivery system and communication points of view, are associated with demand scheduling systems. The requirements for rapid and effective communication are almost as important for the more rigidly scheduled systems, however, if emergency situations are to be handled satisfactorily. In both the Salt River Project and the Chia-Nan system special physical provisions for rapid communication are made.

The social elements affecting communication within the irrigation system context are less clearly defined, but two examples of factors that can inhibit effective communication are the reluctance to transmit unpleasant information to supervisors and the influence of farmers with greater social or economic power.

Degree and Location of Control

The capability to respond to feedback on farmer needs is directly affected by the degree and location of water control in a system. The basic approach in Western irrigation system design is to maintain centralized control to the farm gate, with deliveries measured to that point. Water distribution within the farm unit is the responsibility of the operator. In the United States, farm unit size is usually 50 ha or larger. As the farm unit size is reduced, the extent, complexity and expense of control multiplies. The combination of small farm units, measured farm gate deliveries, and demand scheduling have great potential for meeting farmer needs, but realization of this potential is extremely difficult. High degrees of coordination between the farmers and the system and within the system are necessary, and a relatively high level of skill is required for the position of turnout water controller (ditch tender).[1] The Majaguas project illustrates an attempt to apply the Western concept to small (10 ha) units.

The Chia-Nan project illustrates a system of integrated control to the farm (1 ha) level but centralized control only to the 50 ha level. Distribution beyond this group level is in the hands of the farmers themselves. A high degree of cooperation is reinforced locally by selected leadership. Technical advice from the system staff provides the base for individual water deliveries, but coordination and distribution are farmer ("small group") responsibilities.

As centralized control stops at higher levels (laterals, to mains, etc.), more responsibility is devolved to the farmers. System-farmer coordination is less complex, and scheduling is reduced to relatively fixed rotation. The extent to which the level of control within the system must be coordinated with different levels of farmer cooperation to provide most effectively for farmer water needs is an open question. But a significant potential for improved system operation reflecting such consideration was expressed during the seminar, particularly in the case of rice irrigation. Relatively large deliveries, controlled at the lateral, alternating with zero flow could reduce the requirements for cooperation among farmers while at the same time providing reasonable, if not optimum, satisfaction of farmers needs.

Evaluation

Throughout the seminar the need for and utility of feedback was stressed. Feedback about *performance* of the system, about the degree to which the *objectives are being achieved,* and about *unanticipated effects* should provide the information necessary to improve system operation as well as to improve the design of future systems.

Seminar participants generally agreed that the extent and type of feedback currently obtained are relatively poor. Feedback, together with evaluation and response regarding physical performance, is relatively common. Feedback and evaluation of the achievement of objectives is much less common. Even in the case of pilot projects, response frequently reflects the earlier design rather than a reevaluation of the situation. Unanticipated effects, especially if adverse, are often ignored and unreported. Hence, the possibility of improved design is much more remote.

Summary

This summary consists of three parts. The first is the summary presented at the concluding session by Dr. A. T. Mosher, President of the Agricultural Development Council, on the request of the organizers of the Seminar. The second consists of observations on the Seminar's format and design by the organizers. The third brings together suggestions of research needs that emerged from the Seminar.

Seminar Summary Prepared by A. T. Mosher

My summary takes the form of a progress report on my attempt to integrate and draw lessons from the papers and discussions of our Seminar. Instead of proceeding from the dichotomy between on-farm and off-farm irrigation activities that was prominent in the format of the Seminar, I've been asking myself the question that different participants have specifically posed several times over the past three days: What is the role of specialists from different disciplines at different stages of the design, construction and operation of irrigation systems?

My attempt to answer that question is embodied in the chart on the following page and the remainder of this summary is a commentary on the chart.

Beginning at the top of the chart, it seems to me that with respect to any irrigation system one has to start with three "givens." One is the water source or sources available for utilization within the system. The second is the topography of the agricultural lands to be irrigated and between those lands and the water source or sources. The third is the nature of the soils, the distribution of air temperatures and of rainfall in the area to be irrigated that together determine physically feasible cropping patterns. Each of these is represented by a box in the top row of the chart.

In addition to those "given conditions" there are two additional factors that represent presently existing conditions but that are subject to possible modification. One of these is the existing social structure, existing formal and informal patterns of organization and interaction, and existing cultural values (particularly those that influence cooperation and response to authority). The other modifiable factor is existing market opportunities (including probable future prices) for crops that might be grown in the area to be irrigated.

The middle section of the chart, from top to bottom, indicates the various components that should be included in designing an irrigation system, with an indication of the sequence in which different components can best be tackled.

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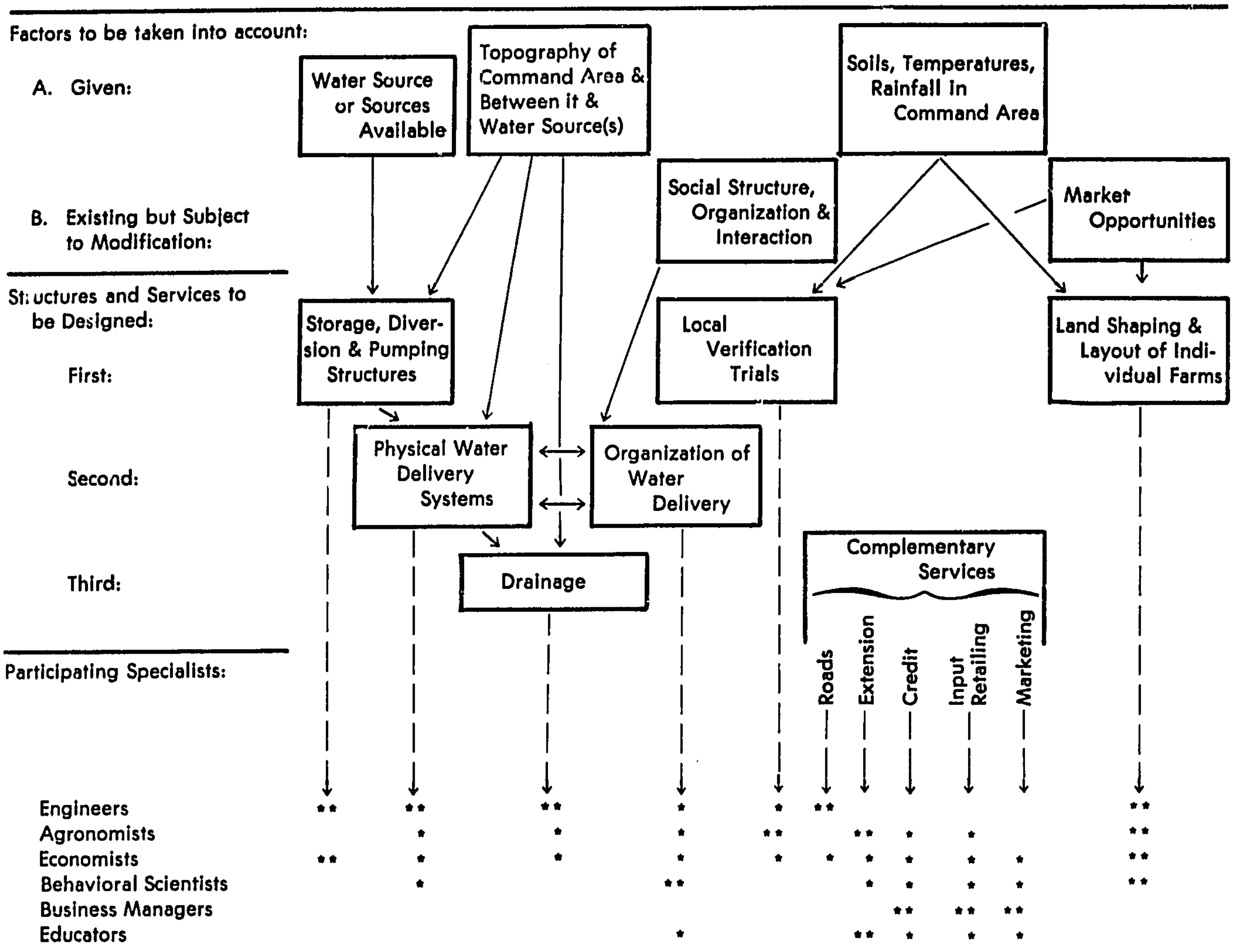
[1] One of the reasons tube wells are popular is that they have fewer requirements for coordination.

ROLES OF SPECIALISTS FROM DIFFERENT DISCIPLINES IN THE DESIGN AND OPERATION OF IRRIGATION SYSTEMS



	Storage, Diversion & Pumping Structures	Physical Water Delivery Systems	Drainage	Organization of Water Delivery	Local Verification Trials	Roads	Extension	Credit	Input Retailing	Marketing	Land Shaping & Layout of Individual Farms
Engineers	**	**	**	*	*	**					**
Agronomists		*	*	*	**		**	*	*		**
Economists	**	*	*	*	*	*	*	*	*	*	**
Behavioral Scientists		*		**			*	*	*	*	**
Business Managers								**	**	**	
Educators				*			**	*	*	*	

* Denotes supplementary responsibility
** Denotes major responsibility

In the first stage of designing a system, three tasks can be tackled simultaneously:

a. the design of structures for the diversion of water from rivers, structures for storing water, and the location and installation of irrigation wells and pumps;
b. establishing a large number of local verification trials throughout the command area to determine what cropping pattern and what combination of farm practices (including crop varieties, levels of fertilization, periodicity of water application, etc.) should be recommended; and
c. Land shaping and the layout into farms of the command area.

In the second stage, design of the water delivery system can be tackled. There are two equally important aspects of this. One is the *physical* delivery system composed of canals, secondary distributaries and tertiary channels to individual farms and fields. The other is the *organizational* arrangements through which water is to be allocated among farmers with respect to both timing and amount. Each of these imposes restraints on, and sets requirements for, the other.

In the third stage, whatever provision needs to be made for drainage can be designed and constructed, and the complementary services required for full utilization of the irrigated land can be developed: access roads, extension and credit services, arrangements for distributing farm inputs and marketing farm products.

Two general comments on the top two-thirds of the chart may be in order. One is that some redefinition of these components in the design of an irrigation system may on further reflection be indicated; as it stands the chart seeks to capture the elements of the problem as brought out in the Seminar. The other is that the suggested sequence of designing a system must be treated cautiously. It was repeatedly stated in our discussions that the usual practice is for all of the design and construction of physical features—dams and canals, wells and pumps—to be completed without giving attention to problems of organizing the delivery system for water, without taking local social and cultural factors into account, without careful experimentation as to what crops can most profitably be grown, and how. What I have tried to accomplish via the chart is to outline the various factors that need to be taken into account, to depict which factors affect which aspects of the design problem, and to suggest a sequential ordering that could facilitate a more satisfactory approach to the problem.

Coming now to the bottom one-third of the chart, the attempt here is to indicate what types of specialists need to cooperate with each other with respect to each of the design and operational activities required within an irrigation system.

Clearly the responsibility for designing diversion, storage, and pumping facilities falls to engineers (for physical design and construction) and to economists (to insist on least cost solutions of the problems to be solved). Engineers have the major responsibility (**) for designing and constructing the physical water delivery system, with economists having the supplementary responsibiltiy (*) of evaluating alternative solutions, agronomists contributing analyses of periodicity and seasonal amounts of irrigation water requirements, and behavioral scientists assuring that the physical delivery system is consonant with feasible (socially and administratively acceptable) social arrangements for water distribution. Behavioral scientists should have the major responsibility for designing the organizational arrangements for water delivery, with engineers checking consistency with feasible physical arrangements for water delivery, economists checking on costs, agronomists supplying data on seasonal water requirements, and educators figuring out how people can be brought to operating the delivery system effectively. Agronomists should have the major responsibility for designing and operating local verification trials, with the cooperation of engineers and economists. Land shaping, and the division of the command area into individual farms and fields should be decided upon jointly by engineers, agronomists, economists, and behavioral scientists.

When it comes to the complementary services to make the irrigation system most effective, similar cooperation among various specialists is required. Road design and construction is primarily for engineers, but with economists having a voice in design and location. Extension services require the joint major attention of agronomists and educators, with behavioral scientists and economists contributing to the decision making. The operation of credit system falls to business managers, with educators helping farmers make optimum use of credit, and behavioral scientists, economists and agronomists helping determine the design, the terms, and the actual procedures for making loans. Input distribution is primarily a matter for business managers, but with the same combination of other specialists contributing to the design of the system. Marketing, too, is a business operation, with the aid of behavioral scientists, economists and educators in developing the system.

Throughout the conference, participants have been contending that economists, agronomists, and behavioral scientists need to be brought into the process of designing an irrigation project at a much earlier stage than is normally provided for. But when, and to do what? The above analysis, it seems to me, can lead in the direction of an answer.

I recognize and hasten to add that this model is a roughhewn approximation of what it seems to me the speakers and participants of the seminar have been saying. The challenge to all of us is to sharpen our insights and our tools to do a better job of designing, constructing and operating irrigation systems that adequately take into account all of the necessary and hopefully sufficient conditions for success.

Observations on Seminar Format and Design

A review of the seminar from the viewpoint of extracting lessons for possible future activity of ADC/RTN groups reveals certain significant points which deserve emphasis:

1. A significant amount of time is necessary to establish a basis for effective communication when individuals with different disciplinary backgrounds are brought together.

The core RTN group achieved this substantive understanding during the course of previous meetings at Logan, Ft. Collins, and Tucson. As soon as the group was expanded, to include other seminar participants, however, the entire process of extended time exposures was again necessary. This communication rapport was only beginning to be reached the afternoon of the second day.

2. The case studies had inherent limitations as devices for total system focus on interdisciplinary problems.

Two reasons were cited. First, the disciplinary depth of the case study material considered necessary by the disciplinary participants is such that it is unlikely that a *single* individual can prepare a complete case study. Perhaps case studies developed by an interdisciplinary team or by an in-depth system analyst researcher would yield greater comparative insight. Second, the extent of pre-seminar study required to extract the significant elements is probably greater than most participants will invest. Perhaps a more appropriate technique for a seminar would be a limited number of position papers which would provide an immediate focus for discussion. Then, attempts at application could be viewed through the presentation of specific case studies. Given the problems in developing case studies, the case study approach would seem to be appropriate for a smaller group using a workshop format.

3. Involvement in active discussion is necessary for mutual understanding.

To a certain extent, the case study writers had difficulty interacting with other seminar participants. This difficulty was probably due in part to language difficulties, in part to the contrast between the academic approach of seminar participants and the writers' more practical experience, and in part to the seminar format in which the writers did not make the initial presentation of their case studies. In retrospect, a good approach might be to allocate sufficient time for participants in small work groups to explore in depth the content-findings and implications of the case studies. This approach would facilitate every person's early involvement as well as his capacity to comprehend the significance of the case study material within the larger system analysis framework. If necessary, different work groups could concentrate on different cases to insure that each was sufficiently analyzed. This work group study might be a suitable evening assignment.

4. Of the main seminar objectives the increase in communication among the disciplines and in the extended group was reasonably achieved.

Increased understanding of the problem did result, but to a lesser extent. The identification of research needs was not explicit; but major problems in the area covered by the social sciences became apparent, and significant research needs were implicitly identified. Progress on the substantive questions could probably be more effectively made through a workshop approach.

Research Needs

Throughout the seminar various participants made suggestions for future research to better understanding of irrigation system planning and implementation. An overriding concern of the group was that parties involved in research investigate the total system and that analysis be carried out on *all* the significant variables involved in a project to allow for a multifaceted view of the scheme. A representative list of research needs includes the following questions:

1. What are the trade-offs between engineering and social investments in an irrigation system? For example, is money alone sufficient to organize a social system for receiving water?
2. How does lack of knowledge about the environment affect both the planners and recipients with respect to:
   a. receptivity to a scheme?
   b. how a system is operated?
3. What are the forces that regulate control in a water-user organization? For example, the degree of cooperation, or the effect of group/peer pressure.
4. What are the requisites for viable farmer groups in irrigation districts? For example, is the amount of family dependence or the value of family labor used on the project important?
5. How can communication between planners and recipients, from the planning stage through implementation of the project, be improved?
6. How are income distribution, social well being, rural migration and the environment affected by different system designs?

Appendix 1

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