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IMPROVING THE PERFORMANCE OF AGRICULTURAL DEVELOPMENT PROJECTS

PART I A PROPOSED DESIGN PROCESS

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Improving the Performance of Agricultural Development...

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I. INTRODUCTION

A wide range, and a large number, of agricultural development projects exhibit unsatisfactory performance. In many, the problems are serious. While specific aspects may differ, the problems usually fall into four general categories: excess costs, low outputs, dissatisfactions on the part of clients or planners, and unforeseen adverse results. On many projects, all four categories of problems occur. The prevalence of these problems in projects with different objectives, with diverse characteristics and in different geographic regions suggests that there are serious flaws in the process by which these projects are planned and implemented. The purpose of this paper is to present the general outlines of a planning and design process which we believe will improve the resulting project performance through a more systematic consideration of goals, resources and alternatives, and through the explicit recognition that project designs are always incomplete.

A. Agriculture As A System

Basic to this revised process is a view that agriculture is a very complex ecological system whose essential nature and performance is determined by the mutual relations among living organisms (including human beings) and by the interactions between these organisms and their physical environment. The performance of an agricultural development project depends on the type of changes which the project brings about in these relationships. Thus, to plan, design, and implement agricultural development projects explicit consideration of a multitude of interacting elements of the complex system of agriculture is necessary.

To facilitate the analysis and synthesis associated with planning and design it seems appropriate to divide this complex system into four subsystems: social, economic, physical and biological. Each subsystem consists of a large number of interdependent elements or variables, which may be characterized in either quantitative or qualitative terms. The relative importance of the various elements will be different for different planning objectives and types of projects, and the identification of the important elements in each specific case is essential for effective planning and design. This will be considered more fully in Part II of this paper.

In very brief terms, the four subsystems are described below:

1. Social Subsystem. The elements relating to the interactions among people performing roles related to plant and animal production.

2. Economic Subsystem. The elements affecting the material well-being that can be derived from the utilization of resources for plant and animal production.

3. Physical Subsystem. Specified elements of the physical environment which affect the potential for plant and animal production.

4. Biological Subsystem. The biological elements affecting the potential for the production and reproduction of living organisms.

The primary outputs of an agricultural system generally can be categorized into two major groups: production of plants and animals (regardless of their desirability to humans) and human well-being. The production of plants and animals is linked primarily to the physical and biological subsystems, though the economic and social subsystems also influence such production. Human well-being is primarily associated

with the social and economic subsystems, though with significant influences from the physical and biological subsystem, e.g. in human health.

While each system is somewhat independently variable, especially in the short run, it must be recognized that the four are interdependent in the longer term, and none can be considered as prior or basic. Thus, the planning, design, and implementation of agricultural development projects should include specific consideration of all four subsystems and their interactions.

B. The Planning and Design Process

Planners of agricultural development projects usually recognize, at least in principle, the importance of considering all four subsystems of agriculture when designing a development project. Yet, the prevailing practice is to place primary emphasis on the physical system, with lesser emphasis on the biological system, even less on the economic system, and almost none on the social system. In part, this bias reflects the fact that most agricultural development projects involve obvious changes in the physical system, with the biologic system recognized as being the vehicle for utilizing the improved physical environment, while changes in the other systems are somewhat less obvious. Furthermore, there is fairly widespread agreement on the nature and the methods of measurement of the variables of the physical and biologic systems which are critical to the success of the project. (This is not to suggest, however, that failure to considercritical variables or that problems in their measurement never occur.) By contrast, critical variables in the other systems

have not been so clearly identified, and measurement techniques often are less well defined.

There undoubtedly will continue to be differences in the degree of precision with which critical variables in the various subsystems are identified and measured. But, we believe that it is possible to improve the planning and design process for agricultural development projects by considering explicitly the variables and the constraints imposed by all the subsystems of agriculture. In the remaining sections of Part I of this paper we attempt to detail the process by which the important elements of the four subsystems can be considered in an integrated manner within the planning and design process.

Conceptually, the design process which we propose is similar to the current procedure, in that it proceeds sequentially from the Pre-project stage to the Pre-feasibility, Feasibility and Detailed design stages. The proposed process differs, however, by increased emphasis upon the evaluation and definition of goals and objectives, by the inclusion of more feedback links, and by the inclusion of the Construction and Operation stages as part of the design process. An additional major difference is the deferment of a policy decision on the specific type of project to be implemented until after the feasibility stage. This is in sharp contrast to the current process by which the project type is decided at a very early stage in the planning-design process. Figure 1 illustrates the sequential staging of the proposed general process. We will consider stages A, B, C, and F in detail in this part of the paper, and will consider the Detailed Design stage more fully in Part II, for an irrigation type project. At that time, the identification of critical subsystem variables, and their utilization in the irrigation project design will be illustrated.

PROJECT DESIGN STAGES

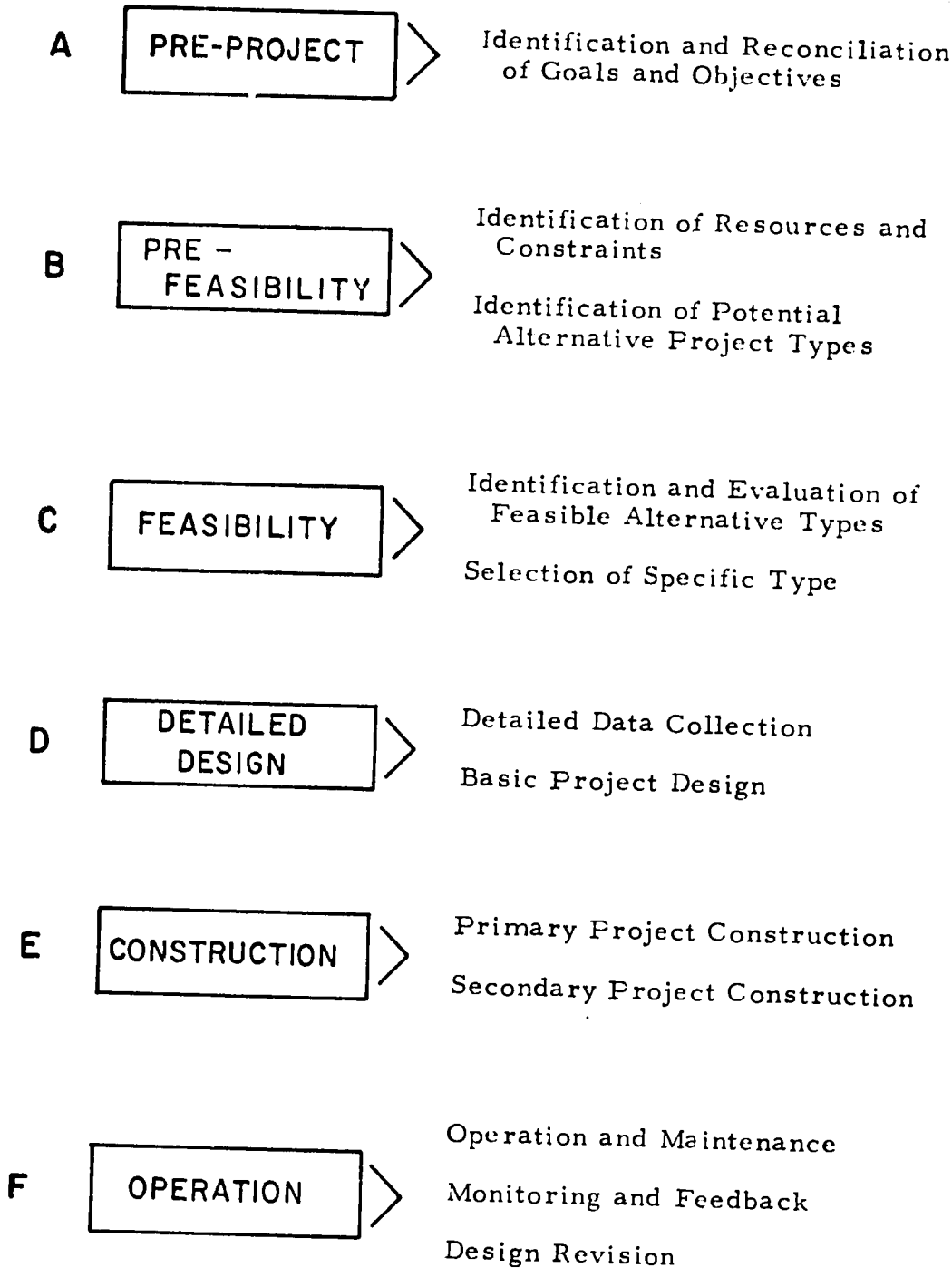

Figure 1. Generalized Design Stages for an Agricultural Development Project

The construction stage will be considered only very briefly.

II. PLANNING AND DESIGN STAGES

A. The Pre-Project Stage

The action and decision sequence in the Pre-Project Stage is depicted schematically with the flow chart, of Figure 2. Three major aspects of this phase of the planning-design process should be noted: there is explicit identification of both governmental and individual (or client) goals; there is specification of the development objectives; there are explicit comparisons between goals, and between goals and objectives, with feedback links to enhance agreement.

1. Identification of Government Goals. This step in the design process is one of the most difficult to deal with, partly because it appears so obvious or trivial to many planners. Yet we believe that the frequent failure to specify such goals is one reason why many agricultural development projects fail to live up to expectations.

The first problem encountered is that of defining what is meant by "government goals". All governments have a multiplicity of goals, some of which may be conflicting in either the short term or over the longer period. Some of the goals may relate to ideology, some to political considerations, others to productivity and still others to equity. Even within the context of an agricultural development project all these areas may be represented in the motivations of the government for the proposed activity. To the extent it is possible, the goals of the government for the project, and the priorities among these should be identified explicitly.

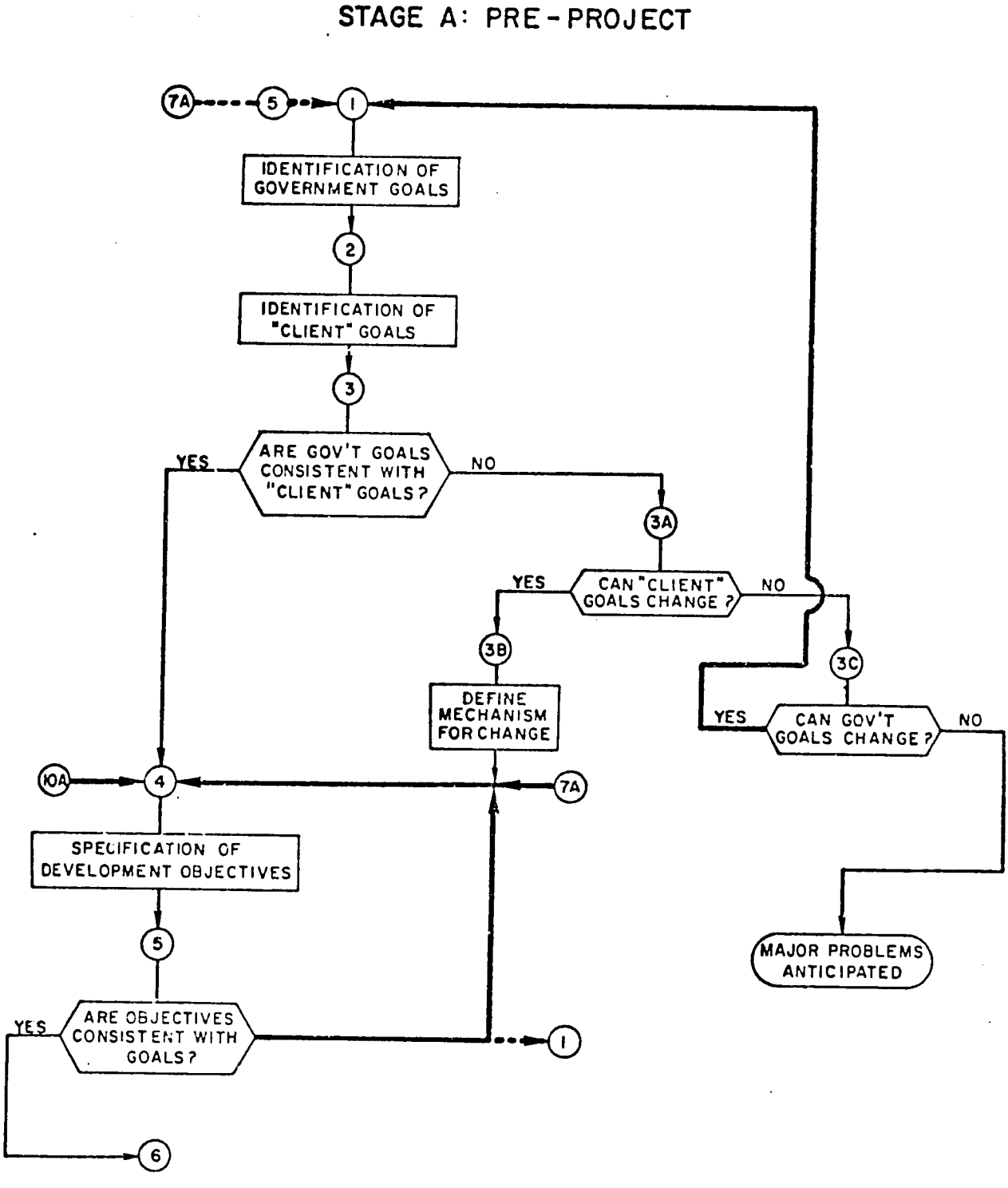

Figure 2. Pre-Project Design Flow Chart

From the perspective of the project planners and designers, the identification of the people whose goals are of interest is considerably easier than identification of the goals themselves. Typically, these are the policy makers and economic planners. Unfortunately, these planners and policy-makers may feel that they can "instinctively" judge whether or not a project is consonant with their own underlying goals, making it unnecessary for them to precisely identify and articulate these goals. One obvious, difficulty, with this position is that within a small group of policy-makers, differences in goals are likely to exist. A perhaps less obvious but more serious difficulty is that when projects are judged in part on feelings which have not been clearly identified, the project will not be examined critically to determine the degree to which it will in fact lead to the goal in mind. Dissatisfaction with project results is almost sure to occur.

2. Identification of Client Goals. In most agricultural projects there is a primary dependence upon the "farm" operator for ultimate success of the project. It is the farm operator (perhaps tenant or owner or collective group) who will grow the crops, raise the animals, use the water, apply the technology, etc. As in the case of the identification of government goals, it probably is easier to identify the client than the goals, but even this is difficult. Not all farmers have the same goals, even when they are in a specified geographic area, or target group. In addition, and somewhat in contrast to the identification of government goals, the mechanisms for obtaining this information generally are poor or essentially non-existent. Generally, if client goals are considered at all, they are those hypothesized by others. To effectively identify and

determine farmer priorities for his multiple, dynamic goals will require planning and design effort not usually expended. Special consideration must be given to the social and economic subsystems at this stage.

3. Are the Goals in Conflict? If the autonomous response of farmers to their total environment is to be the primary mechanism for achieving project results (authoritarian methods, including force have been used), there must be reasonable congruence, or at least minimal antagonism between the priority goals of the government, as articulated by the policy makers, and the priority goals of the farmers. An evaluation of this congruence must be made. Where there is essential agreement, this design process leads directly to the specification of the development objectives (4). Where there are sharp divergences, two basic alternatives exist: the client goals may be changed, in which case the anticipated mechanisms for effecting this change should be identified (3B); the government goals may be reevaluated (see the feedback link (3C) figure 2) and reformulated. Where neither of these alternatives is viable, major problems in any type of project should be expected, and extraordinary measures for project implementation would be necessary.

4. Identification of Development Objectives. Development objectives can be distinguished from goals in that objectives are more specific. The goals identified in Step 1 are broad goals toward which the policy-makers hope their society will move, although the goals may never be fully realized. Objectives, on the other hand, are much more concrete and measurable. An agricultural development program may thus be expected to achieve the objectives which are established for it, and its

performance may be measured by the extent to which it does actually meet these objectives.

Since the exact nature of the agricultural development project to be undertaken has not yet been determined at this point in the design process, the specification of the development objectives needs to be general (although still in concrete and measurable terms). Specification of more detailed project objectives occurs in the evaluation of each alternative project type in the Feasibility Stage.(C). This point is an important one, particularly from an economic perspective. The design process should provide the mechanism for careful consideration, by the policy-maker, of as wide a range of alternatives as possible. If objectives are specified too narrowly at this early stage in the planning process, many alternatives will be completely excluded from consideration.

An objective of increasing dry season production of rice by 1,000 tons would be an example of a very narrowly specified objective which is probably unnecessarily restrictive. As specified, the objective would eliminate from consideration any type of project that did not involve irrigation. The objective could be specified more broadly by removing the words "dry season". This now encourages the policy-maker to consider a whole range of possible projects that would have been ignored under the previous formulation. The objective could be defined even more broadly by changing it to reflect a specific value of production, rather than a specific quantity of a given crop. This allows consideration of projects that might be equally as effective in increasing production, but where the production would be in the form of crops other than rice.

The extent to which objectives are broadly or narrowly defined will depend on a wide variety of considerations and restrictions under which the policy-maker is working. The point that we are trying to make here is simply that the more broadly objectives are defined, the better will be the planning process in terms of providing a careful evaluation of the alternatives available. A policy-maker should examine carefully his reasons for placing restrictions on the objectives.

5. Are the Development Objectives Consistent with the Goals? As the objectives are developed the planner must ask whether the objectives are consistent with the specified goals. He may find that some of the restrictions placed in his objectives reflect considerations which are inconsistent with the stated goals. In such cases he needs to reconsider the objectives, as suggested by the feedback link to (4) in Figure 2, and he may even have to suggest reconsideration of the governmental goals, as indicated by the dashed link to (1). After the development objectives are reasonably consistent with the goal priorities of the government and clients, the Pre-Feasibility stage is entered.

B. The Pre-Feasibility Stage

The Pre-Feasibility Stage has three primary objectives: the identification of the resources available; the identification of critical resource constraints; the identification of project types potentially suitable for the specified development objectives. The flow chart for this stage is depicted in Figure 3.

6. Identification of Resource Requirements and Supplies. We have suggested that in the traditional design process, the physical, and to a lesser extent the biological resources are considered in some detail.

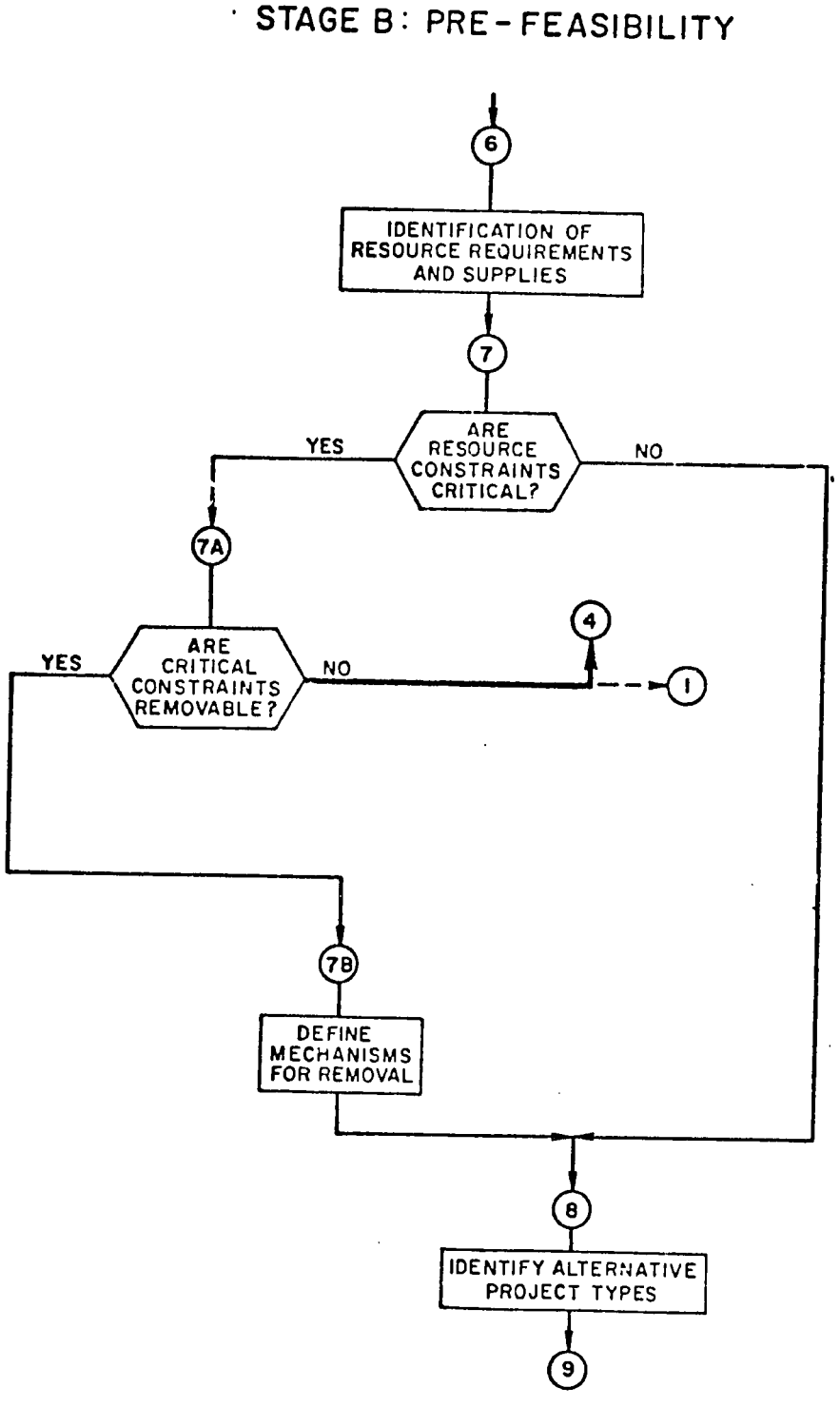

Figure 3. Pre-Feasibility Design Flow Chart

But seldom are the economic, and rarely are the social resources considered in anything more than a cursory fashion. (Some of the reasons for this are considered in Part II.) Instances can be cited where significant physical and biologic factors have been overlooked, or inadequately considered in project design (e.g. the low slope in the Muda River Irrigation Project, in Malaysia, and winter effects on the cropping pattern in the Dez Irrigation Project in Iran), but our emphasis in this section will be upon the important economic and social resources whose availability should be determined. In this context, consideration must be given to the availability of these resources both to the government, and to the intended beneficiaries (clients) of the project.

It is generally recognized that economic resources may be divided into six categories: land, water, labor, physical capital, financial capital, and human capital.* For each of these categories, the extent and time distribution of the available resource must be determined. In addition to availability, the degree of current utilization of these resources must be evaluated. It should be recognized that at this stage the focus is on the prospective clients, rather than on a proposed project, and thus a wider

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* Land and water (sometimes considered together, as land) obviously are elements of the physical subsystem and both usually are evaluated from the perspective of their physical characteristics. Their inclusion in the economic subsystem stresses their economic role as distinct from their physical aspects. Similarly, human capital is an element of the social subsystem, and will be considered from that perspective later in this section.

view of the resources results.

Techniques for identifying, and to some extent, for determining quantitative values for the elements of land, water, labor, physical capital and financial capital exist. Techniques for the identification and evaluation of human capital are much more limited, and this may be a contributing factor to the neglect of consideration of this resource. Where attempts have been made to consider the human capital, it usually has been through the evaluation of the level of formal education of the prospective clients, with the underlying assumption that formal education is equated with knowledge. But knowledge and skills are real resources, regardless of how they were acquired. The experiential knowledge and skills of the clients may be among the most important resources available to an agricultural development project. Conversely, the lack, on the part of the clients, of knowledge and skills regarding the type of agriculture that is proposed for a given project may be one of the most serious resource constraints affecting the potential for a project.

Planners need also to consider the economic resources that are available to the government. The six categories of resources that were considered in investigating the resources of the beneficiaries can also be used here. Land, water, and financial capital are generally considered by planners. Labor is not a particularly important category, since presumably the government can hire the labor it needs, if it has the financial capital. Physical capital in the form of machinery may be considered, although these items may also be purchased if adequate financial capital is available. But human capital is again an important category which tends to be neglected. The availability of manpower trained in various technical and administrative skills is essential, and often may be a

significant constraint that must not be underestimated in the planning and design process. It should again be recognized, however, that formal training is not the only source of this human capital. Experiential knowledge and skills may form a significant proportion of available human capital. Of special importance, and frequently overlooked, is the ability to communicate well with the intended beneficiaries.

As information about the basic economic (and other) resources is being obtained, estimates of the resource requirements must be made. It should be emphasized again that a project type has not been selected to this point, and thus, these resource requirement estimates necessarily are relatively crude. Premature specification of the requirements will restrict the options that should be considered at the policy level.

The social resources that should be considered at this stage in the planning-design process are not only difficult to identify in detail, they even are difficult to categorize. At this period in our understanding of the social subsystem of agriculture, it probably is necessary to focus attention on those elements which have higher probabilities of being constraints on policy decisions, rather than to consider the broader range of social resources which might be utilized. A major exception to this would be the human capital factor discussed previously. In general, we believe these elements would fall into six categories: social control, communication patterns, coherence in cultural organization, interdependence in social organization, institutional adaptability and complexity of role structure. Human capital, elements of which have been discussed, is formed from factors in all of the foregoing categories, and, to some extent at least, represents an important synthesized resource. The importance of each of these categories will vary, depending upon the

specific type of project which is considered, but serious deficiencies in any of these categories of resources would be major constraints on the potential options.

As in the case of the economic resources, primary emphasis is on the client, but the importance of government as a social entity must not be overlooked or underestimated. All six of the general categories identified, when applied to the government, have important implications for appropriate project selection. An illustration will be presented here, and a somewhat fuller consideration will be undertaken in Part II.

Many agricultural development projects require a range of services to be provided to the client, to permit him to act in accordance with the proposed plan. Typical of these services are credit, physical inputs such as fertilizer, technical information, etc. Project designs usually anticipate that these services will reach the client in accordance with his needs. Since different governmental agencies usually have responsibility for delivering the different services, a relatively high degree of coordination among the agencies, and between the agencies and the clients is assumed. Whether such coordination will, in fact, occur is very dependent upon the levels of the social subsystem elements previously cited. The lack of essential coordination, so frequently encountered, suggests that insufficient resources of these types can present serious impediments to the success of agricultural development projects.

To facilitate the identification of these resources and the determination of their levels, it probably would be helpful to establish (to the extent it is possible) the threshold levels at which the resources would act as a serious constraint on different types of projects. There has been little formal explication of this, but experience with social constraints does exist in many projects.

7. Are Resource Constraints Critical? An important evaluation must now be made; are the levels of the identified resources such, that when compared to the required levels, they are in critically short supply? If the judgement, considering the individual elements of all the subsystems, is yes, then an evaluation of the possibilities and probabilities for either increasing the supply of the resource or reducing the requirement must be made (7a). This judgement is verified through a specification of the mechanisms for the removal of the constraints (7B). If the evaluation of critical constraint removal probabilities is such that one or more must be considered unremovable, then reconsideration of the development objectives (feedback link to (4) or of the more basic goals (feedback link to (1))must take place.

8. Identify Alternative Project Types. The planner is now at the point, where, at least in relatively broad terms he can identify potential project types which would meet the objectives specified, for which there are reasonably adequate resources, and for which no unresolved critical constraints can be identified.

Examples of the types of projects that might be considered at this stage are land settlement, road building, unirrigated development of land in settled areas, irrigated land development, and irrigation of existing agricultural land. Identification of the alternatives will in part depend on the imagination and skill of the planner. As was pointed out previously, the more broadly the objectives are defined, the broader will be the range of possible projects that the planner will be able to identify.

After the potential project types are identified, the planner is faced with the problem of evaluating the alternatives, typically part of the Feasibility stage of planning and design.

C. The Feasibility Stage

Three purposes are served by the Feasibility Stage of the planning-design process: to identify feasible project types from the list of alternatives developed in the earlier stages; to evaluate the feasible alternatives within the context of the development objectives and goals; to provide the information necessary for an informed project type selection by the policy makers.

The general process, depicted in Figure 4, consists of three basic steps: a screening of the alternative project types for feasibility (indicated by the flow loop, 9a-d); the evaluation of the alternatives found feasible (11), and the selection of the project type to be considered for continued design (12).

9. Examine Feasibility of Alternative Types. The pattern in this screening loop is similar to that depicted for the Pre-Feasibility Stage, but differs in that project objectives are now identified, and the necessary resources and conditions are specified in greater detail and with direct applicability to each of the project types. The avoidance of excessively narrow objectives again is appropriate, to permit the widest range of specific project alternatives after the project type is selected.

The feasibility being explored at this stage is the basic feasibility of concurrence of project objectives with development objectives (9b) and compatibility between available resources and conditions and the requirements for the project (9d). The more detailed studies, characteristic of traditional project feasibility studies, are to take place within the Detailed Design Stage. Thus, the data on resources (collected in step (6)) and the specification of requirements (in (9b)) are more general than conventional

STAGE C : FEASIBILITY

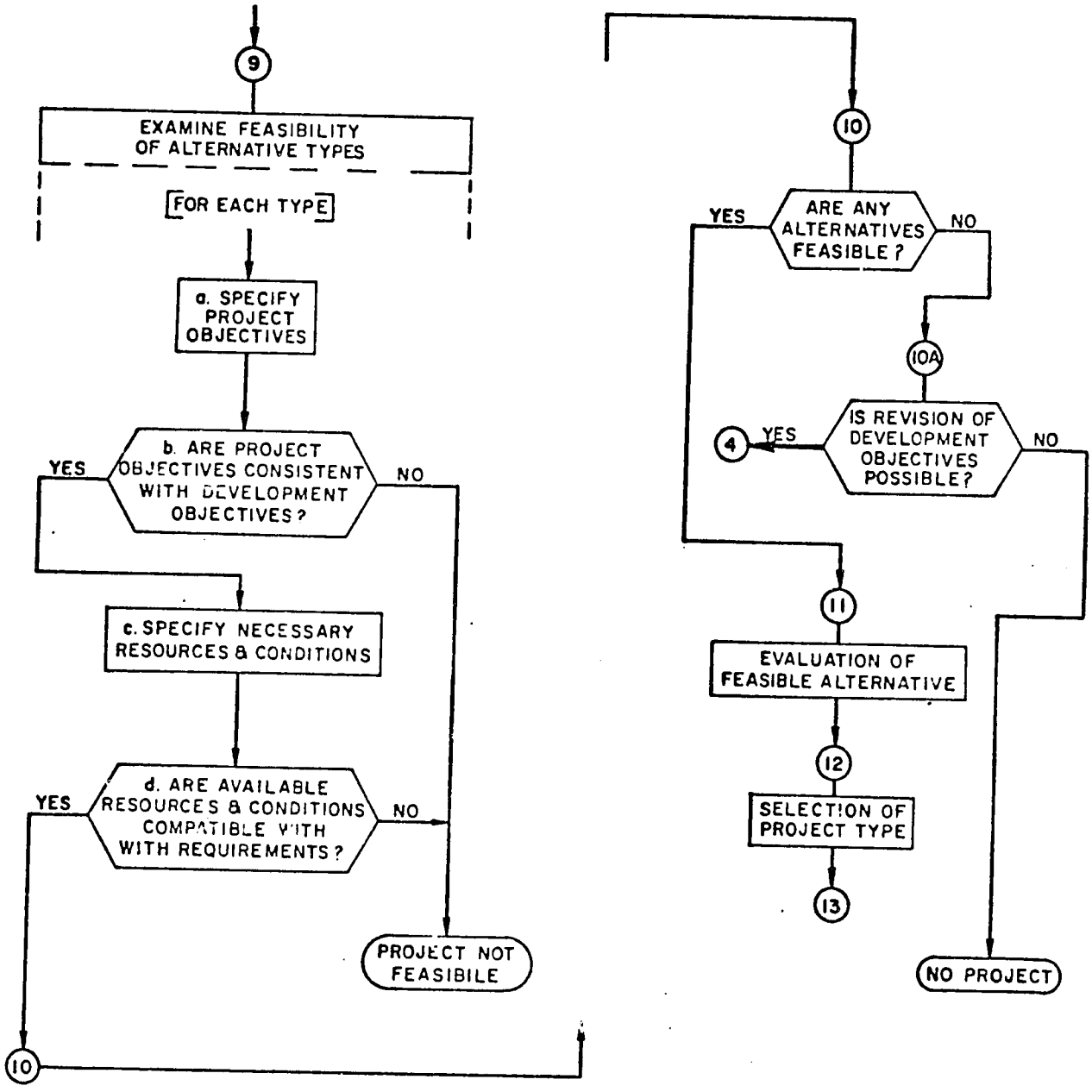


Figure 4. Feasibility Design Flow Chart

feasibility studies, but probably include a wider range of information, especially in the social and economic subsystems.

10. Are Projects Feasible? After the screening for basic feasibility, a more limited set of alternative project types usually remains. In an unusual set of circumstances, no feasible project type may have been identified. In this event revision of the development objectives is necessary (feedback link to (4)) or a conclusion can be reached that no suitable project exists. This is a legitimate, though perhaps unusual, outcome of the planning-design process and it should be considered a viable alternative. The reason it has not, in the past, been considered a reasonable alternative is that there has been a premature focus on one potential project type, with much data collection used to justify the project and to discourage "pessimistic" judgements.

11. Evaluation of Feasible Alternatives. Evaluation of the alternatives at this stage obviously cannot be done in great detail. But it should be possible for the policy maker to evaluate these different types of projects in a general way, considering the nature of their likely effects, and some order-of-magnitude estimates of their costs. Part of the evaluation may include judgements regarding the relative suitability of the various projects with respect to the goals and objectives that have been identified. While all the projects are presumably consistent with these goals and objectives, some of them will be seen as being more likely to lead to the desired results, or as leading to these results faster than will other projects.

At this point in the proposed planning-design process, the policy maker is provided with a much wider range of alternative decisions, and with different types and amounts of information upon which to base his decision. Less of the critical policy making power is left to the technical

staff, and we suggest, the probability of a more appropriate project selection is increased.

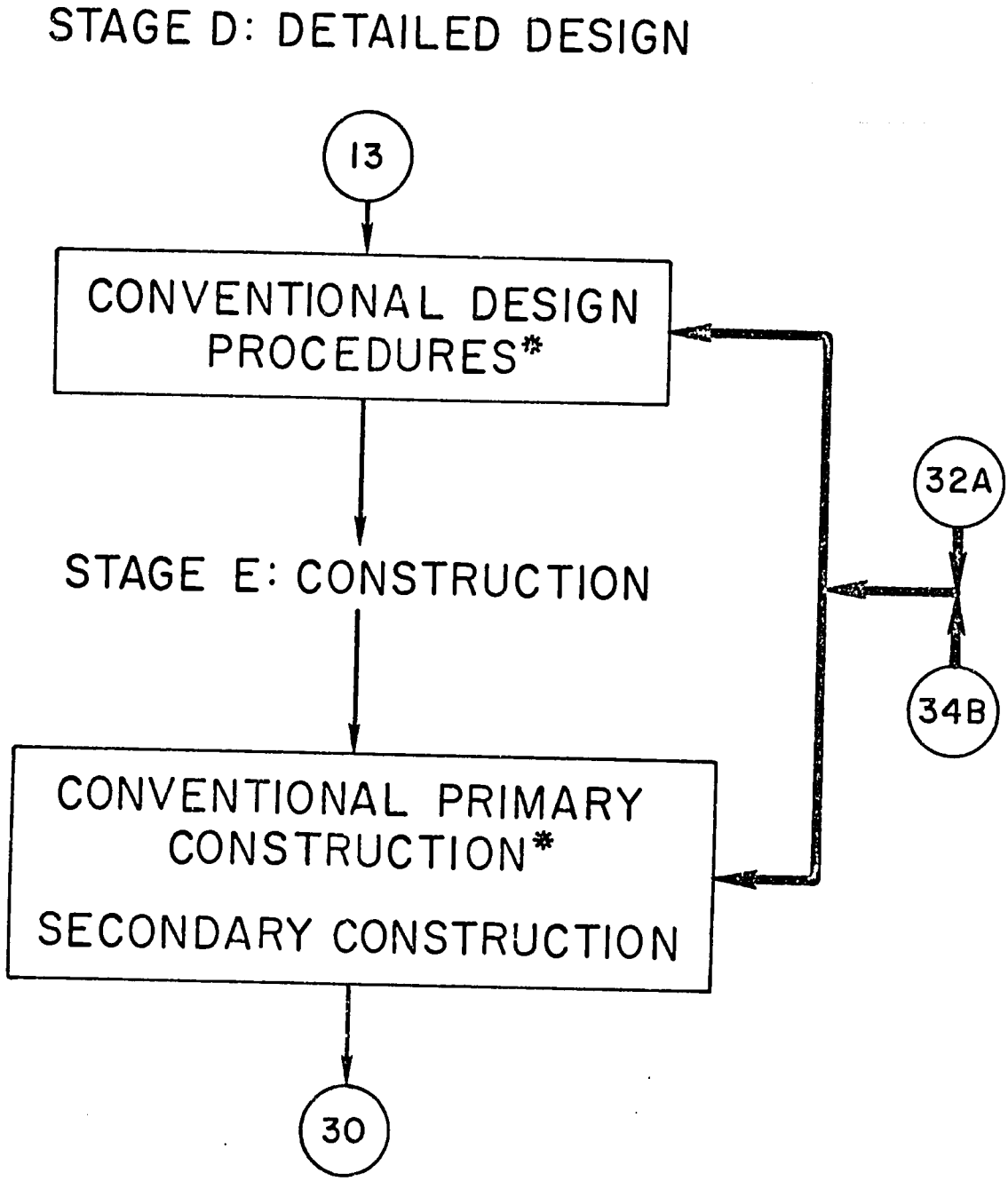
12. Selection of Project Type. There is no simple way to choose from among the various alternatives which have been identified. However, based on the evaluation which the policy-maker has undertaken, one type of project may be chosen for further planning and design. It is possible that the policy-maker may decide that he would like more detailed information on more than one of the alternatives identified. In this case, he may acquire this through a reevaluation process or, if he is willing to invest the resources, it is possible for him to select one or more of the alternatives, and to proceed to the detailed design stage for each of them reserving final decision to that point. In general, however, the decision on the most appropriate project type is made at the completion of this feasibility stage.

D. The Detailed Design Stage and E. The Construction Stage.

As we indicated in the introduction, we will not discuss the Detailed Design Stage or the Construction Stage in detail for two reasons. We are not proposing any significant changes in the procedures for these stages, though we are suggesting significant additional elements to be considered during the Detailed Design stage; we wish to emphasize the departures from the conventional design process inherent in the proposed process.

To illustrate the feedback requirement, however, the Detailed Design Stage, and the Construction Stage are illustrated in Figure 5.

The Detailed Design proceeds from the detailed data collection, to the identification of alternative designs, to the evaluation of these designs, to the selection of one and to the final check on project feasibility.



*These stages are not specified in detail, since the conventional design and construction processes seem sufficiently adequate. Some critical aspects of these stages are discussed on pages 21 and 23.

Figure 5. Feedback Links to the Design and Construction Stages

Construction, where it is an important element of the project, frequently is staged, with primary construction proceeding at a relatively early stage, and secondary construction proceeding over a longer period of time, often with some modification of design as feedback is received from the field.

Before leaving these stages for additional consideration in Part II, we would like to stress our view that in the context of Asian agricultural conditions, (and probably with wider applicability) it must be recognized that all project designs are tentative and incomplete until information on project performance is received from the field. We believe that it is very difficult, if not impossible, to obtain sufficient information to design a project that will meet client needs and project objectives without significant modification subsequent to project operation. We feel this to be true even for a static situation; if we consider a dynamic agricultural situation the probability of its validity is even greater. If we are correct, there should be explicit recognition of the tentative character of the design in the Detailed Design Stage, and feedback mechanisms should be an important element of the design. The explicit provision for feedback is important because project operation is typically the responsibility of a group other than the project designers, frequently in a different agency.

The tentative nature of project design has been recognized in some cases, and "pilot areas" or "Projects" are used to test design aspects. The monitoring of these areas, and the response to the feedback, however, frequently is limited.

F. The Operation Stage.

From the design point of view, project operation provides the opportunity to test both the performance feasibility of the design, and the validity of the assumptions used in the design relating the project changes and project objectives. The flow chart describing this monitoring and feedback mechanism is illustrated in Figure 6.

30.* Operate as Per Design. In many projects the tertiary features, or on farm components (e.g. land leveling in an irrigation project) are scheduled for installation over a relatively long period of time after project operation. Thus, the project may not, in fact, be operating as the design specifics for a significant period. Provision should be made for a "pilot" area in which all phases of the design can be tested. Operation in this area should be as anticipated for the complete project, without the "special" inputs frequently accorded to "pilot" areas. To the extent it is possible, the range of operating conditions (e.g. low water and high water supply levels, in an irrigation project) should be experienced or simulated early in project operation.

31. Monitor Project Performance. The important elements of project design, especially those relating to the client should be monitored to determine the degree of agreement between performance and design.

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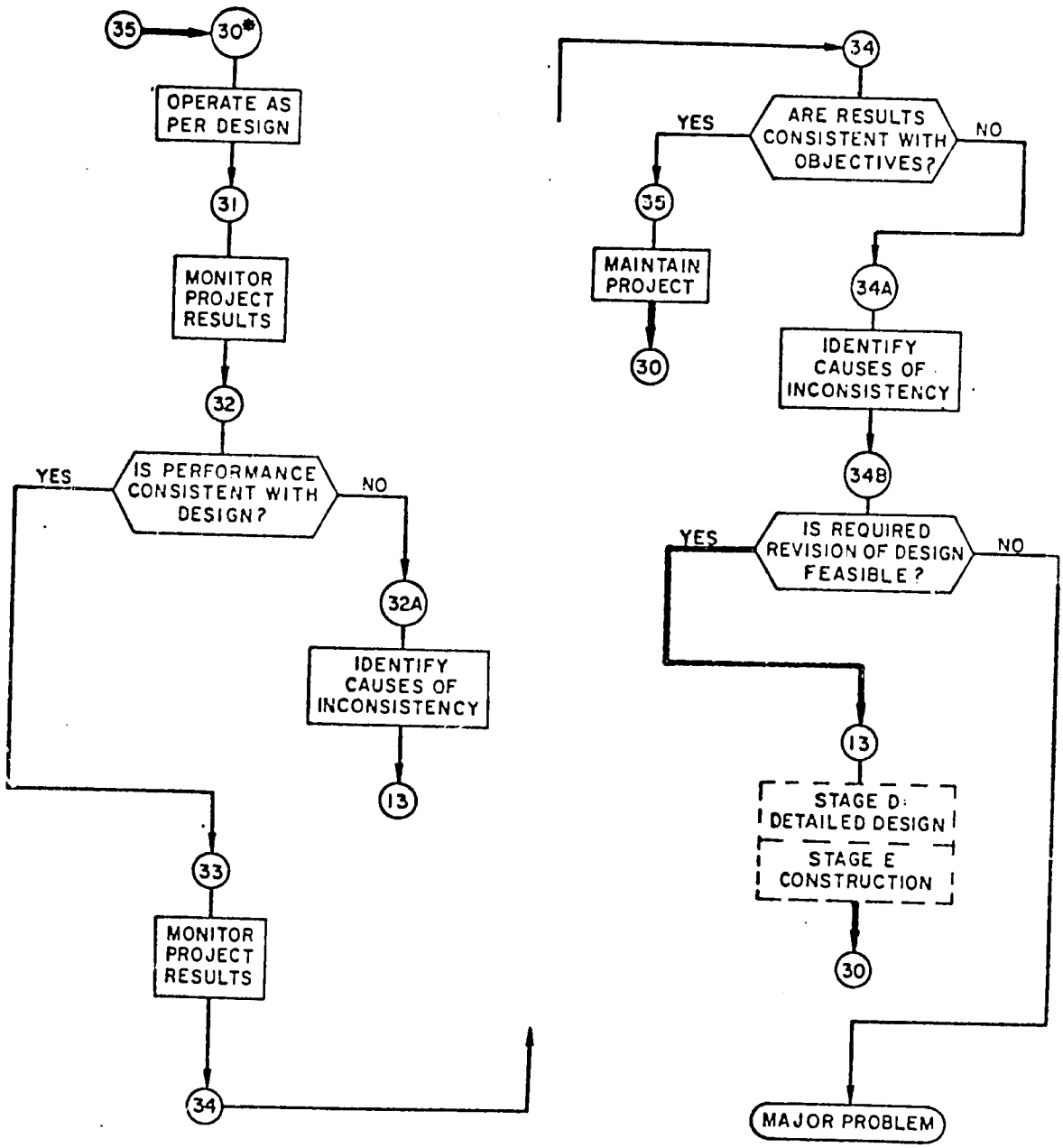
* The step sequence is interrupted to indicate the steps normal to the Detailed Design and Construction Stages; the numerical value of 30, however, is arbitrary and does not imply a specific number of steps in those stages.

STAGE F: OPERATION



* Flow step numbers for this stage arbitrarily start at 30, since flow charts for stages D and E are not specified.

Figure 6. Project Operation Flow Chart

For example, in an irrigation project it would be customary to measure the water flow rates at specified turnout gates for different maingate or canal levels. The flow reaching the individual holdings, and the disposition of that water on the holdings, is also very important though more difficult to obtain. This type of information is necessary, however, to have an adequate understanding of the actual performance of the project.

32. Is Performance Consistent With Design? With the data on project performance obtained, it is possible to validate the design. Where discrepancies between performance and design exist, the causes should be identified. 32a. In some cases these will be physical, in others they will reflect other subsystem elements, but the real causes should be identified, and the design modified. (feedback link to Design)

33. Monitor Project Results. Some of the output aspects of a project can be determined relatively early in project life, while others require a longer period before effective monitoring can take place. In both cases, however, the monitoring procedure should be specified, and the major aspects to be studied should be identified. Cropping patterns, yields, market prices, etc. should be monitored over time to provide the basic data for the later evaluation of the project.

34. Are Results Consistent with Objectives? A comparison of project results with project objectives generally will show some degree of inconsistency. When this discrepancy is relatively large, the causes should be identified (34a) and design revision evaluated. If, for some reason such revision is not possible (34B), then the project represents a major problem.

III. SUMMARY AND CONCLUSIONS

A planning-design process which differs significantly from the process now generally used has been proposed in this paper. It is based upon the premises that within the context of Asia: project results are products of the autonomous reactions of the clients to their total environment; the utilization of experiential knowledge is essential for successful projects; designs are necessarily incomplete until after the project is in actual operation.

The proposed planning-design process stresses the importance of the explicit identification and congruence of goals and objectives of both the government and the client beneficiaries; it emphasizes the maintenance of flexibility of options about the alternative types of projects which might satisfy the specified objectives; it provides for comprehensive consideration of the four subsystems of agriculture, with an emphasis on the identification of constraint conditions.

To achieve the objectives of the proposed process, it may be necessary to sacrifice some of the detail customary for feasibility studies, and to collect additional data on elements of the economic and social subsystems.

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IMPROVING THE PERFORMANCE OF AGRICULTURAL DEVELOPMENT PROJECTS

PART II

AN EXAMPLE OF A SYSTEMS APPROACH TO DESIGN DECISIONS: THE CONTROL OF IRRIGATION WATER

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BEST AVAILABLE DOCUMENT

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INTRODUCTION

In the introduction to Part I of this paper, we discussed our belief that many problems with agricultural development projects can be attributed to inadequacies in the customary process of planning and design. Two interrelated problems with the traditional design process were noted: (1) inadequate consideration of alternatives and (2) failure to give equal emphasis to the social, economic, physical and biological subsystems of agriculture. Both of these problems have led to what are in effect policy decisions being made by technicians in the guise of technical decisions. It was in consideration of these problems that we developed the proposed design process outlined in Part I. The proposed design process deals explicitly with the problem of inadequate consideration of alternatives. It also provides a framework within which interacting variables of the four subsystems of agriculture can be considered, although for the sake of clarity in presenting the main feature of the design process, we dealt in Part I only superficially with this aspect of the design process. In Part II, we examine in greater detail the manner in which systematic consideration of the interacting variables of the four subsystems can affect specific decisions which must be made in the design process.

It is our contention that at many points in the design process decisions are called for which need to be made on the basis of consideration of the interacting variables of the four subsystems of agriculture. In the prefeasibility stage of the design process, such consideration is important both for the identification of resource requirements and supplies (step 6 in the design process), and for the identification of critical

resource constraints (step 7). In the feasibility stage, the identification of the feasibility of alternative types (step 9) also requires consideration of the four subsystems. Likewise, there are numerous decisions in the detailed design stage which can best be made with explicit consideration of these interacting factors. For example, in a road project, the decision as to the specific location of the road, or the decision as to the type of road surface would benefit from these factors. For an irrigation project, decisions regarding cropping patterns and canal capacity are two examples of design decisions where information from all of the subsystems is needed in order to minimize the possibility of encountering major problems in the operation of the project.

To demonstrate in detail the nature of the factors to be taken into consideration, and to indicate the effects of such consideration on decisions affecting the designed project, we have chosen to develop an example of one decision for one type of project. The type of project chosen is that of an irrigation project, and the specific decision which we consider involves the determination of the type of unit (individual farm; ditch; sub-lateral, lateral) at which the major responsibility for the control of the water is to be passed from the central project administration to the farmers. In the next section of the paper, we identify and describe the most important or critical variables which should be considered prior to making this decision. This is followed by a section in which we (1) identify four alternative levels at which the major responsibility for the control of water can be shifted to the farmers; (2) examine the effects of alternative values for each of the variables identified; and (3) evaluate the four alternative levels in light of the discussion of the effects of

the critical variables. In the final section, the major points and conclusions of the paper are summarized.

Although the remainder of this paper thus deals with only one aspect of the detailed design stage of only one type of project, we wish to emphasize that we are attempting to provide a concrete illustration of how our systems approach can be applied to the many policy decisions which must be made in the design of any agricultural development project.

VARIABLES OF THE SUBSYSTEMS OF AGRICULTURE CRITICAL TO THE CONTROL DECISION

Deciding the level at which control is to be passed from the project authorities to the farmers should involve an evaluation of how the success of the project is likely to be affected by the alternative levels which might be chosen. We are therefore interested in identifying variables whose values (a) are indicative of the degree of success or failure of the project and (b) will be affected by the level at which control responsibilities are shifted. Although many such variables undoubtedly exist, we believe that it is possible to identify a limited number of them which are of major importance to the control decision. In this section we identify and describe those variables in each of the subsystems which we believe to be critical to the control decision. The section concludes with an illustration and discussion of some of the interactions among the variables.

Because we are interested in factors affecting the results of the project, the variables we have identified are those which appear to be directly related to the decisions of the individuals who ultimately determine the degree of project success. These people can be categorized into

two groups: the decision-makers for individual farm units (eg., a farm operator or farm family) and the project authorities. Some of the critical variables apply to only one of the groups, while other variables apply to both groups. Since planners do not directly affect agricultural production decisions, our list of critical variables does not include many of the factors (such as cropping patterns) which are typically a part of the planning process. We exclude these factors not because they are unimportant, but because their values are ultimately determined by the aggregate effects of many individual decisions, rather than by the desire of projections of planners.

Variables of the Social Subsystem.

We have tentatively identified five variables in the social subsystem which appear to be of critical importance to the success of irrigation projects. Because these variables relate to social groups, they are applicable to any group of people whose behavior substantially affects the success of an irrigation project. The variables thus apply not only to the farmers in an irrigation project, but also to the government authorities involved in the planning and implementation of the project, and to the merchants who provide supplies and who market the farmers' produce. It is well to remember that critical constraints on the success of an irrigation project may come from problems in the social behavior of merchants or of the government agencies dealing with irrigation, as well as from problems in the social behavior of the farmers.

1. Change in the complexity of role structure.

An irrigation project is likely to result in an increase in the number of types and varieties of roles performed by farmers, government officials and merchants, and in the degree of difficulty in performing these roles.

The degree of compatibility of the new and the old roles may vary considerably from one situation to another. We hypothesize that the greater the increase in role complexity and the lower the degree of compatibility between the old and the new roles, the greater will be the difficulty in establishing and maintaining a social subsystem that effectively supports the irrigation project. Many of the changes in the main patterns of role activity are likely to involve greater difficulty in performance. We can thus expect sensible reluctance and even opposition to change in the social subsystem unless the change is supported by persuasive sanctions (positive and/or negative) in the social and in the other subsystems. It is therefore important that project planning include careful studies designed to attempt to identify both the major changes implied in the main patterns of role activity, and the mechanisms available or obtainable to serve as positive and negative sanctions (rewards and deprivations) in support of such role changes.

2. Change in interdependence in social organization.

An irrigation project is likely to change the types of relationships of interdependence among participants in the system of agriculture. We hypothesize that the greater the congruence between the existing types and levels of interdependence among participants and those required for the proposed irrigation project, the better are the prospects for the development of an effective social subsystem. Types of interdependence include interdependence among farmers; between farmers and government officials; among officials; between farmers and merchants, and between merchants and officials. One type of interdependence among farmers that is of particular importance is that of the cooperative working groups which provide a means of managing the peak labor requirements during the periods of transplanting and harvesting.

Another aspect of the interdependence among villagers relates to the extent to which their agricultural roles are differentiated from other social roles occupied by the same people. One other significant aspect of the interdependence both among farmers and between them and merchants concerns the extent to which the production goals of the farmers are oriented toward the subsistence needs of the farm family, or toward cash income.

3. Degree of cultural cohesion.

In the proposed design process presented in Part I, we emphasized the importance of examining and reconciling the goals and development objectives of the project planners with the objectives of the farmers. The greater the congruence between the government development goals, the project objectives, and the farmers' goals regarding irrigation, the greater is the cultural cohesion. Another important factor affecting cultural cohesion is the degree of confidence that each of the participants in irrigated agriculture has in the competence and reliability of the other participants. Again, this applies to the confidence farmers have in each other and in the merchants and government officials; to the confidence that government officials have in each other, and in the farmers and merchants; and to the confidence that the merchants have in each other, in the farmers, and in the government officials. We hypothesize that the greater the degree of cultural cohesion, the greater the likelihood of success for an irrigation project.

4. Adequacy of communication patterns among participants.

An irrigation project creates increased needs for communication among some of the participants, most notably between officials and farmers. Such two-way communication is needed throughout the planning, construction and operation of the project. If such communication is inadequate, government

officials may be ill-informed regarding the needs and desires of the farmers, and farmers may have unrealistic expections of the likely costs and benefits to them of the irrigation project. We place special emphasis on the importance of two-way communication, since experience with irrigation projects in Southeast Asia suggests that while inadequate communication is a common problem, communication channels from the farmers to the project authorities are frequently particularly weak. We believe that without adequate two-way communication, the prospects for a successful irrigation project are considerably diminished.

5. Adequacy of social control.

Any agricultural system requires a certain degree of conformity among the participants. To achieve an acceptable degree of conformity, the available norms (to induce conformity) and sanctions (to enforce it) must be adequate. Changes in agricultural production patterns, such as those brought about by an irrigation project, require certain changes in the type of behavior to which the participants must conform. If the existing norms and sanctions are inadequate to elicit the necessary changes in behavior, new norms and sanctions must be developed. We hypothesize that the greater the required changes in norms and sanctions, the more difficult will be the establishment of an effective irrigation project.

Variables of the Economic Subsystem

In the economic subsystem, we have tentatively identified six critical variables. The first five of these relate to the behavior of farm families, while the sixth relates to the project administrators.

1. Relative availability of land and labor (land-labor ratio).

This variable is the number of hectares of land available to the farm family divided by the size of the family labor force. It is thus a measure

of the relative endowments of land and labor resources to the farm family. The land may be owned by the family, or may be made available to it under some form of a tenancy arrangement. The important point is that the farm family is able to make management decisions concerning the use of this land. Low values for this variable suggest a potential for agricultural practices involving a large input of labor per hectare, while high values suggest that less labor intensive agricultural practices will be favored. Because irrigation generally involves an increase in the amount of labor used per hectare, a low value of the land-labor ratio could be interpreted as being more favorable to the success of an irrigation project than a high value.

2. Profitability (marginal revenue-marginal cost ratio).

This variable is a measure of the potential market profitability of undertaking a new production activity. It is the ratio of the potential increase in cash receipts per hectare to the increase in cash production costs per hectare. Potential rather than actual increases in cash receipts are considered because of the possiblity that the farm family might decide to retain some of the increased production for home consumption, rather than actually selling it on the market for cash. (It is assumed, however, that the farm family does sell part of its total farm production for cash. If this were not the case, the market price of the products produced by the farmer might be irrelevant to his decisions.) Both terms in this ratio must be calculated for the unit at which the management decisions regarding farm production are made. We assume that this unit is generally the farm family. If, for example, the land farmed by the family is rented on a share of the crop basis, the additional rent that must be paid to the landlord as a result of the increased production must be subtracted from the gross potential increase in cash receipts in order to arrive at the potential increase in cash receipts to the farm family.

One difficulty in calculating the values of this variable related to the question of the relative amounts of family and hired labor used in the new production process. The larger the proportion of the additional labor requirements which is hired, the greater will be the increase in cash costs associated with the new activity. Because there are many factors which will determine the extent to which a family will hire labor for the production process, it seems desirable to make two calculations of the marginal revenue-marginal cost ratio. One calculation should be made under the assumption that no labor is hired, while the other should be based on the assumption that all of the additional labor required for the new production activity is hired. The resulting figures should provide some idea of the desirability of a

given production activity under alternative situations with respect to the availability of family labor.

3. Opportunity cost of the additional family labor required.

Although family labor is a non-market input, the farm family must still consider the production and consumption effects of alternative methods of allocation of this labor. Since we are concerned with variables which affect the behavior of farm families, the calculation of the opportunity cost of family labor must be from the perspective of the farm family, and not from a national perspective. Since each possible new crop or practice which might be introduced as a result of irrigation would have a different total requirement for family labor, the opportunity cost of meeting the labor requirements will be different for each crop. Furthermore, because of the seasonality of labor requirements for crop production, it is necessary to calculate the opportunity costs for each of several time periods (eg., each month) during the year. The lower the opportunity cost of meeting the labor requirements for a crop or practice, the greater the likelihood that the crop or practice will be adopted. Therefore, low values of the opportunity cost variable indicate relatively favorable conditions for the success of the irrigation project.

4. Change in financial risk.

Any new production activity which increases the cash outlay of the farm family increases the financial risk which they face. We suggest that a variable which could be used to reflect this risk is that of the ratio formed by dividing the per hectare change in cash outlay necessary for the adoption of the new practice by the net cash farm income per hectare. Net cash income from farming includes the gross cash receipts which the farmer obtains from his farming operation prior to undertaking the new activity, minus his cash production costs. The value of produce consumed on the farm is not included

in calculating the cash receipts. As in the case of the profitability variable, this ratio should be calculated on the two extreme assumptions regarding the hiring of labor. The larger the value of this variable, the greater is the amount of financial risk which the farmer incurs in undertaking the new activity.

5. Availability of knowledge and skills.

This variable is a partial measure of the endowment of what economists like to call "human capital." Since most of the relevant knowledge and skills are experiential in nature, it may not be possible to develop a precise measure for this variable. But planners should not overlook the importance of the skills of the farmers with respect to the kinds of agriculture which must be developed if the irrigation system is to be utilized.

6. O & M Expenditures per Hectare.

The amount of money budgeted by the project authorities for the operation and maintenance of the irrigation project is a variable whose value depends on the decisions of the project authorities, and not on the farmers. Major problems can be anticipated in case where this variable has a very low value.

Variables of the Physical Subsystem.

It is not possible to identify a single set of variables which, for all conceivable types of irrigation project, would have critical importance to the decision regarding the transfer of control responsibilities. If we limit our consideration to the context of Southeast Asia, however, at least five such variables can be hypothesized. In most cases these variables can be expressed as dimensionless ratios, with wide applicability, but in at least one case the absolute magnitude of the physical factor is the significant aspect.

1. Relative Water Supply (RWS)*

The amount of water available relative to the requirements of the physical-biological environment (the amount of water diverted divided by the environmental requirement) is perhaps the most critical of the physical subsystem variables. It has direct implications for the potential capability of the project to satisfy farmer requirements for water deliveries which are adequate in amount, timing and dependability, and which can be handled with a minimum of effort. It has indirect implications for the development of secondary problems, such as salinity and waterlogging. At the same time, it is related directly to the project administration objective of efficiently meeting the environmental (soil and crop) water requirements, and to the area which can be served from a given water source. Thus, it frequently represents a conflict variable among farmers, project operators, and policy makers and planners. This can be illustrated

* The inverse of this variable is traditionally identified as the project Water Use Efficiency. It is deliberately restated in the Relative Water Supply form to emphasize the frequent inappropriateness of the water efficiency concept in the context of monsoon Asia.

with a typical Southeast Asian situation.

For a project in which rice is to be the dominant crop, the irrigation requirement at the farm level, based upon the physical-biological environmental conditions, frequently will approximate 600 to 700 mm per season (,). From the standpoint of serving the largest possible area with water sufficient for maximum production, a relative water supply (RWS) value approaching 100% would be desired. From the project administration point of view, recognizing both on-farm distribution problems and timing difficulties in delivery administration, an RSW value of approximately 140% at the farm level (usually about 200% at the point of diversion), frequently is considered optimum. From the farmer point of view, however, the desired level may be as high as 300%. Thus, three different attitudes toward this critical variable may prevail, as depicted below.

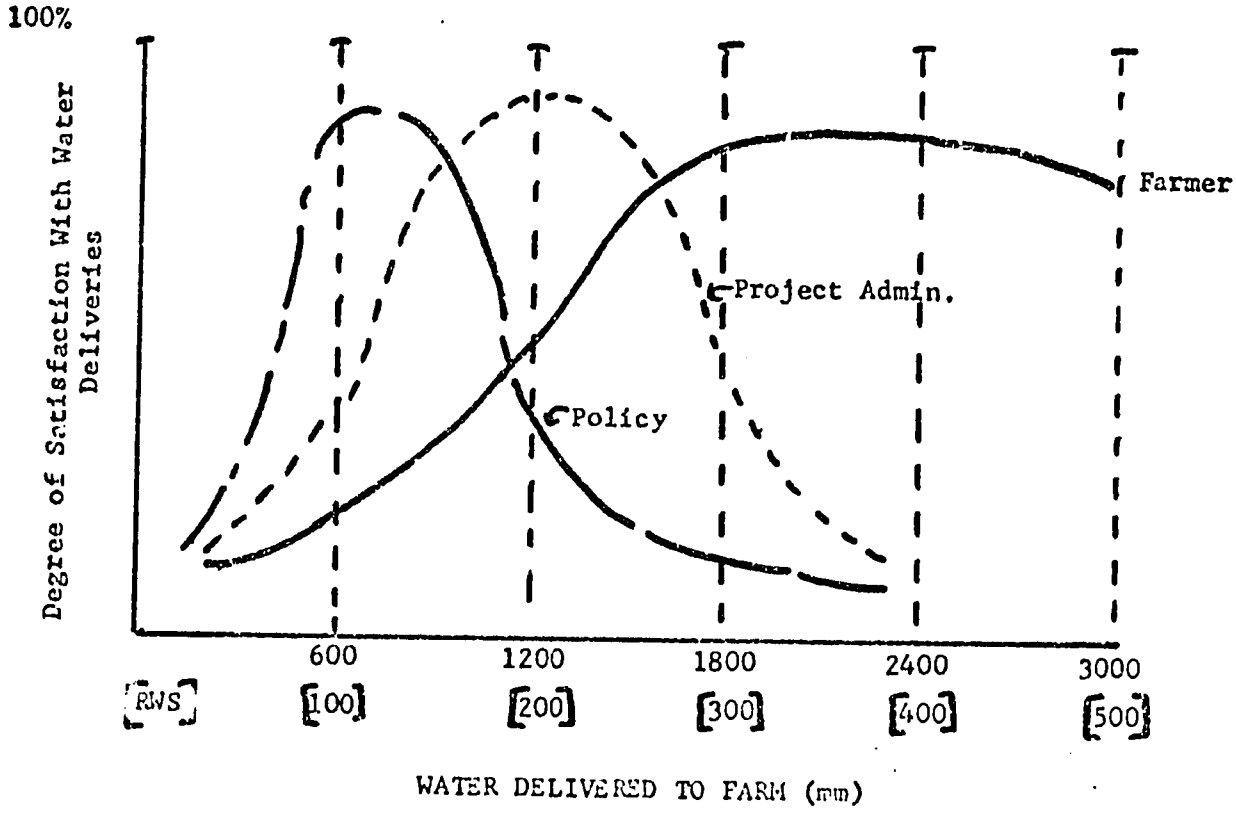

Figure II-1. Satisfaction Levels of Farmers, Project Administrators and Policy Makers as a Function of Relative Water Supply

If a project is designed with an RWS value significantly less than 250%, special attention must be paid to the entire delivery process, including both the physical and institutional aspects, to minimize conflict situations.

2. Average Farm Size.

While this variable has obvious relevance to the economic subsystem considerations, it is also a physical variable with major implications for irrigation decisions. In general, the smaller the farming unit, the larger is the amount of information necessary to design a project potentially satisfactory to the farmers; the greater is the infrastructure requirement; the more complex is the project operation; and the greater is the maintenance requirement.

3. Proportion of Command Area Which is Irrigable.

This variable, while important for efficient operation of wet season supplemental irrigation projects, becomes especially critical for projects with major dry season irrigation objectives. The primary physical factors affecting this variable usually are soil characteristics and topography. As the proportion of the command area which is irrigable decreases, the difficulty of meeting individual farmer needs increases, necessitating a higher RWS for effective service.

4. Control Capability.

The control capability variable reflects the project capability to control the water from the point of capture (reservoir, river or well) to the point of end use. Based on the responsibility for control, this variable can be subdivided into two subvariables, Project Control Capability and Farmer Control Capability. The variable consists of a complex mix of physical components (density of channel distribution, type and

relative frequency of control structures, percent of channels lined, etc.), with important interrelationships with economic and social variables. At this time the components of the control capability variables and the quantitative interrelationships are not defined.

5. Reduction in Catastrophe Frequency.

Objective measures of the frequency of catastrophes caused by drought, floods, typhoons, etc. can provide indices of the effects (if any) of a proposed project on the probabilities of such events. Thus, the variable, Frequency After Project/Frequency Before Project, combined with the absolute values of the Frequency Before Project, is an important index of probable project utilization. If the catastrophe frequency is high before project development and the ratio is low, as might be anticipated in an irrigation-flood protection project, a high rate of project acceptance and utilization would be anticipated. On the other hand, if the flood frequency is high and unaffected by an irrigation project, relatively greater problems of irrigation utilization could be expected. If the project increases the possibility of catastrophic events (unlikely, but possible) relatively low acceptance and utilization levels might be expected.

Variables of the Biological Subsystem

Because of the nature of our individual specialities, we have treated the social, economic and physical subsystems in greater detail than we are able to treat the biological subsystem. Without attempting to specify their precise form, we indicate below the general nature of the variables of the biological subsystem which we believe to be critical to the degree of success of an irrigation project.

1. Increase in yield potential.

Irrigation projects frequently permit farmers to grow new varieties of the same crops that they had previously grown. In such cases, the larger the increase in yields the more probable is the utilization of irrigation water. We recognize that there are both conceptual and practical problems in measuring yield potential. Probably the increase in yields should be estimated both under optimum conditions for plant growth and under conditions expected to prevail on the farms in the project area.

2. Yield variability.

In any given year, yields will fluctuate from locale to locale within the project area; furthermore, average yields for the project area will fluctuate from year to year. It can be expected that for any given average yield, the larger are these relatively unpredictable variations, the more difficulties will be encountered in the utilization of the project.

3. Input requirements.

Achieving the yield potential of irrigated crops generally necessitates the increased use of inputs which cannot be produced on the farm, most notably, fertilizer and pesticides. The larger the amount of these inputs required, and the less previous experience that farmers have had with them, the less is the likelihood that farmers will make full utilization of the irrigation project. Different varieties of a given crop frequently exhibit considerable differences with respect to the levels of these inputs required to achieve their yield potential. For fertilizer, this variability among varieties may be indicated by the ratio of the yield potential divided by the quantity of nitrogen required to achieve the potential. For pesticides, the differences among varieties are directly related to genetic differences affecting resistance to insects and diseases.

4. Local availability of required technology.

The large variation in biological conditions even within a relatively small geographic area generally necessitates considerable local testing and adaptation of new technology such as new varieties or new cropping patterns. Where this type of testing has been done, and locally tested technology is therefore readily available, fewer problems should be encountered in the utilization of the irrigation project than in cases where the available technology has not yet been adapted to local conditions.

5. Pest population.

Irrigation projects frequently result in conditions favorable to the spread of organisms harmful to plants and animals. In some cases, human health may be affected, as in the case of an increased incidence of mosquitos or of snails linked to schistosomiasis. Careful consideration, both in the pre-construction design stages and in the operation stage of an irrigation project should be given to these negative effects of the project.

6. Heterogeneity of the biological environment.

The greater the number of varieties and types of crops grown, the greater is the heterogeneity of the biological environment of agriculture. Irrigation projects may lead to decreased heterogeneity if they result in a decrease in the number of varieties grown with no change in the number of crops grown. This has frequently happened in the case of rice monoculture areas. If a larger number of different crops are grown as a result of an irrigation project, the heterogeneity of the biological environment has been increased. A heterogeneous biological environment places greater demands on an irrigation project, since different crops require water at different times. On the other hand, insect and disease problems may be reduced in a heterogeneous environment.

Interactions among the variables of the four subsystems.

In the above discussion, we have attempted to separate, for analytical purposes, each of the subsystems and consider the variables in it. But in reality all of the variables are interacting simultaneously as part of the total agricultural system. Thus the value taken on by one variable depends on the values of all the other variables, which in turn are affected by the value of the first variable. No one variable or subsystem can be considered to be "basic," nor can a single direction of causality among the variables be assumed. This can be illustrated by the following composite example of a lowland irrigation project in the Mekong region.

A casual oberserver notes that ditches forming the minor distribution network of the irrigation project are in poor repair; that few crops are being grown in the dry season; and that in the wet season most farmers grow traditional rice varieties using traditional cultural practices. Irrigation project officials note that farmers are unwilling to dig and maintain the ditches. They also point out that many farmers allow their water buffalo to damage the banks of the canals of the project, and that some farmers deliberately destroy the banks to obtain water. They complain that few of the farmers seem willing to use the irrigation water which is available in the dry season, and that most of those who do engage in dry season production demand excessive quantities of water, wasting a great deal of water which runs off their land and onto low areas where it is not desired. The agricultural extension officials note that the farmers are very slow to adopt new technology. The program to introduce improved varieties of rice has not been very successful, in spite of numerous demonstration plots showing the superiority of these varieties. Efforts to encourage farmers to use fertilizer have also met with only very limited success. Farmers

point out that water is often not available when they need it. One farmer recalls trying to raise a dry season crop a few years ago, only to see it die when the main canal was suddenly closed for repairs at a critical time. Another farmer says he has difficulty in obtaining enough water to grow a dry season crop because the turnout on the canal is too high. Many farmers feel that the government should be responsible for maintaining the ditches. One farmer notes that he cannot get water because his neighbor will not allow him to dig a ditch across the neighbor's field. Several farmers state that fertilizer is too expensive for them to afford it.

Inferences regarding the values of a number of the critical variables can be drawn from the example. The fact that farmers as a group are unable or unwilling to dig and maintain the ditches suggests an inadequate degree of interdependence in social organization, and a low level of social control. The deliberate destruction of the canal banks by the farmers, and the additional damage caused by their handling of their water buffalo/ further demonstrate the inadequacy of social control with respect to both norms and sanctions. The closing of a canal for repairs at a time when some farmers were expecting water deliveries indicates inadequate communication patterns between farmers and project authorities, and perhaps also among project authorities. The disrepair of the minor distribution system and the difficulties encountered by some of the farmers in obtaining water for dry season crops suggest low values for the control capability and relative water supply variables. The complaint of the project officials regarding the wasteful use of water by the farmers suggests both low control capability and low levels of knowledge and skills with respect to irrigated agriculture. The lack of interest in dry season production, and farmer comments about fertilizer prices suggest that the profitability of irrigated cropping may be rather low, and that the financial risk is rather high. The yield

potential of the rice varieties grown in the wet season is rather low, and while higher yielding varieties are available, the input requirements may be too high to make them attractive to the farmers under the existing profitability and risk situations.

Many of the interactions among these variables should now be readily apparent. The inadequate interdependence in social organization and the low level of social control both lead (through the deterioration of the distribution network) to a reduction in the control capability. This in turn leads to a lower value for the reduction in risk variable, which lowers the average profitability of irrigated cropping. This in turn discourages farmers from utilizing the irrigation water for the production of high yielding varieties, with their high input requirements and the associated high financial risk. But the interaction among these variables is not a simple one-way causation process. The fact that profitability is low and that water deliveries are unreliable makes it more difficult for effective social control and interdependent social organization to be established, because farmers may feel that it is not worth the effort to organize to maintain ditches that do not seem to provide a reliable source of water. Furthermore, given the low yield potential of the varieties which the farmers are currently growing, the improvement of the water supply resulting from better maintenance of the ditches might have little effect on yield (and thus on profitability), therby further reducing the incentive to develop an improved social organization. Thus while profitability and reliability of deliveries "depend" on the effectiveness of social control and social organization, these latter in turn also "depend" on the profitability and reliability of water deliveries. And while the varieties grown (and thus the yield potential) "depend" on profitability, and on the reliability of water deliveries, these in turn "depend" on the varieties grown. It is in this sense that the variables

of the four subsystems are interacting in an interdependent fashion, and for this reason the four subsystems need to be considered together in an integrated fashion in the design process.

DETERMINING THE LEVEL FOR TRANSFERRING CONTROL RESPONSIBILITY TO THE FARMERS

Irrigation projects generally involve the storage or diversion of water at a dam or pumping facility, and the conveyance of this water to individual farm fields. Project authorities generally have responsibility for the control of the water at the point of diversion or storage, while farm operators are responsible for control over the movement of water on their individual farms. Thus at some point in the conveyance of the water there must be a transfer of the major control responsibilities from

the project authorities to the farmers. Because several alternative possibilities exist, it is necessary that fairly early in the detailed design stage of the project, a policy decision be made regarding where in the conveyance network this transfer will be made. In this section of the paper, we consider the nature of the alternatives available and examine the implications of our systems approach for the policy decision which must be made.

Alternative levels for the transfer of control.

In examining the alternatives available, we are concerned with the nature of the units within which control over the distribution of the water is to be exercised mainly by the farmers. In this discussion, we refer to these units as "levels" of water control.

1. Individual farm.

In the context of the Mekong basin, this alternative requires central project control of the water to units which are typically two to four hectares in size. Such a design would necessitate the use of very substantial government resources for the construction, operation and maintenance of a vast canal network. It would also require a complex information system to inform project managers of the water needs of individual farmers. On the other hand, the project would require virtually none of the resources of each individual farmer, apart from those required for managing the distribution of water on his own farm.

2. Ditch.

As an alternative to centrally controlled deliveries to the individual farm units, the project could be designed for central control over the water only to the point of turnout from a lateral or sub-lateral into a ditch. Although the lengths of the ditches would vary from one project to another, in the Mekong basin one ditch would typically serve an area of 20 hectares or more. Thus

probably at least 10 farmers would share the responsibility for the distribution of water among themselves. This level of water control would place much less of a burden on government resources, but project success would depend more heavily on the ability and willingness of the beneficiaries to organize themselves and to mobilize their own resources.

3. Sub-lateral.

A project could also be designed for central control of the water to terminate at the head of a sub-lateral. Again, the size of the area served by a sub-lateral would vary both among projects and within a single project, but would probably be on the order of from somewhat less than 100 hectares to a few hundred hectares. The "service units" which NEDCO has proposed for the improvement of water control facilities in the Central Plain of Thailand would fall into this size category ( ). This level further reduces the burden on the resources of the government, but again increases the demands on the project beneficiaries.

4. Lateral.

Finally, a project could be designed for central water control to terminate at the head of a lateral. Corresponding roughly to the "zone" of irrigation projects in Thailand, the area served might range from nearly one thousand to several thousand hectares. The several hundred farmers in the area would have the right to a specified amount of water delivered to the lateral, and the responsibility for the distribution of this water among themselves. By transferring to the farmers the major responsibility for the control and distribution of the water at this level, the government would minimize the burden on its own resources, while maximizing the burden on the resources of the beneficiaries.

The Critical Variables and the Choice among the Four Alternative Levels

Having identified the alternatives available, we are now in a position

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to examine systematically the implications of different values of the critical variables for the design decision regarding the leven of the transfer of water control. For each of the critical variables, we attempt to indicate, in qualitative terms, the type of values which suggest that major problems in the utilization of the project can be anticipated with at least one of the four alternative levels. We also indicate the types of values which, because they do not result in any particular advantage or disadvantage to any of the four alternatives, place no constraints on the design decision.

1. Social variables.

The greatest complexity of role structure among the farmers would be required for a project designed to transfer responsibility to the farmers at the level of the lateral, while a transfer at the individual farm level would probably necessitate the least complex structure. In many cases the role structure required for operation at the ditch level might be similar to that existing prior to the irrigation project. Considering the complexity of role structure among government officials, however, we find that by far the greatest complexity would be required for a project designed for individual farm deliveries. Substantially less complexity would be involved if the project were designed for transfer of responsibilities at the ditch level. We therefore conclude that from the point of view of complexity of role structure, a project designed at either the ditch or sub-lateral level would have the greatest likelihood of success. A similar conclusion emerges with respect to the interdependence in social organization. For the farmers, the required interdependence is least for a project designed to deliver to the individual farm, and is greatest when responsibility is transferred at the level of the lateral. But for the government officials, a project

designed to deliver water to the individual farm requires a great deal of interdependence both among individuals and among separate government agencies. This interdependence is created by the necessity of obtaining, on a continual basis, a vast amount of information on weather, crop and soil conditions and on cropping plans from the large number of individual farms served by the project, and then translating this information into a form that can provide the basis for making operational decisions regarding the distribution of water throughout the project.

If cultural cohesion is high, no constraints are placed on the project designers. But if there is only weak cultural cohesion, it is likely that a project designed at either the lateral or the individual farm level will encounter serious problems. A project designed for central project control of water to the individual farm will encounter difficulties because of inconsistencies between the goals of the project authorities of the farmers, and because of a lack of confidence among farmers in the reliability of performance of the project authorities, and vice versa. Similarly, the farmers' lack of confidence in each other mitigates against a project designed to transfer to them the responsibility for the distribution of water to the entire area served by a lateral of the project.

With good communication patterns, no constraint is imposed on the project designers, but if communication is inadequate, projects designed for the individual farm level and for the lateral level will probably encounter the greatest difficulties. The greatest need for two-way communication between farmers and project officials occurs in the case of a project designed to control deliveries to the individual farm. Without adequate communication, it is virtually impossible for such a project to be successful.

But a project designed to transfer responsibilities at the level of the lateral places considerable demands on the communication patterns among farmers. If these patterns are inadequate, it is likely that such a project will also encounter serious difficulties. We therefore conclude that inadequate communication patterns tend to restrict the design options available to either the ditch or the sub-lateral level.

As with the previous variables, if social control is adequate, no constraints are placed on the designers of the project. If social control is weak, a project designed to transfer control at the level of the lateral is likely to encounter serious problems, as the farmers have not developed the degree of conformity in their behavior necessary to equitably distribute the water among themselves. This problem will also exist for projects designed to give farmers control of the distribution at the sub-lateral and ditch levels, but it will be less serious, as social control is likely to be stronger among small groups of farmers who know each other and can therefore apply informal sanctions. For projects designed to control water to the individual farm level, serious problems can again be expected if social control is low. The reason for this is that to be successful, such a project requires a vast network of distribution channels and structures which are operated by the project authorities. With poor social control, it is very likely that many of the structures would be damaged or destroyed by the farmers, making them functionally inoperative. Thus, as was the case with all the other social variables, the constraints imposed by unfavorable values of this variable tend to favor the ditch, and to some extent, the sub-lateral levels for the transfer of control responsibilities to the farmers.

2. Economic variables.

Most of the constraints on the design imposed by the economic variables operate through their effects on the value of irrigation water to the farm operators. If irrigation water has a high value, no constraint is imposed. If, however, irrigation water has a low value to farmers, we can anticipate that the likelihood of effective utilization of the water will be greatest when the demands on the resources of the farmers are the least. Considering only the influence of the low value for water, the greatest problems are likely to be encountered with the "lateral" level of control, with somewhat lesser problems at the sub-lateral and ditch levels, and with the least problems at the individual farm level. (As in noted in the discussion of the social and physical variables, however, there are many other reasons to expect problems at the individual farm level.)

The first four of the critical economic variables identified above affect the value of irrigation water. If land is plentiful relative to labor (i.e., the land-labor ratio has a large value), the individual farm family will have both less ability and less need to farm the land intensively than in situations where land is scarce. Irrigation water, which permits the intensification of land use, will thus have a relatively low value when the land-labor ratio is high. Similarly, the lower the profitability of irrigated crop production, the lower will be the value of irrigation water. The higher the opportunity cost of the family labor needed to engage in irrigated agricultural production, the lower the value of irrigation water. Finally, if there is a large increase in financial risk, the value of irrigation water will be lower than if there is no increase in financial risk. To summarize, high values for the land-labor ratio; low values for the profitability variable; high values for the opportunity cost variable and high values for the financial risk variable all mitigate against a project designed to transfer control

at the level of the lateral, and toward a project designed to deliver water to smaller units.

Low levels of knowledge and skills for irrigated agriculture will also tend to favor a design decision in the direction of the individual farm level. In part, this is because with a low level of skills, the irrigation water will have less value to the farmers. More important, however, is the fact that with a low level of skills, the farmers probably will be unable to organize and undertake the activities necessary to distribute the water among themselves. This would be especially true at the lateral and sub-lateral levels. The last of the critical economic variables is the level of government expenditure for operation and maintenance of the project. If the amount of money per hectare which the government is willing or able to budget for the operation and maintenance of the project is small, then clearly the individual farm unit level is inappropriate. The smaller the anticipated value of this variable, the larger should be the size of the unit at which control responsibilities are shifted away from the government.

3. Physical variables.

Both low and high values of the relative water supply variable place constraints on the design decision regarding the transfer of control, while values in the range of 250 to 350 place no significant constraints on this decision. At levels of the RWS below 200, conflicts are likely to arise among farmers regarding the distribution of water. We hypothesize that the larger the group of farmers attempting to distribute the water among themselves, the more serious these conflicts are likely to become. While the individual farm units might therefore appear to be the logical transfer level, major communications and control problems inherent in dealing with the myriad of small farmers in a situation of a limited

water supply suggest that such a project would also encounter serious problems. We therefore conclude that low levels of RWS would constrain the designer to the ditch or possibly the sub-lateral level. If the RWS is above 400, we suggest that control at the sub-lateral level would be appropriate. The major problem here is one of excess water, for which some form of control at the lateral would be appropriate. At the same time, there frequently will be periods of more limited supply, for which smaller group action would be appropriate.

Small values of the average farm size variable place a constraint on the control transfer decision. When the average farm size is less than 5 ha., it becomes impossible (under the conditions in many parts of Asia) for the central project authorities to deal with individual farms. It also becomes very difficult for the farmers served by an entire lateral to manage the distribution of water, due to the very large number of farmers involved. Thus if, as is typical in the Mekong region, the average farm size is two to four hectares, a project designed to transfer responsibility at the ditch or sub-lateral level would appear to offer the greatest promise of success.

It was indicated earlier that, in general, as the irrigable proportion of the project command area decreases, the constraining aspects of the variable tends to increase. Since the factors affecting this are primarily physiographic, an approximation of a reasonably homegeneous physiographic unit would be a logical upper limit to the size of the area for which control responsibilities are transferred to the farmers. For the Mekong region this might vary from the ditch to the sub-lateral level, though in delta areas, the lateral level might fall in this category.

A high degree of control capability places no direct constraints on the decision regarding the transfer of control. We would emphasize, however, that under conditions encountered in the Mekong basin, a high control capability (which implies 24-hour water control, measuring capability at the turnout point, relatively rapid flow velocities, security of control structures, effective two-way communication, scheduled maintenance, etc.) is extremely difficult and expensive to achieve. If control capability is low, a project designed for central control of deliveries to the individual farms can be expected to encounter very major problems. Projects designed to transfer responsibility to the farmers at the level of a lateral would probably also encounter serious difficulties because of the many conflicts among farmers that would be likely to arise. We therefore conclude that a low control capability tends to suggest projects designed to transfer responsibility at the ditch or sub-lateral level.

The effect of the final physical variable, reduction in catastrophe frequency, is similar to that of the economic variables in that it operates through its effect on the value of irrigation water to the farmers. The less the reduction in catastrophe frequency, the less will be the value of the irrigation water to the farmer, making him less willing to bear the greatercosts associated with projects involving substantial farmer responsibilities for the distribution of the water.

4. Biological variables.

The first five of the critical biological variables impose constraints on the design decision mainly through their effect on the economic variables. A low value for the increase in yield potential will tend to lower profitability. A high degree of yield variability reduces the value of irrigation water to the farmer, because of the increased risk of a poor crop. If the input requirements for achieving the yield potential are high, then a considerable reduction in yield, and thus profitability, can be expected if these inputs are not used. Again, lack of locally tested technology will result in lowered profitability. Increased pest populations over time will also reduce profitability, either through lower yields or through higher costs of control. All of the above constraints would therefore tend to mitigate against the lateral design level and toward the smaller units.

Considering the final critical variable, a heterogeneous biological environment implies that many different types of crops are grown at the same time. Since different crops have different irrigation requirements, particularly with respect to the timing of water deliveries, it would probably be difficult to obtain satisfactory results if responsibility for the distribution of the irrigation water for an entire lateral were turned over to farmers. On the other hand, with diversified cropping, a vast amount of information would be required by the project authorities to successfully operate a project designed for central control to individual farms. Recognizing the difficulty of obtaining such information, we conclude that either the ditch or the sub-lateral level would be most appropriate with the heterogeneous biological environment implied by diversified crop production.

Evaluation of the Alternative Levels for the Transfer of Control

At this point it should be clear that a detailed evaluation of the alternative levels of control for any given irrigation project requires the collection of data from the specific project area in order to evaluate the critical variables in each of the four subsystems which we have discussed. The ultimate design decision regarding the level at which control responsibility is transferred would thus be specific to the project being considered, and could be expected to vary from project to project. We believe, however, that from our previous discussion of the effects of the individual critical variables it is possible to draw some general conclusions which would be applicable to most irrigation projects proposed for the Mekong basin.

The first alternative (providing project control of the water to the individual farm) should, if properly managed, result in a satisfactory situation with respect to the quantity, timing, and reliability of water deliveries to the individual farms. Yields, therefore, should not be adversely affected by lack of water, unless there is a shortage of water throughout the entire irrigation project. The farmer will not have to spend time maintaining the distribution ditches of the project, and thus the only labor requirements which he needs to consider are those of producing the crop itself and of managing the distribution of water within his own farm. His profitability calculations will be affected by the charge that he has to pay to the irrigation project for water, and by any costs which he has to incur to lift water from one field to another on his farm. If there is no charge for the water, the benefits to the individual farmer from this approach should be quite high, and the costs low. If a water charge is imposed, part of the benefits will be transferred from the farmer to the government.

(The total benefits may also be increased as a result of the imposition of a charge for the water, due to more economically efficient use of the water.) But while benefits are high, and farmer costs are low, the costs to the government of properly managing such a project are very high. Because the only resources of the farmers that are mobilized are those of labor and skill in the production of crops, the government must provide all of the remaining resources required to make the project operate successfully. The government will have to build and maintain a complicated network of canals and ditches. This requires much detailed information on local conditions which the government generally does not possess. Thus skilled people must be sent out to the various parts of the project area to gather a vast amount of information. The need for information will not end with the completion of the construction phase of the project. In order to operate the project and provide water to the individual farmers when they need it, the government must have a complex network to gather information. The people who must be recruited for these tasks have a high opportunity cost to the society, given the shortage of professionally trained people in most low income countries. The total cost to the society of this alternative will therefore be quite high.

Compared with the first approach, the alternative of controlling the distribution of water only to the ditches results in conditions which are less favorable to the farmers in several respects. First of all, the timing and reliability of water deliveries to the individual farms are likely to be less satisfactory. Second, the labor requirements will be greater since the farmer will have to participate in the construction, operation, and maintenance of the distribution system between the turnout of the project canal and the individual farms. Third, extra cash costs

may be encountered, as it may sometimes be necessary to pump water from the ditch onto a farm field, or from the field of one farmer to the field of another. Fourth, construction of ditches requires different skills than are needed for the production of irrigated crops. Initially the lack of experience in constructing and maintaining ditches may result in structures that are only partially effective. Finally, in constructing, operating, and maintaining the distribution system, farmers will encounter problems of rights of way for the ditches. And because some farmers will have to depend on receiving water from (or draining water onto) a neighboring field, questions of water rights will also be raised. The ability of the farmers to satisfactorily deal with these types of problems depends in part on the variables of the social subsystem. If these problems cannot be resolved satisfactorily, the quantity, timing and reliability of water received by the individual farmers will be seriously affected, leading in turn to higher risk and lower profitability.

Considering these less favorable conditions at the farm level, it is likely that the benefits received by the farmers as a result of the irrigation project will be less than in the case of the first alternative. It is also clear that the farmers, through greater utilization of their own resources in the construction, operation and maintenance of the project, will encounter greater costs than in the previous case. The government, however, would find its costs considerably reduced, since it no longer must concern itself with such a complex distribution system. In particular, the requirement for detailed knowledge of highly localized needs and conditions would be reduced.

The third alternative, that of centrally controlling water deliveries only to the sub-laterals results in even lower costs to the government, as more responsibility for the distribution of the water is passed on

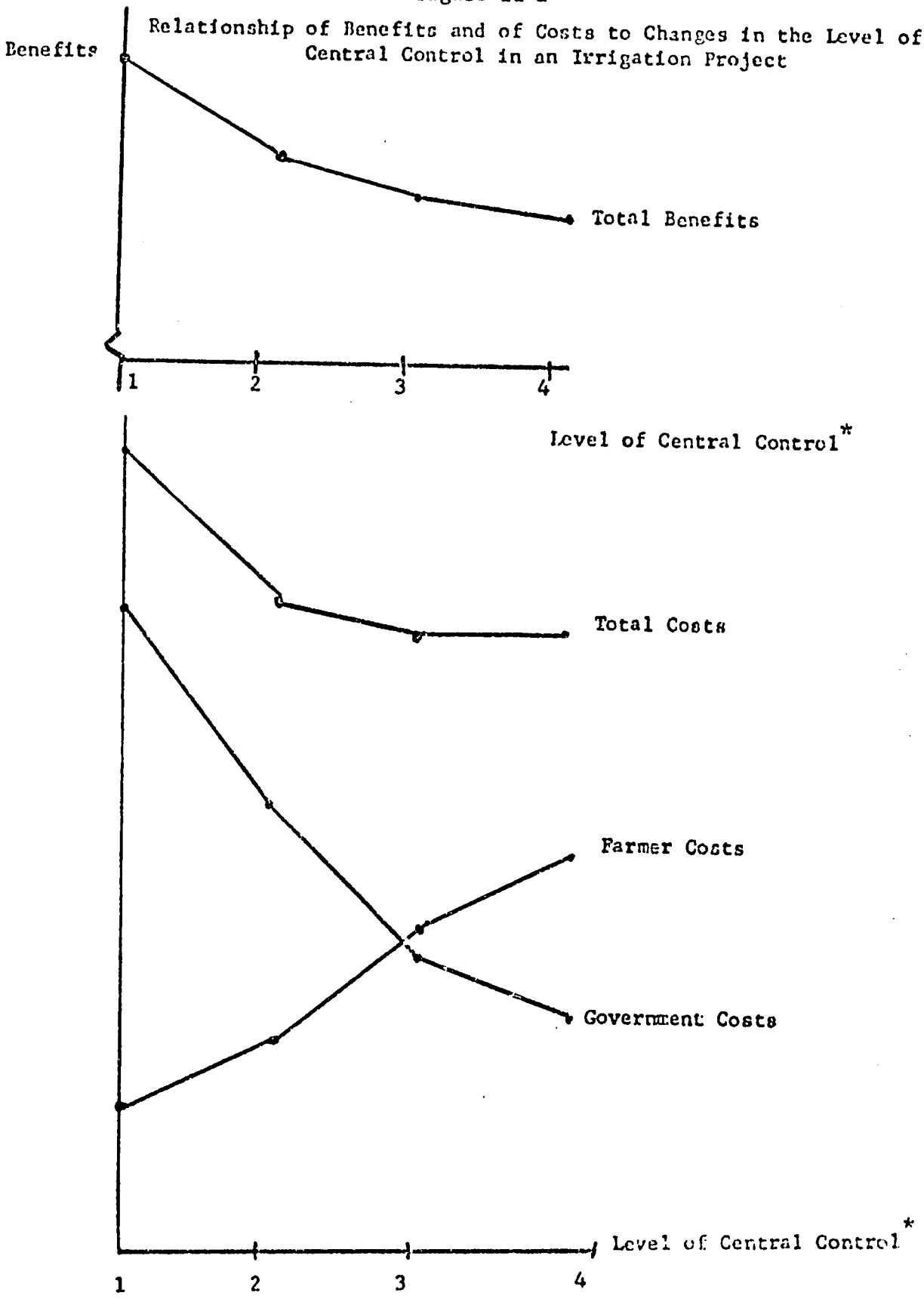
to the farmers. The effectiveness of the organization of the farmers is even more important than in the previous alternative. It is also more difficult to achieve, since the number of farmers involved is larger. With the larger number of farmers involved, and the possibility that rotational irrigation may have to be introduced, a cash contribution may be required to purchase the services of someone to help manage the distribution of water and to help settle disputes among the farmers. This of course affects both the profitability and the financial risk.

With the final alternative, in which the distribution of the water from an entire lateral is the responsibility of the farmers, costs to the government are reduced even further. Although the organization of the farmers remains at least as important as in the previous alternative, the technical skills required for the management of the water are now definitely greater than the skills of the farmers. It is, therefore, no longer possible to rely only on the experiential knowledge of the farmers. Specifically, it would be necessary for the farmers to hire someone with formal professional training in water management skills.

The discussion thus far suggests that as the size of the unit of farmer control is increased, benefits decline (especially as the scale is increased from individual farm delivery to ditch delivery); government costs decline; and farm costs increase. These relationships are shown graphically in Figure II-2. One question not yet dealt with is that of the magnitude of total costs as the level changes. As indicated in Figure II-2, we believe that total costs would generally decline rather sharply as the level of central control shifts from individual farm deliveries to ditch deliveries. A small further reduction in cost might be achieved at the level of the sub-lateral, although this is more questionable. We believe that there would be little change in total costs between the levels of control represented by the

Figure II-2

Relationship of Benefits and of Costs to Changes in the Level of Central Control in an Irrigation Project



*1 = central water control to the individual farm
2 = central water control to the ditch
3 = central water control to the sublateral
4 = central water control to the lateral

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sub-lateral and the lateral.

The decrease in total costs between the first two alternatives implies that the decline in government costs would be greater than the increase in farmer costs. There are three reasons for expecting this to be the case. First, farmers would be utilizing an existing resource (experiential knowledge of local conditions) in performing the tasks involved in the distribution of water among a group of farmers along a ditch. By contrast, the government would have to create this knowledge among its trained personnel in order to effectively carry out these same tasks. In effect, the government would be going to considerable expense to duplicate existing knowledge. Second, the government would have to bear the cost of supervising personnel scattered over a wide area. Farmers in each locality, on the other hand, can undertake the work with a minimum of supervision. Finally, considering the costs from a national production viewpoint, farm labor used during the off season for the construction and maintenance of the irrigation ditches may very well have a rather low opportunity cost. In effect, under the second alternative, farmers may choose to give up some leisure (or to give up more leisurely ways of working) to participate more intensively in the production process. Thus resources are being utilized at little or no cost in terms of foregone production.

As the size of the unit within which farmers distribute the water is progressively enlarged, fewer possibilities exist for the utilization of resources with a low opportunity cost. This is particularly true as the level shifts from that of a sub-lateral to that of a lateral. The skills required to manage the distribution of water among farmers served

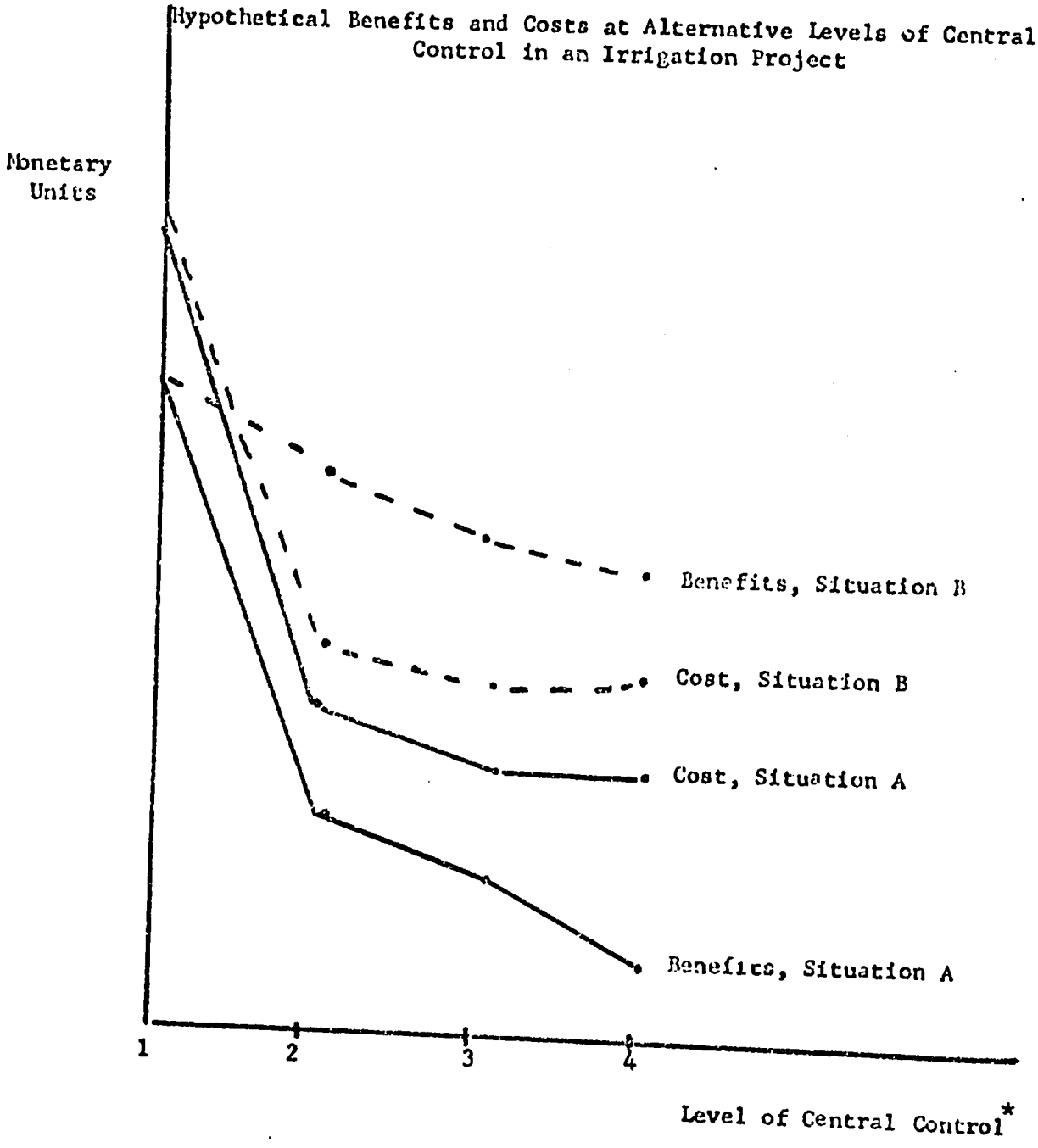
by a lateral are no longer skills which the farmers have or can easily obtain. Professionally trained technicians (a high opportunity cost resource) are required. The main effect in moving from the third to the fourth alternatives is to transfer the cost of hiring and supervising these technicians from the government to the farmers' organization. Thus we have no reason to expect a significant difference in the total cost of these alternatives.

Since both the benefit curve and the total cost curve in Figure II-2 exhibit the same general shape, it is not immediately clear that any one of the four alternatives is either superior or inferior to the others. We believe, however, that two additional points can be made in the evaluation of these alternatives. Figure II-3 is presented to facilitate the discussion of these points.

We believe that in most situations, project control of water to the individual farm would, because of its extremely high costs, prove to be an uneconomic use of resources. This is indicated on Figure II-3 by the costs exceeding the benefits, and by the hypothetical benefit-cost ratio of less than 1.0. Assuming that one of the development objectives stated in the design process is an economic use of resources, then in our judgement, this first alternative would in most cases, have to be eliminated from consideration.

The second point is that substantial variation in the level of benefits can be expected for each of the remaining three alternatives, depending on the values of the variables in the social subsystem. This is indicated on Figure II-3 by the two alternate benefit lines. The line labelled Situation A represents a situation in which the social organization of the farmers is very weak, so that it is difficult or

Figure II-3



Benefit-Cost Ratios Implied by the Diagram

Situation A

0.8	0.7	0.6	0.3

Situation B

0.8	1.4	1.4	1.3

* See note to Figure 2.

impossible for the farmers to deal effectively with the problems of managing the distribution of water. If it is impossible, for example, for the farmers to agree on rights of way for the ditch, there may be only very limited wet season benefits and virtually no dry season benefits resulting from the irrigation project. In such an unfavorable social climate, it is unlikely that any irrigation project, regardless of the level of central control, would be economic. This is indicated by the hypothetical benefit-cost ratios of less than 1.0 for all of the levels under Situation A. If, on the other hand, an effective social environment develops to deal with the problems of managing the irrigation project, then the benefits can be expected to be much higher, as indicated in Figure II-3 by the benefit line labelled Situation B. Since it is assumed that there are some costs, both to the farmers and to the government, in the development and maintenance of an effective social environment, the total cost of the project is indicated in Figure II-3 to be somewhat higher for Situation B than Situation A. But the modest investment in an improved social climate is much more than offset by the higher benefits, resulting in favorable (greater than 1.0) benefit cost ratios for the last three alternatives under Situation B. Because of the increasing difficulty of organizing farmers as the size of the area within which they must distribute the water increases, it seems likely that the costs of developing and maintaining an effective social environment will increase as the size of the area increases to units involving several hundred farmers. It is probably also correct to state that the <u>likelihood</u> of developing an effective social organization decreases as the level of central water control shifts to that of a lateral. We, therefore, believe that the fourth alternative would seldom be optimal. This is indicated on

Figure II-3 by the lower benefit-cost ratio for this alternative as compared with the second and third alternatives. We conclude that for the Mekong basin countries, the ditch or sub-lateral levels of design are likely to be the most desirable.

In comparing the ditch and sub-lateral levels of control, we believe that the most important considerations are not those associated with identifying the precise optimum design. Rather, emphasis should be placed on those factors necessary to create a high level of benefits (Situation B in Figure II-3). Unless this is done, the planners may find that they have developed the optimal design for an uneconomic project.

SUMMARY AND CONCLUSIONS

Underlying the disappointing results of many agricultural development projects are deficiencies in the process by which these projects are planned and implemented. These deficiencies include inadequate consideration of alternatives throughout the design process, and failure to give the same serious consideration to the interacting social, economic, and biological factors impinging on the project as is given to physical factors. In Part I we outlined a design process which emphasizes the examination of alternatives, and which provides a framework which encourages explicit consideration of social, economic, biological and physical factors in the design and operation of the project. In Part II, we illustrated, by developing an example of a single design decision for an irrigation project, the types of social, economic, biological and physical factors that might be considered, and how a systematic consideration of these factors could affect the design decision.

The major points made in Part I are summarized in the concluding section of that part, and need not be repeated here. Concerning Part II, we

wish to emphasize two points. The first deals with the substance of the specific discussion of the design decision regarding the transfer of control over the distribution of water in an irrigation project. Our choice of the case of an irrigation project to illustrate a design decision reflects our individual field research experiences both inside and outside the Mekong basin region of Southeast Asia, and our identification and examination of critical variables stems directly from this experience. Although we regard this discussion to be only tentative in nature, with many possibilities for refinement through further empirical research, we feel that if, in designing irrigation projects, systematic consideration of the factors we have identified were made, the performance of many of the projects would be substantially improved. We therefore feel that this discussion has important policy implications for this specific design decision.

The second point which we wish to emphasize is that the discussion in Part II is intended to illustrate, through the use of a single example, how our systems approach to the examination of agricultural development projects can be applied within the design framework presented in Part I. A similar approach could be used in developing the analysis needed for other decisions in the detailed design stage, and for making decisions in most of the other stages of the design process. Likewise, the approach is not limited to use with irrigation projects, but is valid for many types of agricultural development projects. The specific critical variables identified would, of course, depend on the nature of the decision being made, and on the type of project being considered. The list might include some of those identified in our example, along with others which we did not identify as being critical to the control decision for irrigation projects. The point is that the <u>process</u> of identifying critical

variables and evaluating the constraints which they impose on the particular decision in question can be used in a wide variety of situations to improve the design and implementation of agricultural development projects.

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Insert in "Improving the Performance of Agricultural Development Projects", Part II.

J. Ingersoll
July, 1974

A Variables of the Social Subsystem

A social system is likely to develop among people who are engaged, however diversely and indirectly, in some common activities or interests; it is composed of the interrelationships among the various aspects of their engagement. Farmers, officials and merchants are diversely engaged with their natural and social environments in a complex ecosystem of agriculture. We can discern a social subsystem in the interactions among the aspects of their engagement, that is, the ways in which the participants act, orient themselves, relate to each other, control each other, communicate with each other, and adapt to changing external and internal pressures and opportunities. We consider these six aspects of their engagement as elements of their social subsystem; and the numerous alternative ways in which they may manage each element, as the dimensions of variability of each element. These alternative ways, or variables, may differ (between systems or through time) quantitatively or qualitatively. For example, farmers' patterns of activities could vary quantitatively in the relative amounts of time devoted to subsistence and to commercial farming; and qualitatively, in the types of knowledge used and work performed in raising rice compared to raising kenaf.

Using this approach, we may examine social conditions, such as maintenance of irrigation ditches in an agricultural system; treat such condition as the particular way (from among many alternative possible ways) in which participants manage one of the variable dimensions; and express that way as an alternative value - quantitative or qualitative - of one of the variables of the social subsystem. We would expect the alternative values of each social variable to exist in functional relationship with the values of at least some of the other social variables and with some of the variables in the other subsystems. For example, we would expect a high degree of willingness among farmers to maintain irrigation ditches to correlate with such variables as high mutual trust among farmers to use water allocations fairly, strong confidence among farmers in the competence and reliability of irrigation officials, effective mechanisms of communication between farmers and irrigation officials, high market profitability of crops grown, high physical control capability of water supplies, and the like.

We can thus interpret the current observed value of any variable by associating it with the observed values of other variables in the subsystem and in the larger system, as in the example above. We would thus derive the state of the system from the current observed values of associated variables in the subsystems. We can also interpret change in the value of any variable by associating it with change in the value of one or more other variables. We would thus derive systemic change from changes in the values of associated variables in the system. However, our understanding of stability or change of an agricultural system is incomplete. Agriculture is a very open system, and the values of its variables are always vulnerable to complex influences in the larger natural and social environments. Although incomplete, our understanding of the complex interactions among variables in the subsystems can become coherent enough to support better informed decisions on managing the system.

Given the great number, subtlety and amorphous character of social conditions discoverable in an agricultural system, the identification of a social subsystem of agriculture could include the formulation of a virtually endless number of variable dimensions of the six elements listed above. Identification of the most crucial variables is possible only by examining the ways in which participants may manage these six aspects of their joint engagement with respect to some particular issue. The issue examined in this paper is the implications of transferring control responsibility from an irrigation project administration to the farmers at various alternative levels. The relatively few variables listed below seem the most pertinent ones for our analysis of the social implications of this issue. Analysis of other issues would naturally involve other crucial variables, but the six main elements would probably be helpful in organizing social experience and analysing other social issues.

In summary, we regard the following six elements as the major aspects of the diverse, differentiated engagement of participants in a social subsystem of agriculture; the elements as variable by virtue of the numerous variable dimensions of which they are composed; and the elements as interrelated by virtue of the functional interaction of the values of their

variable dimensions.

Major Social Elements and Selected Variables

1 Patterns of role activities

a The relative number of major patterns of role activities for each type of participants.

b The relative complexity of carrying out these major patterns of activity.

2 Cultural views and values of participants

a Relative definition of the nature and meaning of agriculture, varying from subsistence farming as a way of life to commercial farming as a livelihood.

b The extent to which participants view the irrigation project as 'belonging' to them -- in the sense that they feel able to fashion or modify their own participation in the social subsystem.

c The extent of participants' confidence in each others' competence and reliability in the system.

3 Role relationships among participants

a The relative emphases upon independence, interdependence and dependence in the role relationships among the participants.

b The relative compatibility of established groupings for mutual help with the new irrigation tasks to be carried out.

4 Mechanisms of social control

a The relative compatibility of established role norms with the new irrigation conditions.

b The relative availability of sanctions to provide rewards and deprivations to secure compliance with norms appropriate to irrigated agriculture.

c The relative adequacy of conventional local authority roles to control or manage the new collective tasks.

5 Patterns of communication

a The relative complexity of information needed and of its processing.

b The relative timeliness and adequacy of information exchanged with participants about the implications of the project, enabling them to achieve their own interests through their participation.

6 Institutional adaptability of participants

The relative emphasis by central government designers, varying from centralized direction to involvement of local resources and experience in project planning, construction and operation.

We may now consider the social implications of transferring control responsibility from an irrigation project administration to the farmers at the four alternative levels discussed earlier: each individual farm holding, the farmers and fields served by a field ditch, by a small sub-lateral, or by a large lateral. We shall consider this issue by reviewing briefly the selected variables of the social elements in relation to the different levels of control transfer.

1 Patterns of role activities

The first critical variable would require a simple inventory of the major patterns of activity of each of the main participants: farmers; officials (irrigation, agricultural, credit, cooperatives); and merchants (suppliers of agricultural inputs, buyers of crops, bankers supplying credit, and the like.) The major patterns of role activity for farmers during the rice cycle, for example, would include: preparing seeds for planting, plowing, harrowing, planting seed beds, transplanting, managing available water, inspecting, controlling pests, harvesting, threshing, storing and the like. We would add similar patterns of seasonal activity for other crops, tending animals, and subsistence gathering activities. By interviewing and some observation, we would derive similar inventories of major activities of the different types of officials and merchants concerned.

These inventories of main role activities of the participants become a general variable only when we work out (by interviewing and observing in appropriate projects) the relative number (greater or fewer) of role activities for each participant in the social subsystem at the four alternative levels of water control transfer. The second critical variable is a judgment derived inductively from consideration of the relative number of role activities: the relative complexity of these differing number of activities at the four levels, and the relative difficulty participants would have in performing them. Given our premise that the social variables are functionally interrelated, our hypotheses are that 1) current behavior patterns are already related to a set of cultural views and values, expressed in role relationships among participants, and supported by positive and negative sanctions; and, 2) that the greater the change in behavior patterns entailed in the alternative four levels of control transfer, the greater the required changes in supporting sanctions, relationships and values. Participants are especially unlikely to undertake the real risks of changing occupational patterns of activity without persuasive changes in rewarding or constraining sanctions. Discriminating project design, however, may be able to provide those sanctions to make the changes in behavior worth-while for participants.

The transfer of water control at the individual farm level would entail very little change or added complexity of performance in farmers' patterns of activity regarding handling of water, compared to their previous condition before irrigation; and it would entail the least number of such activities for farmers and least complexity of performance of any of the four levels. Rice farmers have always worked hard to move available surface water among their plots. If the physical control capability were effective, farmers would have more water moving and ditch tending within their own plots to do, but the abundant water would provide a very rewarding, positive sanction. Farmers would enjoy great improvements in harvests and in security at the least price in extra work.

The three higher levels of water control transfer, however, would entail incremental additions to the relative number and complexity of performance of farmers' activities. The physical tasks of digging and tending ditches and moving water are quite familiar and simple to farmers in the Mekong region, but they have conventionally carried out such tasks on a very modest, local scale. Although the volume of water to be managed by farmers served by a ditch would be far greater than anything they had known in the past, they would probably have adequate incentives from the water supply and economic profits. The more difficult tasks of getting and keeping agreement among themselves we shall treat under role relationships and social control.

The third (sub-lateral) level would probably, and the fourth (lateral) level would almost certainly, entail activities of collective decision-making beyond the capacities and inclinations of most farmers in the region. These collective activities would be foreign to their agricultural experience. They could probably hire staff and tractors to carry out the physical tasks, but the organizational tasks would require great changes in other elements of their social subsystem, as we shall see.

For the routine activities of handling irrigation water, most farmers in the Mekong region would find the first level the easiest by far, the second level difficult but within their reach and well worth the effort, the third level doubtful, and the fourth level quite impossible.

A similar increase of relative difficulty of performance at the higher alternative levels would probably also occur though with less intensity, regarding other regular farming activities such as raising other crops, caring for animals, subsistence gathering and the like. The third and fourth levels would probably entail so much additional, complex duties for farmers that they would have much less time for farming tasks as those just cited. The four alternative levels would probably not have very different implications for other activities of farmers, such as organizing in groups in order to obtain agricultural credit. The greatest increase in number and complexity of regular activities for farmers would come between the first level and the others; and the second greatest increase, probably between the second and third levels.

For government officials, especially irrigation officials, the increase in number and complexity of role activities would perhaps be more steady between each of the four levels; but in the opposite direction. Irrigation project officials would have the fewest and easiest duties if they could hand over responsibility to farmers at each main lateral. Their tasks become steadily greater as the transfer takes place at lower levels. The relative number of types of tasks for irrigation officials would probably not increase greatly at the lower alternative levels; but these tasks would have to be performed far more extensively - requiring a much larger staff of officials.

The same direction of increasing difficulty of performing duties at the lower alternative levels would apply to other government officials (agricultural, credit and the like) but with much less intensity of increase in difficulty. They could more easily deliver extension advice or credit to larger groups of farmers at the higher alternative levels, but their work might continue to be organized at the village level rather than at alternative control levels. So they would probably be less affected than irrigation officials by the choice of alternative levels of control transfer. The major activities of buying and selling by merchants, whether in urban markets or village shops, would not be closely affected by the choice of alternative levels. Thus, only the activities of irrigation officials would be greatly extended by transferring control at the ditch or individual farm level.

We have noted that farmers' activities would become increasingly complex at higher levels of control transfer, but that officials' activities (particularly in irrigation) would become more complex in the reverse direction, at the lower alternative levels. We should, however, note an inner contradiction in the nature of irrigation projects: they are normally intended to improve agriculture, carried out by farmers; but it is officials of the remote urban elite who make the major decisions shaping these projects; and the irrigation projects reflect in subtle ways the basic viewpoints and interests of their urban creators. The presence of an urban bias could make for pressure, in projects where transfer of water control occurs at one of the lower alternative levels, to make the project 'profitable' from the urban planners' viewpoint. One means would

be the introduction of highly intensive agriculture, which would ironically result in increasing the relative numbers and complexity of role activities for farmers. Thus, the transfer of control at a lower level could simplify farmers' role activity patterns regarding water management and complicate them with more complex modern agriculture.

2 Cultural views and values of participants

Farmers in the Mekong basin have gradually evolved a number of simple, effective farming techniques in adaptation with the numerous natural and social environments, some of them very demanding for agriculture. In the course of trying to make a living, they have accumulated a loose set of cultural interpretations of their own experience of reality -- views, meanings and values -- in terms of which they understand their particular environment and orient themselves to appropriate action. It is generally in terms of their cultural interpretations that they operate their farms; deal with other farmers, officials and merchants; comply to some degree with common standards of conduct; exchange information; and adapt to changing conditions. Their cultural interpretations, or definitions, of their own life are a combination of pragmatic-emotional judgments of experience too complex or subtle to be observed or totally understood. Similarly, officials and merchants have come to acquire their own cultural views, meanings and values, in terms of which they interpret their particular environments and orient themselves to appropriate action. Although normally invisible, difficult to state concisely and sometimes beneath participants' overt awareness, these cultural views and values are influential in participants' thinking and conduct, and can be somewhat inferred from their behavior.

Of the very many cultural views and values likely to be present we consider briefly only three important examples here -- ones which can be seen as variables with alternative values.

a. At one extreme, participants, especially farmers, can regard the nature and meaning of agriculture to be fundamentally a subsistence way of life. At the other extreme, they define agriculture as a commercial undertaking, directed toward monetary profit. Probably most farmers in the Mekong basin where irrigation projects might be built have already moved at least partially toward sale of surplus crops. But most of them, particularly above the delta, continue to regard their own interests as centered around a decent supply of rice and other foods. They would put more emphasis upon a reliable crop than upon one of higher yield but uncertain survival value. Our prediction would be that the greater the subsistence emphasis among farmers in an irrigable area, the less their interest would be in larger units for control responsibility. Farmers with a strong subsistence emphasis could see real gains, in their own terms of survival and security, in the individual farm and perhaps the ditch unit for control responsibility; but their concerns with family survival would probably dispose them against control responsibility at the sub-lateral or lateral levels. This correlation would often be intensified by the width of the social-cultural-economic gap between urban and rural people in the society. Farmers who see officials as very remote and threatening would be little inclined toward joint control responsibility at the upper alternative levels, which would likely involve local and regional officials to a greater degree. By the same token, subsistence farmers could be expected to regard most government programs of agricultural assistance -- credit, modern inputs, and technology -- with greater suspicion than commercial farmers; and both types of farmers could be expected to have more reservations about such programs (with some justification) than development officials.

b. A second cultural variable, also related to the size of the urban-rural gap, is the manner in which participants, especially farmers, define the irrigation project in relation to themselves. We could treat their definitions as qualitative variables, such as numerous alternative types; and also quantitatively, such as the relative degree they regard the irrigation project as 'belonging' to them -- in the sense of the

degree to which they feel able to fashion or modify their own participation in the social subsystem. This definition of participants is naturally associated with the manner of planning, construction and operation of the project, which we shall examine under communication below. Our prediction is that the more farmers were able to identify with an irrigation project as 'theirs' (because of the way in which central officials create it and local officials present it), the more they would be able and inclined to make the unusual efforts to organize control responsibility among themselves at the higher levels. Conversely, the more farmers view a project as a government affair, the more they would be limited in their vision and motivation to assuming responsibility at the individual farm level. Clearly, the farmers' views in this regard would be closely associated with those of officials. The more officials defined the purpose and meaning of the project as serving farmers' interests, the more they would reinforce such a view among farmers; and this mutual view would strengthen the likelihood of farmers organizing themselves, even at some variance to their traditional patterns of organization and joint action.

c. A third variable is the relative degree of participants' confidence in each others' competence and reliability. Regarding our problem of alternative levels of control responsibility, the major issues would be the confidence of farmers in each other and of farmers and officials in each other. Degree of confidence in and from merchants does not seem significant for our current problem. The degree of confidence in other participants is associated with the degree of interdependence in role relationships among participants, which we shall examine in the next section.

The less confidence farmers have in the competence and reliability of neighboring farmers to make irrigation work, the more they will tend to favor, and work best at, the individual farm level of control. At the beginning of an irrigation project, lacking collective irrigation experience, they must rely on such precedents as they have, which would generally dispose them toward the individual farm level. If farmers held the competence and reliability of officials in low esteem, they would probably anticipate

very few benefits from the project and remain passive in the face of their misfortune, perceived as beyond their control. Similarly, if officials have a low regard for the competence and reliability of farmers to make irrigation effective, they would probably prefer the lower alternative levels. If, however, officials have a low degree of confidence in themselves, they would probably favor the higher alternative levels. Levels of confidence are also closely related to profitability and availability of human capital in the economic subsystem; control capability in the physical subsystem; and increase in yield potential and input requirements in the biological subsystem.

3. Role relationships among participants

The ways in which people deal with others performing roles in a social system are usually reflections (perhaps with some disparities) of their views and values in terms of which they orient themselves to their participation.

a. A very complex dimension pertinent to our problem is the relative emphases which participants place on independence, interdependence, and dependence in their role relationships. This issue includes relationships among farmers, between farmers and officials, and among different types of officials. Relationships among farmers includes their relationship to irrigable land in that tenants are more dependent and owner-operators are more independent.

Farm families operating their own plots, who have relied on rain water and on a few mutually selected kinsmen and friends to handle peak periods of agricultural work, would have very few precedents for collective collaboration beyond the individual farm level. Social interdependence on a wider scale has been limited in many rural communities in the region to religious and family life-cycle celebrations. Most farm families have depended on themselves to run their farms. Owners of neighboring fields usually agree to share rainfall runoff, at least in the sense of not damaging each other's plots. Such an emphasis on independence would dispose them to work best at the individual farm level of control responsibility.

The form of village farmers' relationship with government officials is generally one of deference and social distance. Although they have not been dependent on officials for much substantive assistance in the past, they have been dependent on the good will of officials to avoid punitive measures or informal taxation. Their general relationship of dependence on officials would probably inhibit to some degree the capacity of either farmers or officials to collaborate in organizing and running irrigation control units of very large size.

The role relationships among government officials would probably have the opposite effect. To the extent that regional officials are dependent on their seniors in the capital and thus not very interdependent with their regional colleagues from other ministries, they would be unable to initiate or carry through

collaborative efforts on a great number of irrigation control units needing varied services. Because of their relationships and their limited staffs, they would be able to deal better with a small number of control units, tending toward the larger sublateral and lateral units.

b. A particularly important aspect of the types and degree of interdependence among farmers is the compatibility of their own cooperative groups with the new tasks to be performed at the alternative levels of control. Closely related is the issue of conventional relationships and units of authority, discussed later under social control. To the extent that farmers' own cooperative groupings tend toward the following variable types -- local rather than regional, informal and casual, networks of reciprocating kinsmen and friends acquired by each farmer rather than 'corporate' groups all members of which help all others, interdependence based on commitment to return reciprocal help rather than on permanent 'membership' -- they provide an experiential base for organizing irrigation control responsibility at the individual farm and perhaps ditch levels. Any collection of farmers joining in mutual help, as in Bali, among owners of plots in the same area (rather than only among relatives and friends) would have a sort of 'corporate' group with the sort of interdependence that would greatly help organizing at the ditch level.

4. Mechanisms of social control

Such continuity as most social systems seem to exhibit results, not simply from some static 'tradition' but from continuing use of mechanisms of social control by the participants themselves. The three basic mechanisms are norms, standards of expected conduct which most participants acknowledge to some degree; sanctions, established positive and negative rewards which reinforce conformity to the norms and punish excessive deviance; and authority roles or units which have enough respect to promote the norms or enough power to enforce the sanctions. Some combination of these three mechanisms are essential for legitimacy as well as continuity in any social system. These mechanisms can be stated as variables pertinent to our problem.

a. The relative compatibility of established norms with the new irrigation conditions has a direct bearing on the alternative levels issue. Norms of expected, respectable conduct are not of central or pervasive importance for most

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rain-fed farmers. They generally believe that they should keep their draft animals out of neighbors' seed beds and fields, that they should not steal neighbors' water or flood them with excess water; and they generally agree on the most appropriate ways of raising familiar crops and animals. But since most of their working relationships are fairly independent, their deviations do not seriously interfere with neighbors; and normative conformity is not a major issue. Regular management of a water supply, however, implies standards of acceptable conduct. Farmers with agricultural norms which seem too limited or incompatible with new irrigation conditions could probably adapt new standards much more easily at the farm level of control, with some difficulty at the ditch level, and only with very great difficulty at the higher levels.

Similarly, the compatibility of established role norms of government officials with irrigation conditions has an important bearing on the alternative levels issue, but in the opposite direction. The more their norms support the conventional, distant, hierarchical relationship with village farmers, the more these officials would be limited to relating to farmers at the higher levels, lateral or sublateral.

b. A closely associated variable is the relative availability of sanctions to provide enough rewards and deprivations to ensure some compliance with norms appropriate to irrigated agriculture. Although not immediately observable, well-established behavior patterns and norms (such as those for rain-fed rice culture) are closely related to supporting sanctions which make the behavior and norms intelligible and worth-while. Similarly, officials have established sanctions which regulate and make worth-while their behavior patterns and norms. These sanctions are intrinsic aspects of their environments, but they would very likely not suffice for irrigated agriculture. It is of crucial importance to ascertain what sanctions would be available in the environment to regulate the new forms of behavior and what additional sanctions the project design might have to include for the different alternative levels. It seems evident that farmer role sanctions would have to become increasingly strong to regulate appropriate behavior at each higher alternative level, but that official role

sanctions would have to increase at each lower alternative level. The major positive sanctions for farmers would inhere in the other subsystems, such as greater economic profitability, physical security, and crop yield potential and stability. New positive and negative sanctions in the social subsystem would probably also be required.

c. A very intimately related variable is the adequacy of conventional authority roles or units to control or manage the new collective tasks. A fundamental feature of social life in the region is that village leadership roles are functionally adapted to the relative independence with which farm families operate. Most hamlet headman roles have adequate legitimacy for settling disputes between villagers; but headmen can enforce compliance with accepted norms only on the basis of their prestige or forceful personality, not their positions. Conflicts between people in neighboring villages can be settled by the senior headman of a group of ten or more village headmen. No further authority roles, units or relationships among villagers exist beyond the level of clusters of ten or more villages. The next step is the district officials. Thus, a distinct but limited social basis of traditional authority does exist that is adequate for resolving most disputes at the farm and ditch levels but which would not extend to the entire areas of most sublateral units. The hamlet and cluster headmen, however, do not already have authority to manage water control at any alternative level. For example, neither they nor any other local roles or institutions have adequate authority to arrange for extra ditches to be dug to connect the current ditches with all of the farmers' plots in the area to be served by the ditch. As farmers also needing to make a living, headmen could assume such duties only with the positive sanctions of authority from the district office and the irrigation project and extra compensation.

5. Mechanisms of communication

Farmers, officials and merchants can act and interact in a rain-fed, partly subsistence, agricultural system with very modest exchange of information. Irrigated agriculture, however, involves a great transformation of the natural and social environments which requires a much greater exchange of information, including new types of information. Concern with communication in irrigation

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projects too often ends with provision of new physical equipment such as telephones and radios. Our concern here is with variables closely related to other social variables already stated.

a. The types of information farmers would need at any of the alternative levels seem to be generally similar: amount of water available, timing and regularity of delivery, bases of its availability, and its distribution over the terrain inside the control unit. The complexity of that information for farmers to receive and share would increase greatly at each higher alternative level. The local units of authority (and hence channels of information) are the local village and the cluster of villages. These units would probably include most ditch units of water control, but only some sublateral units, and probably very few lateral units. Thus, farmers' capacity to receive and handle irrigation information beyond the ditch level should be very carefully examined.

The complexity of information and the difficulty of receiving and handling it, however, would increase for irrigation officials at each lower alternative level of control transfer. Their capacity to handle the information task below the ditch level should be subjected to doubt and examination before any design decision.

b. A very complicated variable is that of the relative timeliness and adequacy of information exchanged with the different types of participants about the implications of the project, enabling them to achieve their own interests in their participation in the system. The timeliness of the information can be judged from the length of delay after the first rumors began to circulate about a project. The adequacy of the information can be judged from the degree to which participants, especially farmers, understand ahead of time the likely costs and benefits to them of the project. The more timely and adequate this information exchange, the more effective the operation of the other social elements is likely to be. If irrigation and district officials informed farmers in each village of the project implications to them and bargained with them about whether they wished a lateral or sublateral dug near their village and what they would contribute in order to get it, a superior basis could be laid for cheaper, better construction and better organization of farmers for operations.

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Such an information and bargaining effort would involve more two-way than one-way communication. We would predict that the more through such a preparatory process were, the more effectively farmers could later organize themselves, and thus the more effectively they could operate at even the higher levels of control transfer. This sort of preparatory process would also be rewarding to officials who could expect good promotions from saving construction costs (through better local participation) without sacrificing quality of work.

6. Institutional adaptability of participants

This final element of the social subsystem would probably become apparent only as participants gained experience in the system, but the values of variables of adaptability are interrelated with many variables that became discernible earlier. We include here only one of several pertinent variables of adaptability.

a. As central government officials place more emphasis on deliberate involvement of local resources and experience in project planning, construction and operation, the local participants will have greater capacity and incentive to adapt to the new social subsystem and to continue adapting it to future changing conditions. As all types of participants are more able to contribute some of their own thinking to their own manner of participation in the subsystem, they will have greater flexibility and capacity for continuing adaptation. Greater flexibility stemming from an emphasis on decentralization would enhance the likelihood of farmers' ability to organize themselves at the higher, if not the highest, levels of alternative control.

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