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WATER RESOURCES PROBLEMS IN DEVELOPING COUNTRIES

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ECONOMIC DEVELOPMENT CENTER

Department of Agricultural and Applied Economics

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UNIVERSITY OF MINNESOTA

Seminar on

WATER RESOURCES PROBLEMS IN DEVELOPING COUNTRIES

Edited by

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PREFACE

The Seminar on Water Resource Problems in LDC's was sponsored by the Economic Development Center in the Department of Agricultural and Applied Economics at the University of Minnesota. The idea for the seminar came from the director of the Center, Martin E. Abel, who was instrumental in organizing and implementing the seminar.

The papers by Howe and by Levine and Wickham, along with the extended comments by Schramm, Bromley, Easter and Abel provided the focus for the seminar. These proceedings include three papers and the related discussions. Howe's paper considers water development emphasizing its relationship to development of other natural resources, emerging conflicts in the allocation of water, and environmental concerns. The Levine and Wickham paper focuses on the multitude of irrigation management problems with particular reference to the Philippines. Finally Abel's long discussion of the planning and management of irrigation systems in Taiwan evolved later into an article, which is included as published.

The discussion drew on the experience of the participants in other countries. Schramm talked about irrigation problems in Mexico. Bromley considered the problems of LDC's ranging from the non-viability of some African nation states to the lack of a latent entrepreneurial ethic in LDC's. Easter discussed improving village irrigation distribution systems in eastern India. Larson discussed the cost and potential for irrigation in Nicaragua. Finally, Corey related the experience of AID in water management projects.

In addition, the seminar addressed the general question of the role of American universities in training for LDC's in natural resource economics. This discussion revolved around the following questions:

(1) Can American universities and research institutions be of assistance to developing countries and donor agencies in dealing with the economic problems of natural resources? What assistance--training, research, or consulting--is most needed and how can it be best delivered?

(2) If training is one of the priority needs, what kinds of skills are needed by resource economists trained for the developing countries--economics of irrigation, fisheries, nonrenewable resources, forestry, environmental quality, etc? How should training programs be organized and operated?

(3) Can resource economists contribute significantly to meeting some of the most important needs of developing countries? If so, how?

(4) Is it possible for a group of resource economists to play a useful, if modest role, advising donor agencies trying to assist developing countries dealing with economic problems integrally connected with natural resource development?

(5) Is it possible that a panel of resource economists could be useful as an honest broker in bringing together resource economists and those who need their services--developing countries and donor agencies?

The editors wish to thank all the participants who made this seminar truly exciting. Hopefully readers of these papers and discussions will get a flavor of the ideas and interaction that occurred during the seminar.

K. William Easter
and Lee R. Martin
July 1977

WATER RESOURCE PROBLEMS OF THE DEVELOPING COUNTRIES: INCREASING SCARCITY, ENVIRONMENTAL IMPACTS, AND DEVELOPMENT OF OTHER NATURAL RESOURCES

Charles W. Howe 1/

Summary

Under "increasing water scarcity", it is argued that (1) present schemes for the provision of potable water to rural populations in developing countries are terribly inefficient, absorbing vast resources and experiencing high failure rates; (2) conflicts between irrigation and hydro-power which emerged in the 1960's have been given a sudden twist by the international petroleum situation and need to be re-evaluated; (3) there are increasing concerns about the trade-offs between consumptive water uses in agriculture and the maintenance of coastal ecosystems, including valuable fisheries; (4) water related development projects often have the effect of worsening the already skewed distribution of wealth.

Environmental considerations do not receive high priority in LDC's. Yet, industrial developments and urban population concentrations are having highly detrimental environmental impacts which need to be controlled and/or taken into account in planning.

The development of other natural resources requires less water than commonly assumed. Horticultural and dryland opportunities which use very small quantities of water are widely overlooked. The incredibly important problems of range management under traditional (tribal) social systems are closely geared to water management. While high value mineral development can bear very high water costs, new low value mineral-water combinations are needed to broaden the relevant resource bases for the semi-arid LDC's.

Introduction

The themes of this paper will be developed in three sections as indicated by the title. The development is based largely on case study material extracted from the author's experience rather than being based on any complete theoretical framework. The three sections containing these materials are not mutually exclusive, either, in that a problem might well involve both a water supply conflict with other uses and significant environmental impacts.

1/ Professor of the Department of Economics, University of Colorado.

A. Increasing Water Scarcity or Emerging Conflicts in Water Allocation

The idea that water is a bottleneck to economic growth in many developing countries is widely held and is undoubtedly valid in some of them, but the ways in which water or water related services can be a limiting factor need to be spelled out in some detail. Five ways are suggested by theory and experience.

1. fixed production coefficients;
2. fixed or slowly expanding supplies with limited substitution possibilities of other inputs for water;
3. rigid allocation of water among uses;
4. as a factor in human health and productivity;
5. through the absorption of limited complementary resources, especially trained manpower and capital, in the process of water development.

The fixed coefficient representation of water as an input to agricultural or industrial processes is frequently used in planning models but can easily be exaggerated. While fixed coefficients may appear at the macro level and even at the level of the firm or farm in the short run, the observed responsiveness of farmers to impending water shortages or to the initiation of water charges and the responsiveness of industry to environmental constraints (especially water pollution constraints) demonstrate the flexibility of the water-product output relationship.

The more general representation of production processes by production functions permits the explicit expression of substitution possibilities. The real issue is the ease of substitution. If water supplies expand more slowly than the supplies of other inputs or can be expanded only at increasing marginal cost, then water can be a drag on the expansion of production in spite of substitution possibilities.

Institutional and physical factors which result in a rigid allocation of existing water supplies among uses is an important factor in the creation of growth bottlenecks. Since the economy consists of different sectors and geographical regions which seldom grow at the same rate, the reallocation of water from the lowest value uses to emerging high value uses can facilitate continued expansion even with fixed or sharply increasing-cost supplies. While such reallocation does trade one activity against others, the net value gain can be extremely high. Kelso's studies on the Arizona economy (1973) and Cummings' work on water alternatives in Northwest Mexico (1974) illustrate the existence of such beneficial trade-offs very clearly.

The human input into economic growth is critical, both as an unskilled energy input and as an agent of organization and management. White et al (1972) have documented both the enormous amount of human energy which goes daily into the gathering of water and the tremendous variety and complexity of ways in which debilitating human conditions are transmitted to man through water systems. Too often, however, one facet of man's complex water milieu is identified as the source of trouble with resultant ineffective investments.

The fifth way in which water may act as a constraint on growth grows out of its own development projects and relates closely to the point above: an uneconomic over-expansion of the quantity or quality dimensions of water supply systems absorbs resources which could, by definition, be used elsewhere to greater advantage. While this would be true of investment in and maintenance of any sector of the economy, there are institutionalized biases in the water resources sector pushing toward over-investment in water quantity and quality. More on this later.

We will now look at some specific situations involving increasing water scarcity which appear to be of increasing frequency and importance. Scarcity may be manifest in any of the ways mentioned above.

1. The Provision of Potable Water, Especially Village Water Schemes.

At least 90% of the developing world's population lives in rural areas or villages. There are great political pressures to bring reliable, high quality water supplies to these people but the scale and methods used are generally inappropriate. The results often include (a) over-investment of limited capital and manpower in a small number of sophisticated systems; (b) exclusion of large parts of the population from any assistance in water supply; (c) a very frequent failure to achieve the desired results even in the areas served because of supply system failure.

White *et al* (1972) makes it very clear that, in the East African context, improved water supplies result in great savings of human time and energy and are positively related to improved health conditions -- although the strength of this relationship is not well quantified or understood. A middle income worker ($80/month) in Nairobi may spend 8% of his income on water -- more than on fuel, transport or household equipment, but a heavier relative burden falls on unskilled, low income urban dwellers who pay carriers 1 to 3 cents per 4-gallon tin, representing as much as 10% of income. These expenditures are incurred to avoid the time required to fetch the household's requirements when carried by a member of the household: 33 minutes per day on the average for urban dwellers (range: 14 to 68 minutes) and 46 minutes per day on the average for rural households (range: 11 to 84 minutes) [White *et al*, pp. 102-104].

White provides a useful classification of diseases related to water:

Table 1. A CLASSIFICATION OF INFECTIVE DISEASES RELATED TO WATER

Category	Example
I. Waterborne	
a) Classical	Typhoid
b) Nonclassical	Infectious hepatitis
II. Water-washed	
a) Superficial	Trachoma, Scabies
b) Intestinal	Shigella dysentery
III. Water-based	
a) Water-multiplied percutaneous	Schistosomiasis
b) Ingested	Guinea worm
IV. Water-related insect vectors	
a) Water-biting	Gambian sleeping sickness
b) Water-breeding	Onchocerciasis

Source: White _et_ _al_, Table 6.7, p. 163

White also shows a striking relation between access to water and toilet facilities and morbidity, shigella incidence, and ascaris incidence:

Table 2.

Access to Water	Morbidity/1000 0-4 yr.	All Ages	% Positive Shigella	% Positive Ascaris
Water and flush toilet inside	428	139	1.1	7.0
Water inside, toilet outside	829	238	2.4	25.0
Water and privy outside	1140	360	5.9	42.0

Source: White _et_ _al_, Table 6.6, p. 160

How much of these differences are due to water quality, how much due to better personal hygiene, and how much to the toilet facilities is not known.

The real health issue from an economic viewpoint is to know the trade-offs among accessibility, quantity, and quality and impacts on health. White found for East Africa that "diseases potentially related to water supply" account directly for 11.2% of the deaths (for which causes have been attributed), 11.8% of all in-patient diagnoses, and 20.9% of all out-patient diagnoses. Working from much more detailed data, White concludes that the expected reductions in these percentages which could be achieved through "greatly improved supplies" are 5.6%, 6.1%, and 10.9%. Just how "greatly improved supplies" are defined is not made clear.

White estimates a total cost due to poor water supplies (health care, loss of work, and up-bringing costs of young children who die from water-related disease) of about $0.14 per capita per year or $3,769,000 for all of East Africa, a surprisingly small sum. Again, the real issue is the rate at which these (and other) losses could be reduced through various water-related investments. White concludes:

> ...We can be confident that increasing supply by half a liter for those consuming 3 liters a day will have some effect... There is a sector - we would guess somewhere in the 20 to 80 liters per person range - where health benefits of increasing water (quantity) begin to level out... The common delusion that everything useful or important is already known about infections and water-borne disease is clearly far from true...

In spite of such vast ignorance, rural water "needs" have been translated into quantity, quality, and system design criteria by WHO and other national and international organizations which are nearly the same as those applied in the industrialized high income countries. The assumptions implicitly behind these criteria are that (1) water-related contamination will not occur from other sources (e.g. irrigation water); (2) the sophisticated plants will be operated as intended by the designer; (3) that people will use the water when provided; (4) that there are constant or increasing returns to water quality and quantity in terms of health effects.

That misperceptions exist regarding the utility of rural and village potable water supplies is seen in the opening sentence of a World Bank paper (IBRD, 1971): "Urban communities of any size without adequate piped water and sewerage are not viable and thus seriously compromise national development prospects." This simply is not true of all areas. One observes traditional villages in Africa (e.g. in Botswana) of 20 to 40 thousand persons which exhibit good economic and human health without either of these amenities.

What in many cases goes wrong when overly sophisticated potable water systems are installed is excellently described for Thailand by Frankel (1974, 1975). The Community Potable Water Project was started in 1966 as a major development effort for the Northeast. By July 1972, 165 potable water systems serving some 357 communities (average population 1350) had been completed. It is estimated that 25,000 rural communities are still to be served. During the planning and design phase, the Environmental Health Division of the Ministry of Public Health adopted a small number of standard designs intended to expedite and simplify the program and to meet WHO standards for product water. Frankel's *ex post* analysis of the 165 projects uncovered the following (1975):

1. the systems were over-designed and too sophisticated for small rural communities;
2. water quality generally failed to meet WHO standards but was still highly acceptable to the customer populations;
3. the standard design criterion of 50 liters per day per capita for villages using standpipes or 80 lpcpd for villages having individual house connections, greatly exceeded actual use rates of 15 to 30 lpcpd;
4. use of local building and maintenance materials was not incorporated in the designs, and differences among villages in terms of water sources, quality, and demand growth were overlooked;
5. plants were shut down on an average of 20% of the time with shut down times averaging between 12 and 30 days; 36 plants were closed the entire year of the survey.

The main factors behind the down time were lack of spare parts, lack of chemicals, and poor operator training and pay, the last resulting in incorrect use of chemicals, lack of maintenance, incorrect use of filters, and general neglect of duties.

The main characteristics leading to acceptance of water supplies seem to be convenience and availability of water during the dry season. It clearly does little good to develop systems capable of producing water of WHO standards when system failure for prolonged periods forces the users to return to traditional, low quality sources. Costs of the systems also averaged about $1.00 per thousand gallons, an extremely high figure by any comparisons.

Such systems obviously fail to meet the desired health objectives, they drain the foreign exchange resources of the nation, and they deprive the majority of the rural population of any water supply improvements.

2. Irrigation vs. Hydroelectric Power.

Few general statements can be made regarding priorities to be assigned to irrigation and hydro-power, except that the world energy crunch since 1973 has significantly changed the parameters of the appropriate benefit-cost analyses. In many of the world's river basins, there is a definite trade-off between development of the head for power and consumptive diversions for irrigation. Efficient allocations of water depend upon the physical trade-offs and the product values involved.

Looking back over the post-war period, it might be said that 1950-1965 was the period of large-scale hydro-power developments. In Africa, Owen Falls Dam on the Nile in Uganda, Kariba Dam on the Zambesi, Volta Dam in Ghana, and Aswan were undertaken. With the exception of the latter, these were power dams, intended to stimulate industry and urban growth. By the late 1960's, the picture began to change: population and food demands were burgeoning and pressures for new land settlement were mounting. Where the trade-offs existed, irrigation began to look much more important.

An excellent example is found in the Tana Basin in Kenya. In the early 1960's under World Bank sponsorship and with the consulting help of Sir Alexander Gibb and Company, Kenya "finalized" a national power plan, concentrating upon the construction of five major power dams on the upper Tana. No study of irrigation trade-offs was included in the analysis. The World Bank funded the first two of these dams and became very much committed to the entire plan, partly because the storage provided by later projects of the system would enhance the energy output of the earlier dams. In the middle and late 1960's, the Government came under increasing pressure to consider large-scale irrigation in the upper Tana Basin. Population had exploded and the politically most influential tribe wanted more arable land, having already pushed to the margin of cultivation close to the Tana River. Under Dutch sponsorship, several large-scale irrigation projects in both upper and lower Tana Basins were studied at the pre-investment surveillance level. Power-irrigation trade-offs occur only in the upper basin since that is where the head is but the lower basin suffers from a desert climate, tribal hostilities to resettlement, and extremely high development costs. By early 1972, making allowances for advances in thermal-electric generation and long distance transmission, irrigation in the Upper Basin began to appear economically feasible. Exactly what an appropriate benefit-cost study would show at this point for the Tana and similar situations is not known, but new analyses are needed, with emphasis on the optimal plan's sensitivity to future oil prices.

3. Irrigation vs. Coastal Resources Management.

An area of increasing concern around the world and of relevance to some developing countries is the effect of diminished streamflows and consequent concentration of salts and other pollutants on the ecosystems of bays, estuaries, and coastal areas. The major cause of diminished streamflows is consumptive use in irrigation. The detrimental impacts, realized and potential, are upon fish and shellfish populations either growing or breeding in coastal waters.

Specific cases in which this has been a concern would include the West Coast of Mexico, the Texas Gulf Coast (in relation to the Texas Water Development Plan), and, in an ex post sense, the dams at Aswan and Volta. The potential severity of the impacts in the Mexican and Texas cases is currently being studied. In the Aswan case, the high degree of control and lack of nutrients formerly carried by the sediment loads of flood flows are thought to have been the cause of the loss of the Delta sardine and shrimp fishery and other large-scale changes in eastern Mediterranean fisheries. In the case of the Volta dam, one unanticipated effect of creating the large lake has been a significant change in the ground water regimes and coastal lagoons in the region. Large areas which used to flood seasonally and then drain off to form excellent farm land are now permanently flooded (e.g. in the Keta Lagoon area). Lagoons which used to be salty during the dry season and fresh during the rains are now filled continuously with fresh water. Changes in fish and shell fish life have been noted, but poor baseline data make meaningful comparisons difficult.

These conflicts between increasing consumptive uses and control of river flows and appropriate management of coastal ecosystem resources appear to be growing and attracting policy-makers' attention.

4. The Wealth Concentrating Effects of Water-Related Developments.

We have entered fully into the age of multiple-objective planning, income distribution being one objective of great importance. The World Bank is concentrating its plans for the next several years on programs which will reach the poorest countries and the poorest people within each developing country served by the Bank. Yet a number of important traditional forms of water related developments frequently have the effect of concentrating wealth in the hands of a few.

There is frequently a clash between equity and efficiency when choosing the form for irrigated agricultural development: small holder agriculture or large-scale commercial development. For field crops in Northwestern Mexico, Cummings has estimated the difference in gross product per acre to be 15%. Some of the earlier apparent reversals of this situation where small holders appeared to be out-producing large-scale farms now seem to be disappearing, e.g. the quantity and quality of small-holder produced coffee in East Africa. Others appear to be maintained, e.g. tea production.

A major source of concern in the semi-arid and arid parts of the developing world is range management. The Sahelian conditions, also found in parts of East Africa and Southern Africa, arise in part from the elimination of water as the limiting factor on livestock with range taking its place. When these conditions are combined with a common property tradition over rangeland, destruction of the range results -- an often irreversible process. The most frequently used policy in controlling livestock numbers is borehole spacing and private ownership of the water. In Botswana, boreholes are to be drilled no closer than a 5 km. radius and nearly all livestock boreholes belong to syndicates of owners who legally either prevent non-syndicate members from using the water or charge handsomely for it. In either case, the borehole owners have an interest in restricting the number of livestock in the neighborhood of the well.

An effect of these policies is to squeeze out the small stockowner. Naturally, part of the problem is political since the cattle syndicates could be formed of small stockowners, but to date this has not happened.

A closely related resource management and distributional issue is also found in Botswana: the methods being employed for hoof and mouth disease control. Aside from the more recently found minerals, cattle constitute the major form of wealth in Botswana. The excellent range, when properly managed, permits production of high quality beef, even when long drives are required to reach the market (cattle actually gain weight on 500 km drives from some parts of the country). At the same time, wild game such as the various gazelles -- springbok, impalla, eland, etc. -- still pervade the country and, by casual estimates, still provide a substantial part of human protein intake (drivers may carry an old family rifle along on business trips, and one may return to find a buck laid out across the hood). Since these animals can carry hoof and mouth disease, there is a trade-off between their presence as a continuing protein source and the probability of a serious outbreak of hoof and mouth disease among the cattle herds. The nature of this trade-off is not known in any quantitative sense, but the Veterinary Department in the Ministry of Agriculture has an "all out" program to stop hoof and mouth disease. In addition to the usual quarantine camps for the inspection of cattle, chain-link game fences have been erected across the country, presumably to prevent the transmission of disease, but effectively stopping seasonal migration of game herds. The effect has been the decimation of native game of all sorts with increasingly severe impacts on its availability to the population.

In concluding this section on conflicts in water allocation, two factors contributing to inefficient decisions can be identified:

1. Water is frequently unduly subsidized, especially for livestock and irrigation purposes;
2. Water is frequently provided (and financed) through programs which do not induce or indeed permit local decision-makers to consider trade-offs between water and other programs.

An example of the former is found in many irrigation schemes around the world, where no charges or only very low charges are made for water, inducing inefficient water use. Another is the former high degree of subsidy in the drilling and equipping of boreholes for cattle in Botswana, leaving very much in doubt the actual economic viability of much of the past expansion of that industry.

The second factor mentioned above constitutes one of the institutional shortcomings of planning in many countries: particular types of investments or programs are offered to local areas on a "take it or leave it" basis without permitting the local unit to consider various trade-offs or to express their own values over alternative programs. Calling on Botswana again for example, the country is divided into districts for governmental and planning purposes. Most planning decisions are formulated by a District Planning Board and approved by an elected-traditional District Council. Development funds for health, education, and roads are granted by central government largely on the basis of the overall development plan submitted by the District and negotiated with the central Planning Ministry. Water funds, however, are either granted without any District inputs (for village water supply schemes) or are made available without apparent limit (for boreholes for all public purposes) by permitting the District to "queue up" its requests for borehold drilling and equipping along with all other Districts. The problem then is that the lowest priority borehold request is indistinguishable from the highest priority needs, and no attention is given to the ordering of priorities <u>among</u> functional areas, e.g. between water supply and health clinics, education, or roads.

B. <u>Environmental Considerations</u>

Environmental concern is not widespread in developing countries -- with the exception of a few genuine efforts being made to preserve wildlife. The problem is that modern development projects, whether they be public sector large dams, thermal power plants, or private industrial plants, are large relative to the assimilative capacities of local environments. Thus negative externalities (other than simple aesthetic degradation) are often quite serious but are seldom considered. This is partly a function of the institutional segmentation or separation and lack of bureaucratic coordination mentioned at the end of the previous section, but is also a function of shortsightedness.

The possibility of irreversible damages to ecosystems should always be considered and appropriately weighed (in a present-value sense) when considering the economic feasibility of different developments. The major potential for irreversible damages as observed by this author is destruction of coastal ecosystems and fisheries resulting from industrial-municipal pollution (e.g. the Gulf of Thailand) and sedimentation due to deterioration of soil conservation practices (e.g. the Tana River in Kenya). The attitudes of LDC's toward contamination and waste from nuclear power plants are yet to be seen.

1. Preservation of Natural Environments.

The developing countries which, at the time of their independence, still had significant endowments of natural areas and wildlife have done a commendable job by any comparison with more economically advanced countries of taking steps to preserve significant parts of these systems. As experience has shown, it is frequently difficult to tell what steps will result in "preservation." The British banned "poaching" (the name given to native hunting methods) of elephants in Tsavo Park (Kenya), only to have the elephants multiply to the point of destroying their habitat. Two thousand elephants per year are being cropped by professional hunters (or illegally by game wardens' friends), just the number estimated to have been taken by tribal hunters in earlier times! On the other hand, the development of intensive European farming along the Limpopo River, both in Botswana and on the South African side, has enhanced the wildlife populations of the region. Farmers, who have built barrages to hold back the seasonal flows for irrigation, proudly show off "their" hippos which occupy the pools, and one nightly sees new leopard and crocodile tracks.

Excellent examples of the dilemmas faced by LDC's in preserving natural areas and wildlife are the wildlife resources of East Africa (Kenya, Tanzania, and Uganda) and the Okavango Swamp in northwestern Botswana.

In the East African case, the resources have been relatively well developed for tourism, a solid foreign exchange earner for the countries involved. The major problems appear not to be "poaching" as frequently asserted but encroachment of competing land uses, namely agriculture. Population pressures and the gradual breakdown of traditional tribal land areas create pressures for settlement at the borders of the large wildlife preserves. The major difficulty is that the people who are asked (required) to forego this settlement receive few benefits from the tourism supported by the preserves. Again, a distributional issue lies at the core of a resource management problem.

The Okavango Swamp is a totally unique wilderness swamp environment. Its scientific and curiosity values are high, but its tourist potential is limited by its remoteness. Very high priced air safaries both for hunting and sightseeing yield high government revenues per user but small totals. About 12 million acre-feet of water is "lost" from the swamp through evapotranspiration each year, a large amount in an arid country. To date, the costs of extracting water and transporting it to the populous and industrializing regions of the country has been too high to make this attractive. However, growing water demands, especially the establishment of several large mineral complexes (diamonds, copper-nickel, iron ore) may eventually make it possible to utilize the scale economies in water transport to bring the unit costs to a competitive level. The questions will then be (a) what is known about the impacts of water removals on the swamp and on possible groundwater recharge to much of the country?; (b) what trade-offs will the country opt for, given the natural swamp does not produce much tourist revenue?

2. Pollution Problems.

One could undoubtedly cite many horrors of pollution, from the air pollution of Mexico City and Delhi to the contamination of the Gulf of Thailand. The real question, however, is "What makes sense from the LDC's own viewpoint if all effects are taken into account?" The quantification of external damages in physical or value terms is difficult at best, but not always impossible. The eradication of the shrimp fishery in the northern Gulf of Thailand could be valued in terms of the annual net value lost by having a smaller catch and having to fish at greater distances from the markets. Air pollution damage in the crowded cities is more difficult to quantify. In either case, the identification of sources and decisions on efficient programs of control are extremely difficult, both technically and politically.

Industry and population tend to congregate in areas until their pollution loads surpass the assimilative capacities of the environment. Industrial complexes are now often established on such large initial scales that they cannot be treated as "marginal" changes from either economic or environmental viewpoints. For developing countries as for the industrially advanced countries, a system of effluent standards for stationary sources linked to the desired levels of ambient environmental quality and allowing for the loads of non-stationary sources, is the only practicable approach. Obviously, costly externalities clearly call for some controls, e.g. Bangkok has no sewage treatment (some homes and hotels have septic tanks, but the water table is at the surface) and Thailand imposes no effluent constraints on industry.

A point frequently forgotten by the LDC's is that when new plants and towns are established, the costs of avoiding the worst pollution loads are relatively low. While one usually encounters the rejoinder, "But we're poor and must feed our people first", it is also true that the poorest get hit hardest by the pollution: the workers who cannot afford to move out of the industrial smog or the fishermen who find their livelihood wiped out by municipal and industrial wastes. If anything, the incidence of pollution by income group reinforces the rationality of basic control programs.

C. The Relationship of Water to Other Natural Resource Developments

This section lists various forms of natural resource development which relate in important ways to water availability. A major point is that natural resource development projects commonly require much less water than people perceive them to. Even in agriculture, horticultural and dryland opportunities which require very little water are commonly overlooked.

Another point of general importance is that in mixed economies, private sector response to public sector water undertakings is often the crucial determinant of success or failure. An excellent example is found in the Owen Falls Dam at Jinja, Uganda, on the Nile River. It was intended in 1955 to create "the Detroit of Africa" on the basis of cheap power. When no industry was attracted by either the power or the industrial tract, the excess power was sold on extremely attractive terms to neighboring Kenya (see Elkan and Wilson, 1968).

Another excellent example of the crucial nature of private sector response is found in the failure of farmers to construct field channels within irrigation project commands. The importance of this failure in parts of India and possible responses to it are analyzed by Easter (1975) and are emphasized as _the_ major reason for underutilization of water from irrigation projects in India in the Government of India's _Report...on Underutilization of Created Irrigation Potential_ (June 1973).

A final general point on supplying water for natural resource development _is the importance of a mechanism for water reallocation over time_. Again, the Kelso _et al_ study (1973) and the experience of the high growth centers of the semi-arid Southwestern United States are highly relevant.

Among agricultural developments, horticulture yields many benefits. It can be developed to serve different markets. It combines very efficient water use (as little as 10 inches per year) with labor intensity (up to 10 persons per acre). The market may be local, as in Botswana where fresh produce is now purchased from South Africa, or it may be foreign. For the latter, Kenya ships fresh fruit and flowers by air to European markets, but other countries have opportunities for growing and shipping less perishable commodities such as flower plantings, young trees, and seeds. Botswana is in an excellent position to undertake the latter type of activity because of its (plant) disease-free environment.

It is shocking how little research is underway on the development of drought resistant varieties for use in semi-arid zones. The great variability of precipitation in such zones also means that agriculture must be risky. In eastern Kenya, much of Botswana, northern Ghana, etc., two crops out of five are likely to be nearly complete failures, even with the use of drought resistant millets, beans, sorghums, maize, etc.

In the face of these conditions, traditionally oriented agricultural ministries and their advisors seem to have given up. This appears to overlook a great potential, necessary inputs to which are (a) a reliable supply of water for households and draft animals, (b) a national (regional) food purchase and storage scheme from which supplies can be taken to support the population during drought, and (c) capacity for rapid processing of range animals after drought begins. Northern Ghana lacks even a seasonal grain storage system so that there is a "hunger season" every year. Botswana farmers in good years sell off their grains to South African traders at harvest, only to buy them back, processed or unprocessed, at high prices later in the season. In bad years, some simply starve. Ways in which these basic adaptations to drought can be provided need further definition and discussion.

High value minerals can bear high water costs. In Botswana, the large diamond mines utilize a combination of surface water (unreliable) and ground water the average cost of which is about \$1.50 per 10^3 gallons. The copper-nickel complex at Selibe-Pikwe was part of a "package" which involved building a very large surface impoundment 50 miles from the mine and smelter site. The water is filtered and sent by pipeline to the smelter and further distributed to the township which was constructed to house the work force. The delivered cost of the industrial water is approximately \$1.50 per 10^3 gallons, while the distributed cost of the residential water for the township is about \$2.50 per 10^3 gallons (highly subsidized by the mining company). With such mineral commodities, water cost is not a critical factor.

Low value minerals in remote areas are likely to be unexploitable unless new ways of using them are found. For example, Botswana has vast deposits of lignite and low BTU coal. Distances to the South African and export markets combined with the low BTU content rule out exports per se. Suggested alternative uses include (a) mine-mouth generation of electric power which would be exported on ultra-high voltage lines, or (b) exportation as a water slurry with the joint coal-water product being sold. The Transvaal in South Africa is very short of water, so the joint purchase of coal and water might be attractive to both parties.

D. Conclusions

Water is becoming increasingly scarce in many LDC's. Trade-offs must be studied with greater precision than in earlier years. Further, the scale of water projects and other development projects has become so large that very extensive natural systems are involved with "externalities" being pervasive. Environmental capacities are being exceeded and valuable natural areas are being impacted.

LDC's typically do not have established environmental policies nor the analytical capabilities for studying the large systems involved in large-scale development projects. Nonetheless, the desirability of much more frequent applications of broad benefit-cost analyses of both public and private undertakings is obvious. Assistance must be given these countries by developing in their own people the capacity for such analysis.

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II. DISCUSSION OF HOWE'S PAPER

SCHRAMM:

My comments on Professor Howe's paper are necessarily selective, touching only upon a few of the many topics he discussed. But these are topics I have had to deal with on several occasions, and topics I believe to be quite important in the context of orderly and efficient water resource development in low-income nations. The first deals with the broad problems of increasing water scarcity and emerging conflicts in water allocation; the second with some issues related to project scope and timing.

Most of my examples relate to Mexico where I am presently participating in the work of the National Water Plan, but the issues are undoubtedly similar in many or most of the more arid and semi-arid nations around the world.

Let us first look at some of the problems related to present or future water scarcity. In most of these nations, agriculture still provides the largest share of employment. But in those regions in which rainfall is limited, output is limited as well. One of the ways of increasing the income of the backward rural population is by irrigation. In Mexico, for example, a hectare of irrigated land will produce, on average, five times more in terms of value of output than a hectare of rainfed agricultural land. Of course, this ratio does not apply to very arid areas where the land, in the absence of irrigation, can at best be used for extensive livestock raising, but to areas with at least 700-800 mm of seasonal rainfall. Equally interesting are the labor intensities. On average, two or three times more labor will be employed per hectare on irrigated land than on dry-land farms. From these two points of view, income and employment, irrigation looks like a useful tool to bring about (a) increases in agricultural output; (b) crop diversification, which is important in markets where relative prices and demands may change rapidly; (c) increased income and, (d) increased employment.

On the other hand, we also know that, in terms of value added, the value of water in agriculture is very low, relative to other uses (with the exception of hydro-electric energy production). One cubic meter of water, used for irrigation, may on average produce output worth between 2 to 4 cents; the same cubic meter, dropped a few hundred feet through a penstock to produce electricity, may generate perhaps one cent worth of it. However, used in a so-called "wet" industry such as pulp and paper, the value added supported by that cubic meter will increase to twenty cents to one dollar, while in a typical dry industry such as apparel manufacturing or automobile assembly the value added may rise to several hundred dollars or more. From an economic point of view there appears to be no question that in situations where water is scarce and choices between different uses have to be made, it should first be allocated to domestic-commercial-industrial uses rather than to agriculture.

This conclusion is contrary to many legal and institutional water allocation rules. In the water-scarce Western United States, for example, the prior appropriation rule applies, and all a user would have to show to maintain his water rights is some form of "beneficial use," regardless of its relative merit compared to competing uses. In Mexico, the rather recent 1972 Water Law determines a hierarchy of beneficial uses which ranks domestic use highest, followed by agriculture, hydro-electric energy production and, finally, industrial use. It seems clear that the legislators who formulated this ranking order were more attuned to Mexico's revolutionary history (which was essentially an agrarian revolution) than to the necessities of modern economics in a country that by the year 2000 will have more than eighty percent of its population living in urban centers.

The Valley of Mexico provides an excellent example. This hydrologically closed basin, lying at an altitude of roughly 7,500 feet, is running short of water. Groundwater tables have been falling for many years, downtown buildings and streets have settled in some places by as much as twenty feet, and fierce, choking dust storms rake the City during the dry season when the ancient saline lake bottoms surrounding it are dried out. Housing by now some 12.5 million people and growing at an annual rate of 6 to 7 percent, physical water supplies are running short. Planners now are seriously considering a huge water transfer scheme, tapping far away sources some hundred miles and two mountain ranges away, and almost 3,000 feet below the City's elevation. This scheme would cost some 1.5 billion U.S. dollars and require, among other things, pumping plants with a capacity equal to 20 percent of the country's present electric power supply system. Water costs would run at some 25 to 30 cents per cubic meter, or more than 10 times its gross value in irrigated agriculture.

On the other hand, there are some 55,000 hectares of irrigated land in the Valley. Assuming an annual application of 25 inches of irrigation water per hectare on 37,000 hectares, the annual use of irrigation water would amount to something like 20 percent of the total present water use in the urban area. If this water were to be transferred out of agriculture, the (perhaps inevitable) water transfer scheme could be postponed by about three or four years. Given the opportunity costs of capital in a country that has an annual net borrowing requirement of some $3 billion, the savings in interest alone would be of the order of $150 to $200 million per year.

But desirable as it may sound, nobody is going to take that water away from those farmers, because these are small-scale holders with, on average two to three hectares each, living at the marginal end of the income scale. From a realistic, political point of view it is clear that water, once it has been allocated to irrigation, is almost impossible to get back for other uses. This, of course, is true not only in Mexico, but all around the world. We only have to remember the wildly uneconomic scheme of treating saline irrigation return flow water in the Colorado River with an atomic desalinization plant in order to deliver water of acceptable quality to our Mexican neighbors who will use it for low-value irrigation.

Given these political facts of life, it is not hard to draw the conclusion that it is highly unwise to allocate presently nonutilized water resources to low-value uses in those regions in which (a) physical supplies are limited and, (b) alternative, higher-value uses are likely to grow at rapid rates. This is certainly true on the high mesa of Central Mexico which already contains half the population of the country and is, from the point of climatic and environmental considerations, the ideal location for those additional 40 to 50 million urbanites that will live in the country some 25 years from now. However, institutional arrangements generally militate against such sensible precautions. In Mexico, for example, irrigation planning is in the hands of the powerful Ministry of Hydraulic Resources whose clients and political supporters are those farmers that stand to benefit from government-paid irrigation works. While the same Ministry is responsible for urban water supplies as well[1/], traditionally some 85 percent of its budget goes to irrigation and most of its prestige and political power come from that base. Hence, while current urban and industrial needs may find recognition, future demands and needs do not. As a result, we now find in Mexico some 32 major groundwater basins in which the water table is falling steadily, but in which expansion of irrigation works is still taking place.

But a rational water allocation policy cannot stop at sectoral decisions only. As we all know, the marginal value of water in practically all uses drops rather rapidly after the most important requirements are met. A village family, living several miles away from the next water source, will make do with a few gallons a day while an urban family with indoor plumbing will use many times more. In the Valley of Mexico, which contains some 50 percent of the country's industrial capacity, the majority of these industries pump their own water, and control over quantities pumped are perfunctory at best. Most household connections are unmetered, and it is a common sight at seven in the morning to see the maids in the better parts of town hosing down the hundreds of feet of sidewalks in front of their properties. Would this pattern persist if their owners had to pay the full costs of future incremental water supplies, i.e., some 25 to 30 cents per cubic meter plus distribution costs? It hardly seems likely. But it is quite certain that the additional investment and collection costs of metering would be far less than the costs of transferred water.

The same is true in many other areas of the world. In Lima, Peru, for example, a $500 million plus water transfer from the Mantaro River in the Atlantic Watershed is thought to be necessary to provide the incremental water needs of Lima in a few years hence. But at the same time, industrial plants in the metropolitan watershed pump their own water, without any quantity limitations, at a perfunctory license fee that is paid to a Ministry which has no direct responsibility for water supply. Again a more rational policy would be to charge these firms the marginal opportunity costs of groundwater use, which are equal to the marginal costs of future water supplies. Such a pricing policy would undoubtedly reduce water utilization and, therefore, postpone the time when additional water supplies are needed. With interest cost savings of between $50 to $100 million per year (in a country which has the unenviable record of having the highest debt/GDP ratio in the world) this certainly looks like a good alternative.

Let us now look at some problems related to project scope and timing, and particularly to one which some years ago I christened the "lock-in" effect. As a result of the sudden 1973 increase in world oil prices many countries have once more turned their attention to the development potential of their more remote hydropower sites. These sites, usually far from existing load centers, have to be very large in order to be economically viable, since transmission costs are high but subject to rather substantive economies to scale. For example, the cost per kilowatt-mile of a 230 kilovolt, 270 megawatt, 600 mile long transmission line would be about two-and-a-half times as high as that of a 345 kilovolt, 800 megawatt line; if the voltage would be further increased as well as capacity, to between 3,000 and 4,000 megawatt capacity costs, per kilowatt-mile would fall to something

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1/ During the 1976/77 reorganization of the Federal Government, the Ministry of Hydraulic Resources was combined with the Ministry of Agriculture. The urban-industrial water supply responsibilities were transferred to the Ministry of Public Works. This division of responsibilities is likely to exacerbate the problem.

like 20 percent of the kilowatt-mile cost of the 270 mw line. But even at these low unit costs, total transmission costs are high because of the large distances involved. On the Nelson River power development in Manitoba, Canada, for example, costs of the 550 mile long transmission line amounted to over 40 percent of the initial investment costs of the overall project. Practically all transmission costs are capital costs. Hence, once a line is built or committed, marginal transmission costs are essentially zero since all costs for the 40 or 50 year life expectancy of the line have been committed in advance. As a result, the developer is essentially "locked-in", regardless of changes in the costs of alternative power sources. In the Nelson River Development case, the transmission line "locked-in" Manitoba Hydro, the owner, into a 20 year hydro development scheme which it now has to pursue even though civil works construction costs on remote sites have increased much faster than the thermal power plants. These later plants could have been built in discrete, smaller unit sizes to meet incremental demand. When the decision to proceed with the Nelson Scheme was made, however, both its assumed costs and that of the thermal alternatives were essentially equal. The question which must be asked in such situations is what kind of a risk premium should be applied to the large scale, non-reversable alternative. This risk premium obviously should be higher the larger a given scheme is relative to the financial capacity of the developer. While a rich country such as Canada or the U.S.A. could accept a gamble, a country such as Zaire (with the fabulous, 100,000 mw potential of the lower Congo River), India (with the almost equally impressive potential of the Upper Brahmaputra) or Peru (with its precarious financial position) obviously should and could not.

A related question is that of timing. It generally will be wise for a developing country with scarce capital and skilled human resources to postpone the development of very large or interdependent project sites as long as possible. Objections to Mexico City's or Lima's water transfer schemes are frequently brushed aside by the remark: "Even if we use some intermediate solutions eventually we have to do it anyway; therefore, we might as well do it now." Clearly, whoever voices such an opinion has given little thought to the question of the opportunity cost of capital and other scarce resources.

A more subtle, but equally important issue is that of optimal timing for multi-purpose projects. In Mexico, for example, the federally-owned Electricity Corporation is pressuring the Ministry of Hydraulic Resources to participate in the financing of the various hydropower dams on the Grijalva-Usumacinta complex near the Guatemalan border. Incidentally, from the power development point of view, this is a development scheme to which the "lock-in" effect, described above, applies forcefully, since the sites are huge and more than 600 miles away from load centers. Participation by the Ministry of Hydraulic Resources is sought because of the potential flood protection benefits in the lower, almost undeveloped basin. But for the latter Ministry, agricultural development of the Grijalva-Usumacinta flood plains has (or should have) low priority, since there exist several million hectares of un- or underdeveloped tropical land along the Gulf Coast rim which could be developed at considerably lower costs. Until these lower-cost land reserves are fully utilized, the Grijalva floodplains are really not needed. Developing them now would substitute a high-cost land development scheme for lower-cost alternatives elsewhere. Even if the hydro-development could be justified on its own merit, the percentage contribution by the Ministry of Hydraulic Resources, should be limited to the lower per hectare costs of alternative development schemes outside the Grijalva floodplain.

These, my rather selective comments on the topics raised in Professor Howe's paper, were strictly limited to economic issues. This restriction was deliberate. I am, of course, fully aware that in the development of water resources political, institutional, social, cultural and historical factors may play a much larger role than economic ones. However, for us, who are advisors to these nations and governments, it is essential to stress the economic side by answering the twin questions of "how much" and "for whom". This as analysts we can do. What we cannot do is to tell these governments and these societies what they actually should do, since this involves value judgments; making value judgments is exclusively their business not ours.

BROMLEY:

What I will try to do is focus on issues to keep in mind in our discussions tomorrow. As we sit around this room and begin to formulate problems and research areas, I want to share my concerns with you. The issues I will raise are familiar to all of us and yet we tend to forget them sometimes and need to have our memory jogged.

The first issue is that many countries--particularly in Africa where we have seen the emergence of many independent nations over the last ten years--are not viable nation states. Rather, they are pieces of geography occupied by tribes or by military governments. When you are talking about national policy in those situations you are dealing with a vastly different institutional structure than what most western economists are familiar with. This is less true in Latin America, but it is characteristic of many of the LDC's.

Secondly, most of them are characterized by severe misuse of power and control. We all know this, yet it must loom very large in our discussion of policy. Most policy, if not all of it, is undertaken by a very small fraction of the population with the expectation that the gains from that policy will be distributed in about the same way that power is now distributed. It is necessary to distinguish between nice sounding pronouncements that come out and actual behavior or performance. I am reminded of John Mitchell's quote when he said, "Don't listen to what we say, watch what we do," and in a slightly better context, that is what I have in mind. It is one thing to listen to what governments say, it is another to see what they do. We all know that the push for colonization projects in developing countries is a high-sounding concept, but in fact it is a way to deal with the mal-distribution of land without really confronting the current distribution of wealth.

My third point is that most of these countries are what Myrdal would call "soft states". The best possible interpretation of a soft state is that favoritism flourishes. The worst possible interpretation is that non-violent corruption is rampant; it is what we call white collar crime. With this potential for "slippage" in the system, economic planning and policy formulation is extremely stochastic in its output effects.

My fourth point, and perhaps the most important, is that with few exceptions, there is an absence of a latent entrepreneurial ethic on a widespread scale among people in these countries. I do not see any reserve army of willing risk-takers or profit-seeking economic men. Rather, I see a reserve army of largely illiterate, risk-averse people who struggle from day to day just to get by.

There are my four starting points for any discussions about problem definition in the LDC's. We must avoid transferring not only incorrect technology to these countries, but also incorrect intellectual concepts and problem definitions which derive from those intellectual concepts. It was at this point that I went back and read Myrdal's first chapter of his book, The Challenge of World Poverty--the title of the chapter is "Cleansing Our Approach From Biases"--and that was a nice reminder to me of these biases. The bias I had in mind here is that we define a problematic situation from our cultural and intellectual heritage and tend to impose that in another context; that scares me. The real problem in dual economies is the lack of a positive net expected value on the part of any individual actor from undertaking fairly certain costs to change traditional behavior. We can talk all day about public policy, about the public sector, and about what the governments of these countries ought to do, but we all know it is the little guy who has to "pull it off". When the expected value of his private gain is low vis-a-vis the rather certain cost he has to incur, we know what he will do.

I would now like to turn to Chuck's paper and mention a few places where our cultural and intellectual tradition might lead us down the wrong path. The first concerns the rigid allocation of water. As economists we are all concerned about highly mobile resources, and getting water to the highest use. We talk about getting a "better allocation of water," and yet those of us who have traveled in LDC's have seen the traditional watering hole "laundromat" where the women go to wash their clothes and fetch a bit of water. If we increase the mobility of water and move it from one use to another, I am concerned that third parties will get lost in the shuffle. I fear that when we talk about transferring water rights we exclude some third party interests that are fairly significant in the LDC's. The protein from wild game in Botswana is another example of significant third party benefits from a given set of property rights.

In Gunter's example regarding the reallocation of water in the Mexican valley, there are some third parties that are benefiting from the current rigid allocation of water. Can we be certain that the opportunity costs of changing that allocation do not far outweigh some obvious economic gains?

Skipping to another issue, Chuck, I see that old bugaboo common property resources rear its ugly head as the villain of the piece in the Sahel. If it has to bear the blame now, then it must also take credit for dealing with the resource allocation problem for thousands of years in which the tribes in the Sahel dealt with what Western economists would call a common property situation. I do not see it as a common property problem, I see it as an institutional lag vis-a-vis, a changing environment, and I am not sure that it is fair to put the blame on common property, *per se*.

You also discuss viable irrigated agriculture and mention the complementary inputs that must go along with it. The very recognition of the complementary inputs, which, of course, I agree with, is even further evidence that we have to be very careful when we talk about irrigated agriculture and efficient water use. We are all in favor of efficiency, but I like the way Al Schmid puts it: "efficiency for whom?" Efficiency like optimality is a unique function of some existing set of property rights and opportunity sets, and I get uneasy when I hear Western economists talk about efficiency in the context of a different culture.

Another point concerns treating water as an input to growth. It might be better to think about water as an input into reducing the degree of dualism that exists in these economies rather than as an input to growth.

In conclusion, all of Chuck's problem situations derive from our unique intellectual heritage and that is crucial regarding economic policy. Any problem identification is, by definition, based upon some conceptual framework about what is a little better, or what is a little worse. We start with some criteria (objective function) and the problematic situation is a felt need which compels us to move closer to some goal.

Tomorrow we will be discussing the following kinds of things: Can U.S. universities and research institutions assist in natural resource use? Can resource economists contribute to meeting important research needs? How might research needs be better addressed? What are the priority resource training needs in developing countries? How can resource economists contribute and how can U.S. universities help? I am concerned about, and sensitive to, intellectual imperialism and I hope that we can be very careful of this tomorrow, and later on this afternoon. Our definition of problematic situations derives out of a particular view of the world which comes from our culture and our intellectual history; that is rather ominous when we plan to sit around this room tomorrow and pontificate about what ought to be done about resource use and development in the LDC's.

General Discussion

TIMMONS: Chuck, in your paper dealing with water, why did you omit the whole dimension of drainage? Both drainage *per se* and drainage in conjunction with irrigation?

HOWE: An omission probably caused by a particular set of problems that I have dealt with in LDC's. I am now involved in a project studying damage in the lower Colorado basin due to inadequate drainage and which could be ameliorated by drainage improvements. I should not have left drainage out of my discussion. This is clearly an important issue.

TIMMONS: Do you feel that pressures currently in LDC's toward immediate use of water and other natural resources has important intertemporal allocation implications? Do immediate pressures of population and export demand on resources cause serious intertemporal misallocations, particularly of exhaustible and nonrenewable resources when future demands for these resources may be greater than current demands? This question would apply to soil erosion, forest deterioration and water losses, in particular LDC's pressed with current needs for food development and for improvements in income distribution now. How will current pressures on national resources affect future productivity and loan repayment potential?

HOWE: The World Bank and other institutions making financial loans are concerned about the payback potential of their loans. If the resources are being depleted or their income flows being guided by mistaken assumptions, it could have serious implications for loan repayment and future levels of living based upon this resource.

ABEL: May I put this question in a different context? To what extent are we pushing countries to a technological frontier that exceeds their capability to manage the investments? Developed countries have had more time to evolve their technical systems and develop their management skills. Now we are going into developing countries to build large water works for a city or irrigation systems that cannot be operated effectively with existing management capability.

GOLAN: I disagree totally. If you look in terms of the final reports on which investment decisions are based, it may look like that is the case. In the preparation of feasibility studies, however, in case after case we are looking into (a) multi-purpose projects which have other uses, other demands, and (b) future demands. Look at the number of country-wide studies being done to determine water allocations, not just for today, but 20 years from now. I can give you one example after the other. In Thailand, the government is undertaking a fairly expensive study of the Chao Phrya Basin to determine future demands. There is no serious conflict over water use at present, but it will probably arise in a few years. They are studying this problem at very high cost in order to resolve conflicts between transportation, salinity, irrigation, power, fishery, etc. In the Philippines the same thing is being done in central Luzon.

HOWE: I want to differentiate between studies made of projects to be built, and actual implementation of a project with its technology to manage, and the relation between private and public activities.

You have to evaluate future demand in order to determine how best to allocate water between conflicting demands, and I am very happy to hear that it is being done, but it is not done as a matter of course. It is done on a one country here and one country there basis.

There is a distinction to be made between renewable resources such as water where you do want to project future demands to avoid some of the problems in fixity of use, and nonrenewable resources like the mineral resources. The question with respect to the latter is the rate of exploitation of the nonrenewable resources such as diamonds and copper. For example, are the oil resources of Nigeria being intelligently utilized with respect to time? The developing countries appear to be doing as good a job as we are as a developed country. These considerations are not very adequately taken into account in our own society.

I am not aware that any of the development projects I have worked on have had any real analysis. Is this deposit worth more to us today or shall we hold it for future markets? In our course work we tell students of the importance of looking at the optimum time for undertaking a particular project. In practice we usually looked at the benefit/cost ratio, or at the present value today, and if it is positive, we go ahead.

QUESTION[1/]: Do you think exhaustible resources ought to be a part of our concern?

HOWE: It should be in developing countries like Botswana, where they have come upon rich mineral deposits which are finite, although some of them are very large. What kinds of activities are going to replace the exploitation of natural resources once those deposits run out? A question related to optimizing the rate of exploitation over time is in what kinds of activities do we invest the proceeds of resource exploitation, in the hope of having a viable economy when the resources are depleted? This brings me back to my worry about the inappropriate pricing of resources, water in particular, in the sense that you can distort the calculation of viability of

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1/ When we were unable to identify the speaker from the tape recordings, QUESTION or STATEMENT was used to indicate that a new person was speaking.

alternatives which are being built up from the foreign exchange proceeds of current resource exploitation. Are we subsidizing certain inputs and making investments look socially profitable which are in fact not socially profitable? Once the net savings from resource exploitation are exhausted (the easy source of subsidy for these on-going activities that have been built up), then a lot of these activities are going to be found to be nonviable.

That does not answer the question about how we ought to time resource exploitation, but I do not think those calculations are being made. One thing that is being distorted by inappropriate pricing of water and subsidizing of water enterprises is heavy investment in water dependent activities in the hope that they will carry on after the diamonds are gone in Botswana or in some parts of Africa. These water dependent activities are not going to survive because nobody around them is going to be willing to pay the bills.

If you look at the total water consumption of a developing country, industry takes a small percent of the total water and the overwhelming amount is taken by agriculture. How you price water for industry goes in terms of the amount taken and in terms of the cost of water for the industry as a whole. How you price water will not make a great impact on decisions. In terms of agriculture, pricing of water is not really the critical element, it is much more of a political decision. We have the example of the Tana River in Kenya. As far back as 1917 there was a report done by consultants for the government of Kenya which stated that the power investment will preempt any future irrigation development upstream of the power dam. We reviewed it; it was nothing new. The government decided to go ahead, nevertheless, based on political considerations. It was not an economic decision, it was a political decision. No pricing of water would have changed it. In most cases, the government makes a decision on how to allocate water, irrespective of how you charge the consumer. The question of pricing of water is blown out of proportion for developing countries.

If in 1970 you had charged the farmers in the Upper Tana basin the opportunity costs of that water in terms of power, none of them would have paid it. But this is not the issue. Whether the farmer pays for water is a question of resource and revenue generation. We are looking for the economic allocation of that quantity of water for irrigation or power, not whether they can recoup the investment from the beneficiary. How much you price the farmer for that investment is not an issue.

GOLAN: However, with 10,000 farmers in a river basin, prices charged farmers is quite a problem. There are really two types of pricing questions involved. One is on the revenue aspect of the pricing, the repayment of the investment. That can be done either through pricing the water or through taxation or through other means. But there is another important aspect and that is the efficiency with which water is used on the individual farms and the extent to which price can play an allocative role.

MARTIN: A third price question is the one concerning water use efficiency. I am not denying that you can allocate water efficiently administratively. It is a lot easier if you know in the design stage that you are going to do it that way, but it is harder to do afterward. What may come to be the reason for pricing water is the income distribution effects of giving farmers water free versus charging them for it. Every country we are thinking of has so many peasants that there is really no way the government can do as much for all peasants as it is going to do for those to which it is giving irrigation water. Even if they were marginal farmers under the old situation, you are going to put them in the upper quartile of the income distribution of farmers after irrigation water is made available. Unless the political reasons are overwhelming it makes sense to try to collect what the water is actually worth to farmers and use these capital funds to help somebody else in the society. Otherwise the value of the irrigation water will just be capitalized into higher land prices. In one of Randy Barker's sections of the annual IRRI reports they found a place near Bataan where in a five-year period the combination of making free irrigation water available and the Green Revolution drove up land values by three to five times their former level. If you do not use water prices, it will be difficult to do the same things well that you can do with prices.

HOWE: I agree that incorrect pricing of water leads to misallocation of resources. Water pricing is a critical element in terms of income redistribution. The failure to price water correctly leads to investment decisions that are incorrect. Another aspect of this is the extent to which a government considers water to be a scarce resource. This does not mean that it has to charge the farmers a certain price for the water to pay off the project, but at least in doing its investment planning, it should arrive at a shadow price that reflects the scarcity value of water. If the project evaluation assigned shadow prices to water that reflect scarcity value, this might lead to a different type of investment decision.

One has to define the degree of centralization of the planning and the allocation process before you can be sure what decisions will be affected by pricing. If you are going to plan downward from the major storage project to the final field channel, you can always have centralized decisions that will accomplish what prices will accomplish. We may have in mind an unrealistic degree of centralization of the actual decisions that go into planning. There is a lot left for private initiative in most countries. There is also a lot of private investment if the right atmosphere is created by the provision of structure or services. One of these is water.

Another illustration of inefficient investments being made privately in response to the public provision of water is the vast expansion of range cattle in parts of Africa. The government permits the district to put together groups of small cattlemen and apply in their name for government provision of water including the pump and the tank for cattle. If the value of the cattle sold is sufficient to cover the costs of the cattle scheme, then it will go. At the moment there is a large expansion of cattle raising going ahead simply because the government is not imposing the cost of that water on the people who are making the decisions. If the ground water is fossil water, then there is another cost that should possibly be imposed.

SCHRAMM: There is still another efficiency issue. For the typical irrigation project, you end up with an assumed cropping pattern that is a mixture of high-value and low-value crops, reflecting historic patterns. In Mexico, for example, about 60 percent of the crops grown on irrigation are grain crops with relatively low value. If you look at project proposals you see 100,000 hectares here, 50,000 hectares there, and a mixture of 40 percent or 50 percent grain crops, 20 percent vegetables, 10 percent fruit and so on, which may in fact be the actual pattern once it is established. If you combine this analysis with the market analysis for high value crops, you find that you preclude a switch in an existing irrigation district from low-value to high-value crops by taking part of the market for high-value crops for the new land. The marginal contribution of the 100,000 hectares of new land is only the addition to grain crops and not the output from the high valued crops. It still has very substantial effects and who gets the benefits is still a very important issue. If there was enough of a market for strawberries, a lot of other people would like to produce them. However, the demand for strawberries is limited so that small increases in production bring considerable decreases in price. That is why projects under consideration should be valued in terms of efficiency in a national and a marginal context.

STATEMENT: What you are suggesting is that the economic evaluation of the project assumed a total demand for a high-value crop that does not really exist. The country is already in equilibrium and all you are doing by growing high-value crops in this particular project is displacing production elsewhere. An example of this was the California water plan. The West Side water was assumed by the planners to go into high-value crops. When economists did the price analysis, they found the production of high-value crops on the West Side would displace almost as much high-value crops grown elsewhere in the state. Even in terms of the California economy the California Water Plan was a gross over-estimate of the net value of additional production.

ABEL: I would like to come back to John Timmons' original point. One problem is that only a very narrow range of investment possibilities is being considered dered. Whether we are talking about irrigation, range management or management of forest resources, one starts from an existing resource use pattern. Existing investment is associated with a known technology in the use of the resource, the demand for the resource, and on a certain set of institutional arrangements. Typically we look at alternatives in terms of the best we can do; that is the most modern of engineering designs, the most modern aspects of management techniques, etc. These alternatives usually place a great deal of stress on indigenous capability to manage the system being created. What one usually does not consider is an incremental approach of improving resources in a way that does not put great stress on the existing managerial capacity and institutional structure. In the water area, the kind of thing that Bill Easter was working on in India on improving village irrigation was an incremental approach, as is the work of Tom Wickham and others in the Philippines.

There is a lot of irrigation in place and incrementally improving the quality of existing irrigation systems is an alternative to building new systems. Are we looking seriously at the sequence of incremental improvements in our resource use that may be more consistent with institutional and managerial capabilities in developing countries rather than at the alternative of coming in with the most modern system?

A short, cynical answer is that it is appearance that counts. Non-marginal changes have a nice appearance and make it look as if things are being done; marginal changes are hardly noticeable.

TIMMONS: Martin, two of your statements bother me. You mentioned undue stress on existing institutions, and you imply that incremental investments should be made that are consistent with existing institutions. I would be more comfortable arguing that we should stress or alter some of the institutions now in existence. Economists are not being very helpful when they assume away institutions or when they assume that institutions cannot be changed. This is a real bias that people from developed countries have in working with less developed countries. Institutions are going to have to be changed in terms of being made conducive to resource utilization in such a way that resources yield their potential productivity with an income distribution and employment patterns that are consistent with national goals of less developed countries. This may be one of the greatest single biases that people from developed countries take into developing countries. The way out is to realize that institutions are man-made and can be changed by man when they do not serve his purposes. Institutions can be put into a programming framework where the institutions can be tested as constraints right along with other kinds of constraints and relaxed in normative terms in order to predict the outcomes of changes in institutions.

ABEL: I would agree with you wholeheartedly.

TIMMONS: What do you mean when you say we should not understress institutions or we should make incremental changes in technology?

ABEL: We have not paid enough attention to institutions and to the required changes in institutions. Implied in an incremental approach is an assessment of how rapidly the existing institution structure can be changed, in what direction, and what is it going to take to do it? Large modern projects are a way of ducking the necessity to deal with institutions in any way. Modern projects may be outside the mainstream of human relationships, not always, but many times they are. In a settlement scheme you are trying to create a new set of relationships that hopefully will not be in conflict with old relationships. To what extent are some of these jumps so big that it is beyond the capacity of the country within the foreseeable future either to provide the management or to be able to operate these projects efficiently?

CROSSON: Water management presents a set of issues where the question of confronting institutions cannot be ducked. It is fairly well known or is widely believed that bringing in large new irrigation schemes from now on is going to be a lot more costly in most parts of the world than it has been. In an economic sense, the alternative you suggested of making better use of what we now have is going to look increasingly attractive. Once you start thinking of it that way, you cannot make any headway on better water use without confronting the institutional issue as the reason why so many irrigation projects are using only a small percentage of their potential capacity. The reason is not because they are badly designed in a technical and engineering sense. The problem arises because the terms on which water is made available to farmers do not provide them an incentive to use the water efficiently, or the water never reaches them due to breakdowns in the institutional structure.

In Latin America, the characteristics of these irrigation systems are the rigidity and centralization of control at high levels. In effect, decisions are being made about water use by water managers who are sitting in a district office or in some cases even in a capitol. They do not really know what the conditions for efficient water use are on a farm. As a result of their decisions, the patterns they impose are inconsistent with efficiency under existing conditions, to say nothing of future conditions as markets change, technology changes and so on. This extremely rigid set of institutions governing water allocation at the farm level is crucial to getting at the question of how do we do better with what we have? It may be a place where economists can play a role perhaps in the way that Timmons suggested of estimating what it costs to keep this institutional structure. In other words, the opportunity costs of this existing pattern of allocation in terms of output foregone. This can be a point of argument for those who want to change things.

ABEL: This matter of efficiency depends a little upon just what aspect of efficiency you are talking about. If you are talking strictly about the efficiency of water application and you have a reasonably well-designed surface or gravity irrigation system, you can increase the application efficiency by going to sprinkler systems and perhaps save 25 percent of the water. You may not increase yield very much. That does not provide much incentive, and it is going to cost you quite a bit more. In Hawaii the sugar growers are changing systematically from surface to sprinkler irrigation because they have a fixed amount of water and can afford to make the changeover. The change will allow them to irrigate 25 percent more land. They can afford to do it, but the situation may be quite different for small farmers in a developing country.

In the developing countries the cost and income situation is a lot different and the most efficient method is not necessarily the best. It might be in Hawaii, where labor has a different relationship to production. I can see good reasons for many countries to subsidize farmers and to make water available to them at a subsidized rate. In some districts where water is a scarce resource and has high value in alternative uses it might be desirable to price water at the margin to reflect its value in these other uses. Marginal pricing can still be combined with a subsidy. You can give a farmer a layer of two-acre feet and make that free. That is the minimum to grow a crop under the ecological conditions. If the farmer wishes to go to some higher value use of the water, we will charge for it. The cost of metering and administration is an added consideration. However, you would only want to meter the water if you had some other use for the water. If you have 100,000 hectares of land, of which only 30,000 are irrigated, and you could extend the canals at reasonable costs, then a marginal water pricing scheme would be highly beneficial.

You also might need a scheme to subsidize the farmer who installs meters. The law could require meters next year, but also provide the money for the equipment. You cut back administratively or price-wise on the amount of water a farmer can get because of its other valuable uses.

The cutback could be for energy reasons. In Nicaragua the government has sponsored sprinkler irrigation which costs them up to twice what it should. The government is making up the difference, but it is taking roughly twice the amount of energy because you must pump it higher. If it is government policy to do that to save water, it might make sense, but it does not in this particular case. In Columbia a good-sized surface irrigation project from stream flow was operating at one-third the capacity. The canals and distributaries are there for irrigating three times as much land but farmers grow only one crop of rice per year because they do not have enough water. The basic reasons are no water storage capacity and sediment. Operating at full capacity would require basic changes in the water supply system but area farmers are not interested because they are doing all right as it is. They have enough land and it may be in their interest to keep things as they are but it may not be in the best interest of the country.

WICKHAM: Martin, you started by saying we push on developing countries technology they are not ready to adopt. When we talk about water that is true if we give them a sprinkler irrigation or irrigation they cannot handle. In developing countries the bulk of irrigation is gravity. They have been using it for thousands of years. You are not installing a new sophisticated system. It is a simple irrigation system and in India there are very few sophisticated systems. There are also very few well managed systems in India. You cannot simplify the system any further, so the issue is not that we are giving them too complicated a tool. The problems are different.

Second, it is very easy to talk about efficiency on the farm. In the case of India or the Philippines, when systems were analyzed, it turned out first that the system was not properly designed. Long before you come to the farms you cannot deliver the water to the point where the farmer can make efficient use of it because the system was not designed for efficient water delivery. In India, when we reviewed system after system, we concluded that the government has to accept that past investment in large scale systems is probably only about one-third of what is required. Before you can talk about efficiency to the farmer you have to have additional investments in the system and its structures.

The next question is, can the farmer be efficient? It makes no sense to talk about farmers using water efficiently if they cannot level their land or if they do not have proper drainage. We have to see that they have a real opportunity to use the water efficiently and that may require a lot of capital. They are finding it out in country after country.

ABEL: The word efficiency is being used here in several different ways. I do not think we are using it the way I would use it as an economist.

WICKHAM: I am using it in the way an irrigation engineer would use it. How much of the water is used for crops and how much of it is wasted?

ABEL: I do not have any objection to that. But what you may conclude is the most technically efficient way to deliver water, I may conclude is economically very inefficient.

WICKHAM: I am looking at efficiency in terms of the incremental (marginal) investment versus the savings of a cubic meter of water price at its opportunity cost? Then you would ask, does it pay to invest in improving the system to save that cubic foot of water?

ABEL: Now you are turning around and looking at economic efficiency.

WICKHAM: I am looking at it both ways. What we are asking is how much can you invest to obtain the optimum use of that water? Does it pay the farmer to invest in improving the efficiency of his water use?

III. IRRIGATION SYSTEMS IN TAIWAN: MANAGEMENT OF A DECENTRALIZED PUBLIC ENTERPRISE [1/]

Martin Abel

ABSTRACT

The efficiency of the management of irrigation systems in Taiwan, viewed as decentralized public enterprises, depends on four interrelated factors. These factors are (1) the recognition that water is a scarce factor in agricultural production, (2) the legal administrative basis for centralized planning of irrigation investments but decentralized management of irrigation systems, (3) the information systems which permit the exchange of agronomic and engineering information between the users of water and the managers of a system, and (4) the use of incentive structures for both the managers of irrigation systems and the users of water that appear to be compatible with the efficient use of water within the irrigation system.

1. Introduction

The use of irrigation, particularly in Asia, is centuries old. Irrigation systems were built in India as early as the second century A.D., and irrigation development was given major emphasis in British India during the nineteenth and early twentieth centuries [Ministry of Irrigation and Power, 1972, pp. 60-82]. In Japan, emphasis on irrigation dates back to the Tokugawa Era (1603-1867) [Fukuda, 1973]. In Taiwan the first large irrigation system was built during the period 1680-1719 [Ko and Levine, 1972]. One can find similar long experiences with irrigation in many other countries of Asia [Takase and Kano, 1969].

Despite this long history of irrigation, only a few countries have evolved designs of irrigation systems and the management principles and techniques that result in efficient water use. Japan and Taiwan are undoubtedly the most advanced in these respects, followed probably by Korea. The People's Republic of China may rank high in efficiency, but insufficient information is available to make any firm judgments. Throughout the rest of Asia, efficiency in canal irrigation system water use is quite low.

Our concern is with surface, or canal, irrigation systems, typically constructed and operated by public agencies, which provide water to a given area of land from a combination of streamflow and reservoir storage. The area irrigated can involve numerous farms and an even larger number of fields.

In an ideal situation, water would be allocated efficiently in an irrigation system when the marginal value product of water in each use is equal to the marginal scarcity value (shadow price) of the water in the system. Alternative mechanisms could be employed to achieve optimal water allocation. One mechanism would be to charge the marginal scarcity value of water in the system for each type of use. The other mechanism would be to allocate to each user of

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water the optimal quantity, whereas the actual price paid by users could be less than or equal to the marginal scarcity value of water in the system. If the users paid less than the shadow price of water, they would be capturing part of the economic rent associated with irrigation.

In an irrigation system with storage (reservoir) capacity the manager of the system must be concerned with the allocation of water among farms, among crops, and between crop seasons or even crop years. The supply of water in any particular crop season may not be treated as fixed because water might be carried over from one crop season to the next. The calculation of the optimal distribution of water is a problem in intertemporal allocation.

The efficiency of an irrigation system can be increased through either improvement of the management of the system or improvement of the physical design of the system. Both types of improvements may be desirable. However, there may be some degree of substitution between management and design dimensions of a system.

A great deal has been written about the importance of increasing the efficiency of water use in irrigation in Asia, particularly with respect to canal irrigation systems [Asian Development Bank, 1969, 1973; International Rice Research Institute, 1973; Ministry of Irrigation and Power, 1972; International Rice Research Institute and College of Agriculture of the University of the Philippines, 1969]. Improved efficiency in water use is judged to be an important source of growth in agricultural output and productivity and is of particular importance in most countries of Asia, where land is a scarce factor of production. There are compelling reasons to economize on or to increase the productivity of land in relation to the more abundant factors, most notably labor. Expanding the irrigated area and improving the efficiency of water use are two ways of increasing land productivity, which as yet have not proven to be simple matters.

Increasingly, it is being recognized that efficient canal irrigation systems are very complex entities involving interrelationships among economic, technical, and administrative factors. A recent publication [International Rice Research Institute, 1973, pp. v, vii] summarizes well the complexities involved:

> If the irrigation system is to be effective, the farmer must be able to depend on getting the water when he needs it. This requires an administrative mechanism that can build and maintain physical structures for providing water--dams, canals, ditches, and pumping systems. At the same time, it requires a mechanism to insure fair allocation and efficient use of water among farmers. Maintenance of the physical structures can be confused with management of the system because these two tasks often merge in the hands of one individual (e.g., the ditch-tender). Thus the ways in which the tasks differ, and the different talents they require, often go unnoticed.
>
> One prerequisite for sound management of an irrigation system is a set of procedures for keeping continuously informed about the farmer's situation--the size of his farm, cropping patterns, soil characteristics, the availability of water from other sources, etc. Representing the farmer's interests in water management decisions calls for an ingenuity that is not yet in evidence in the management of many irrigation systems. Some administrative functions performed by government or professional bodies also require reciprocal cooperation and action from the farmer. Where these responses are essential to management success, there is a need to find policies and mechanisms of the administrative body which would help to secure them.

> Good water management, and especially good management of irrigation projects, requires a balance of at least four kinds of inputs: physical facilities, inputs of scientific and technical knowledge, management inputs, and inputs of current information and data. And, the management of these inputs will have to be adapted to the cultural and political settings in which irrigation systems operate. It is wasteful to make investments in ways that put some of these factors far ahead or far behind the others. What steps can be taken to analyze systems to see how well these ingredients are balanced and to identify and correct points of imbalance? Development of human resources is clearly an issue here ...

This paper attempts to describe the operation of canal irrigation systems in Taiwan, judged by many people to be quite efficient with respect to water use. The focus will be on how economical, technical, and administrative factors have been incorporated into the management of these irrigation systems to yield a high level of efficiency of water use. The factors judged to be important have been distilled from available literature. No attempt has been made to evaluate empirically the relative importance of each of these factors or the precise way in which they are handled. These are subjects for future work. Nor is it feasible in this paper to compare the operation of irrigation systems in Taiwan with those in other countries. By implication, however, all of the factors critical to the successful management of an irrigation system discussed for Taiwan are not present in full measure in most other countries.

An examination of the management of irrigation systems in Taiwan reveals four factors that seem to contribute strongly to efficient management of the systems. These factors, which are different from what one finds in most other countries of Asia, seem to be highly interrelated, which makes it difficult to evaluate the contribution of one in isolation from the contributions of the others.

First, in order to increase agricultural production, Taiwan has recognized water as a scarce factor of production to be used as efficiently as possible. Second, the national government of Taiwan has evolved a basis for centralized planning of irrigation investments and at the same time decentralized management of the systems. This was true until 1975. During 1975 the national government took several steps which appear to restrict the degree of decentralization in the management of irrigation systems. Our concern in this is with the development of irrigation systems in Taiwan up to 1975. Planning of new investments by the central authorities was important to ensure rational allocations of resources among all categories of development expenditures. However, responsibility for management of irrigation systems was given to those who directly benefited from irrigation. The mechanism used was the cooperative irrigation association. Users of water have participated in the planning and management of irrigation systems. Third, within the irrigation associations, information systems were developed which permitted the exchange of agronomic and engineering information between the users of the water and the managers of the system. These information systems were and still are especially important because water is administratively allocated to the users on the basis of some calculation of the scarcity value of water; prices actually charged do not play a major role in the allocation of water among users. The information systems also facilitated continued improvements in the physical design of irrigation systems and in the agricultural production technologies used by farmers. Fourth, the irrigation associations employ systems of incentives for both managers of irrigation systems and users of the water which appear to be compatible with the efficient use of water.

2. Clear and Effective Policy to Increase Agricultural Output

One of the essential principles which contributes to efficient irrigation systems as well as to rapid growth in agricultural output is a clear and effective set of policies that place high priority on agricultural development and that recognize water as a scarce factor of production. Historically, in many countries of Asia, either strong emphasis on agricultural development was lacking, or if agriculture was emphasized, water was not visualized as a scarce factor. Levine and Wickham [1975] point out that a great deal of the irrigation in Asia was developed to provide supplemental water during the wet season at which time expected rainfall is almost equal to total crop requirements but is unevenly distributed throughout the growing season. In this approach to irrigation, water is not viewed as a scarce factor to be managed intensively.

Taiwan has emphasized agricultural development and has treated water as a scarce factor of production, at least since about 1920. The early impetus for these policies came from Japan, ruler of Taiwan from 1895 to the end of World War II. The long-run strategy of Japan was to supply the Japanese market by developing the agriculture of Taiwan. Heavy emphasis was placed on increasing the production of sugar cane and rice [Ho, 1971]. During the first two decades of the twentieth century there was a decline in the rate of growth in rice production in Japan, while demand for rice continued to grow rapidly. This resulted in rapidly rising rice prices and the rice riot of 1918. The Japanese government adopted a policy to develop Taiwan into a major exporter of rice. (Sugar cane production was also emphasized to meet the import needs of Japan and to free foreign exchange for industrial development.)

The Japanese strategy to increase rice exports from Taiwan relied on two basic policies. One set of policies was highly exploitative. It reduced the incomes of Taiwan farmers through heavy taxation and forced Taiwanese to substitute sweet potatoes and other 'inferior' foods for rice in their diets. The other set of policies was directed at increasing agricultural productivity through programs of investment in irrigation and water control, research and extension to diffuse high-yielding Japanese rice varieties adapted to local conditions in Taiwan and institutional development to support the development of a more productive agriculture. These efforts yielded a tremendous surplus of rice for the Japanese market [Hayami and Ruttan, 1970, pp. 570-571].

Lee [1971] has described the period 1895-1930 as one in which the economic and social basis for future agricultural growth was established by relying heavily on strong measures of force rather than on economic incentives [Lee, 1971, pp. 39-42]:

> Development programs emphasized both material input as well as institutional organization. Emphasis was placed on heavy investment in infrastructure, such as communications, transportation, harbors, power, education, general public health, flood control, and irrigation ... Institutional and organizational reforms were imposed on the administrative system, land tenure system, monetary and fiscal system, and farmers' associations.

Irrigation came under government control in 1901. Before that date, irrigation projects consisted largely of repairing damaged canals, but now expansion of paddy land and protection from the hazard of drought were the main goals of the program. Institutional roles underwent significant changes in this period with the creation of the landlord class ... They were convinced that agricultural improvement was to their benefit under the new land-tenure system and land-tax payment. They were encouraged to direct villagers to adopt new seed varieties and better cultivation methods... The farmers' positive response to new technology, in this period, was pervasive, largely because of the influence of the landlord class and the government.

The profitability of the new technology, however, was not broadly recognized by cultivators until 1922, when the new variety of Pon-lai rice appeared and previous investment in agriculture began to show results. The process of altering the old cultivation methods and the extension of the use of the new varieties ... was not characterized by persuasion, but rather by government enforcement. Police stayed in the local communities and effectively participated in agricultural extension services.

The period 1931-1940 saw a continuation of basic developments, infrastructural, technological, and institutional, but with one major difference: the activities of Taiwanese farmers were guided more by economic incentives than by force [Lee, 1971, pp. 42-43].

In the post-World War II period, agricultural development was concerned with the recovery and rehabilitation of agriculture from the damage and neglect which occurred during World War II and with the sustained growth of agricultural output at rapid rates beyond the period of recovery. The government of Taiwan recognized the fact that rapid agricultural development was essential to create a domestic surplus and the foreign exchange earnings required to finance industrial development. Strong emphasis was given to the development of infrastructure, including irrigation and water control, institutions, technology, and economic incentives. And this emphasis did create large amounts of resources for industrial development. Taiwan also benefited from large amounts of foreign aid from the United States. It is significant that this aid did not seem to lessen the efforts of Taiwan to mobilize domestic resources for development [Lee and Hsieh, 1971].

Ko and Levine [1972] state that in 1895 there were 107,716 ha.of land in Taiwan irrigated by canals and ponds. During the next 50 yr.the irrigated area was expanded to 561,999 ha. In recent years there have been 540,000 ha of irrigated land, which accounts for about 60% of the total cultivated area.

There have existed since 1895, and especially since 1920, clear policies to increase agricultural output in which water was recognized as an important and scarce factor. Further, the development of irrigation and the control of water were necessary to exploit the output potential of high-yielding fertilizer responsive varieties of rice and other crops [Ishikawa, 1967, pp. 108-109]. These policies were not mere pronouncements by governments. Rather, they were policies which were implemented with considerable vigor. There was a clear recognition by all levels of government in both Japan and Taiwan that investments on a broad front were necessary to increase agricultural productivity and to generate a surplus to finance industrial development [Falcon, 1974].

3. Centralization of Planning and Decentralization of Operations of Irrigation

It may be important to distinguish between the optimum level of centralization in decision making for planning of investments in irrigation systems and the optimum level for operating a system. In many countries of Asia, government agencies responsible for planning new investments in irrigation systems also have the responsibility for operating these systems. The skills required and the criteria used for planning and constructing new systems are not necessarily those needed to operate a system efficiently. Levine and Wickham [1975] make this same point with respect to the distinction between operation and maintenance of a system. The distinction between the two functions in terms of skills and criteria is not always recognized.

Explicit recognition of the need for centralized planning but decentralized management of irrigation systems has evolved in Taiwan. The planning of new irrigation systems or the improvement of old systems was guided by the policy objectives discussed in the previous section. There was a fairly clear basis for assessing the social value of additional agricultural output, particularly rice. The demand and price structure for rice was reasonably well understood both in Japan prior to World War II and in Taiwan in the postwar period. The cost of improving and expanding irrigation was also well known. The social costs of and returns to irrigation development had to be evaluated in relation to other investments, especially in the nonagricultural sector, since government provided a substantial part of the capital used to construct or improve irrigation systems. Centralized planning of water resource development was required to allocate development resources efficiently among alternative investments. However, the skills of farmers and local government officials, supplemented by a limited number of technical and administrative personnel provided by the central government, could be used to manage irrigation systems. Mechanisms to utilize local personnel in the management function were developed which reduced the administrative burden on the central government and gave farmers a vested interest in how well the systems were operated.

The separation of responsibilities for planning and management is reflected in the national laws governing the use of water and the assignment of legal responsibilities for different functions. The national water law is fairly comprehensive, covering most relevant aspects of water resource use for all purposes. A detailed description of the law is contained in "Water Law of the Republic of China," promulgated by the Chinese national government on July 7, 1942, as amended on November 29, 1963, and promulgated on December 10, 1963. The law governs the control and utilization of surface water or groundwater with respect to flood control, tide control, irrigation, drainage, leaching of injurious salts, soil conservation, storage of water, water supply for human and industrial consumption, harbor construction, water transportation, and development of hydroelectric power.

The law stipulates which agencies of government, referred to as water conservancy agencies, have responsibilities for the planning, the development, and/or the regulation of water use. These agencies are specified at the central, provincial, and municipal levels of government. The law also defines water rights, i.e., the legal rights that persons individually or collectively have to the use of surface water or groundwater. As a part of the water rights, priority is assigned to various uses of water. These priority uses, in descending order of importance, are domestic use and public water supply, agricultural use, power use, industrial use, water transport, and other purposes. It is not clear that the ranking of priorities for water use corresponds to a ranking of the marginal value products for water in these different uses. For example, the rapid growth of industrialization in Taiwan may have resulted in the marginal productivity of water for power and for industrial use being higher than the marginal productivity in agriculture. Provision is also made for the transfer of water rights among individuals and organizations, private or governmental. With the growth of urban areas and industrialization, water has been transferred from agriculture to human, industrial, and power uses.

Procedures are also specified for the development of water utilization or conservation projects, the protection and maintenance of water structures, and the assessment of penalties for violations of the water law.

The national water law provides a basis for the central, provincial, and municipal governments to plan the development of water resources in Taiwan with respect to all uses of water resources. Theoretically, at least, this form of centralized, or governmental, control over the development and use of water resources should yield results consistent with national economic and social objectives. And we suspect that there is in practice a reasonably high degree of performance.

With respect to irrigation, and possibly other uses of water as well, the national water law provides for the management of irrigation systems to be conducted by autonomous local organizations in the form of irrigation associations. In addition to the national water law there are separate regulations governing the establishment and operation of irrigation associations. (These are found in "General Rules Governing the Organization of Irrigation Associations," promulgated by presidential decree on July 2, 1965, and revised and promulgated by presidential decree on February 9, 1970, by unofficial translation.) These associations are self-governing corporate bodies organized by users of water for construction and operation of irrigation facilities. The associations are cooperative in nature and are operated by those who use water for their own benefit. In the late 1960's there were 26 such associations in Taiwan, covering 464,872 ha. of irrigated farmland [Takase and Kano, 1969, p.537].

The concept of cooperative irrigation associations was developed in Japan and introduced into Taiwan during the period of Japanese rule. In Japan the Irrigation Association Law was passed in 1899. This law together with the Land Improvement Law of 1949 provided the basis for farmers' organizations engaging in the construction, operation, and maintenance of irrigation facilities [Fukuda, 1973, p.205].

Either a group of farmers or the government may take the initiative in establishing an irrigation association. Proposed irrigation projects must be approved by appropriate governmental agencies. Once established, the responsibilities of the association include the construction, improvement, operation, and maintenance of irrigation projects, the prevention of damage to facilities, the financing, the study and further development of systems, and the performance of any other duties entrusted by appropriate authorities under law.

The members of an irrigation association are entitled to irrigation water and other benefits and are required to pay fees and perform certain duties for the association. Noncompliance of a member with the obligations imposed on him by laws and regulations can lead to a suspension of rights to water and other benefits.

While members of the irrigation association are entitled to receive water, this does not mean that each member receives all the water he desires in any given crop season or that he receives it in all crop seasons. Clearly, when there is not enough water in the system to meet total needs and the water available is allocated efficiently, some users will receive only a part of the water they desire, and some producers will not receive any water in certain years. But as will be discussed in the next section, users know the quantity of water they will receive before planting decisions are made.

The government has borne part of the construction costs of irrigation systems, as much as 50% in some instances. The remainder of the construction costs and the operating expenses of a system are paid for by the membership of the irrigation association. Usually, separate schedules of fees exist for construction and engineering costs and for operating costs. The fees are based on the approximate amount of water used.

It is not clear how well the water fees reflect the scarcity value of water in the system or how the fees are actually set. This is an important topic for which more research is needed. Are the special fees covering construction and engineering costs set to cover the full cost of these activities incurred by the irrigation? Are the regular fees, which supposedly cover the operating costs of the system, based on average or marginal operating costs?

The association membership elects a general assembly which has the responsibility for formulating the policies and operating rules. The policies and directives of the general assembly are carried out by the staff of the association. Staff members may be either hired by the association or appointed by an appropriate government agency, depending on the functions to be performed and the skills required. Even employees appointed by a government agency are responsible in large measure to the governing body of the association.

4. Integration of Agronomic and Engineering Information onto Management of Irrigation Systems

One outstanding characteristic of irrigation associations in Taiwan is an information exchange system between water users and managers of the system. The formal handling of information is important not only to the management of a system of a given physical design but also to the improvement of efficiency of water use by changing the design of systems. The design and management of irrigation systems have an influence upon each other. According to Levine and Wickham [1975, p. 3]:

> Management must be organized around the physical components of a system, which are specified by design. Certain management practices are precluded by some design choices while others are favored. Rotational irrigation at the turnout cannot be practiced if farm ditches are not provided in the design. Management's influence on design is less obvious but equally important. Shortcomings commonly attributed to poor design can sometimes be alleviated by intensive and dedicated system management ... No design can be considered ideal in a permanent sense, and an evolving management program is necessary to continually bring out the fullest potential of a system and to identify appropriate

changes in the physical system. Evaluations of different management priorities in existing systems will also provide excellent information to serve as a base for design choices for future systems.

Irrigation associations have developed the capacity to integrate information and technology concerning crop production and engineering design into the management practices used in distributing water. Mechanisms have been devised which facilitate the flow of information between farmers and system managers on a timely basis. These informational mechanisms contribute to an efficient allocation of water and reduce the uncertainty of the availability of water to farmers.

It was recognized some time ago, probably in the 1920's or earlier, that a high degree of certainty of water supply to farmers could lead to more efficient use of water in rice production. Increased certainty of water supply to farmers involves both the amount of water supplied and the time during the growing season when it is received.

The rice plant tolerates and thrives on large amounts of water. As a minimum, the soil should be saturated fully with water during the growing season. However, the plant will tolerate standing water in the paddy fields, the depth depending on the height of the plant. Standing water is also an important form of weed control. The fields are drained and allowed to dry just prior to harvest time.

The need for a high degree of control can be traced to the particular nature of the water response function for rice. More detailed discussions of the water response function for rice are reported by Barker [1970] and Reyes [1973]. A typical function is illustrated in Figure 1. Too much water in the paddy fields will cause the yield response curve to decline. This portion of the response curve is not shown in Figure 1.

The shape of the water response function can result in sharply asymmetrical effects on rice yields of given absolute changes in the level of water application about some given level such as W_0. If farmers face uncertainty in the amount of water they will receive in any time period, they will tend to apply water at some rate higher than W_0 in order to minimize losses in yields. They can do this by permitting a greater depth of standing water in the rice fields, i.e., by maintaining an in field reserve of water. We are ignoring the beneficial effect that

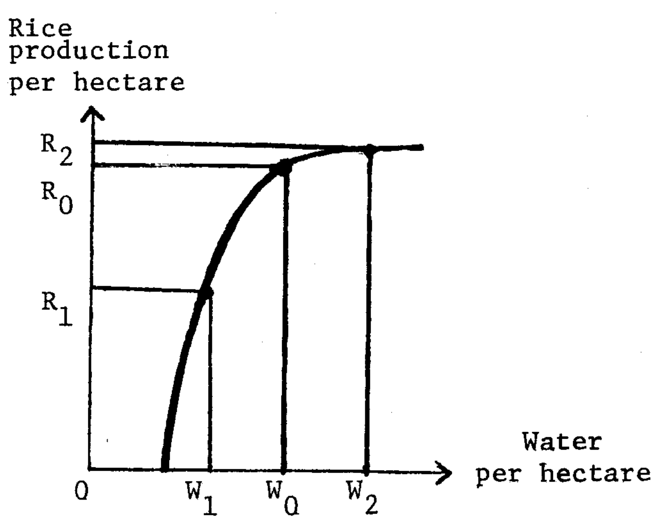

Fig. 1. The water response function for rice.

deeper water has in the control of weeds. To the extent that the total supply of water available in an irrigation system is limited, excessive use of water by some farmers will result in reduced availability to others. Such a situation will not lead to the optimum allocation of water throughout the irrigation system.

Farmers will try to get as much water as possible if the variance in their water supply is large. They may try to obtain an average amount of water which may exceed the level of W_2 in Figure 1 in order to minimize the risk of operating to the left of W_0. Thus the larger the degree of uncertainty in the supply of water, the more farmers will use on the average. Conversely, reducing the variance in water availability can reduce the average amount of water used per hectare of land without necessarily reducing the output per hectare.

Information developed about the nature of the water response function for rice provided convincing evidence that reducing the variance in the amount of water to farmers could increase the total area irrigated from a given total supply of water. This information was used to modify the physical design of irrigation systems and management practices used to deliver water to farmers.

There was also another important set of new information which had a profound impact on the design and management of irrigation systems and the efficiency of water use. This was the discovery through experimentation that rice did not require a continuous stand of water during the growing season and that a continuous flow of water through the rice fields is not necessary. As a result of this information, the rotational system of irrigation, which led to a large increase in efficiency of water use within each irrigation system, was developed, and the design of the systems was modified to provide controlled delivery of water to individual farms and fields. A larger area could be irrigated without increasing the water supply [Vandermeer, 1968; Joint Commission on Rural Reconstruction, 1968; Tsui-Yuan, 1965].

In a system of rotational irrigation, each farmer receives water at regular intervals, for example, once every 5 days. The amount of water received and the length of the rotation interval are sufficient to provide the necessary amount of water for maximizing the yield response of the farmer's crops but not in excess of that amount. The delivery of water and the length of the rotation interval are based on the requirements during different parts of the growing season. These requirements will depend on the requirements of the plants, amount of rainfall, nature of the soil with respect to its ability to hold water, etc.

Another form of rotational irrigation deals with the distribution of water among farmers when the supply of water is regularly insufficient to irrigate all the land in a system. In this situation the whole system may be divided into several large parts, each part taking its turn receiving water from one crop season to another or from one year to another.

Increasing the certainty of water supply to individual farmers and adopting the system of rotational irrigation have greatly reduced one type of externality common to most irrigation systems, the stealing of water [Vandermeer, 1971]. Increasing the certainty with which individual farmers receive water when needed reduces the incentive to steal, since an individual farmer can rely on the system to provide the water he needs. Rotational irrigation also makes it more difficult for farmers to steal water, since it is no longer continuously available in the ditches serving their fields.

Related to the two developments in irrigation just discussed was the evolution of an information system which permits managers of systems and users of water to exchange information about water needs and availabilities and to evolve water use plans which result in technically efficient utilization of the available water. In its simplest form, farmers announce their water needs to the irrigation association prior to planting their crops. The irrigation association estimates the amount of water available for irrigation from reservoir storage, streamflow, and groundwater at the start of a crop season. If the total amount of water is insufficient to irrigate all the land in a system, the allocations to individual farmers are such that they achieve the most efficient use of water for each hectare actually irrigated.

At times the initial estimate of water availability and the estimated irrigated acreage are too high. This may be due, for example, to below normal rainfall during the period of irrigation, which both reduces the amount of water available to the system through streamflow and increases the amount of irrigation water needed by farmers to compensate for lower rainfall. In such situations a new set of calculations is performed on the basis of the two-way flow of information between system managers and farmers, which results in a new allocation plan designed to maximize rice production from the available water supply.

It might be in the interest of individual farmers to inflate their estimates of water needs in order to ensure getting all the water they want. However, this is difficult to do in a situation where those responsible for the allocation of water know (1) the size of either individual farms or fields, (2) the nature of the soils in these fields as it affects water requirements, and (3) the parameters of the water response function. It is not easy for Taiwan farmers to lie about their water needs because the above information is available to system managers. It should also be obvious that in other places where this type of information is not available to system managers, farmers are in a position to exaggerate water needs and, in the process, to reduce the overall efficiency of water allocation.

The available literature does not indicate the precise basis used to determine how much water each user receives during each crop season. In the simple case, where only one crop such as rice is grown, it is not clear whether each user gets the same amount of water regardless of the size of each farm or whether water is allocated among farms in proportion to farm size. This would not be an important problem if all farms were about the same size. But typically, this is not the case. This issue needs further investigation.

The actual allocation procedure is much more complex than the simplified example just presented. Farmers usually grow several crops with varying needs for water. The irrigation association has to take into account the water needs of these different crops. Furthermore, the cropping patterns utilized by farmers are based heavily on the way the irrigation association allocates water. However, rice is usually considered the primary crop and has a priority claim on available water.

The information system internal to the irrigation association seems to have led to an efficient allocation of water supplies in situations where the agricultural technology and the physical design of the systems are stable. But the information system also played an important role in facilitating dynamic change in the irrigation systems with respect to the introduction of new agricultural technology and the redesign of physical features of the water distribution facilities.

Taiwan has a well-developed system of agricultural research and extension capable of developing viable new agricultural technologies and demonstrating their use under farm conditions. In other words, new technologies can be delivered from research stations directly to farmers. In irrigated areas, farmers who are members of irrigation associations are also members of, or have direct access to, organizations concerned with the dissemination of new agricultural technologies or new production inputs. If farmers individually or collectively decide to use new technologies or inputs and these require different patterns of water use from the old ones, this information can be transmitted to the managers of irrigation systems. The irrigation managers then calculate new water delivery plans. Through the interaction between farmers and the managers of the irrigation systems, irrigation bottlenecks to the adoption of new technologies are minimized.

This same information mechanism is used to change the physical structure of irrigation systems. These changes may involve substantial investments by the irrigation association. They can include expansion of water storage capacity, extension of the area receiving water from the system, and redesign and improvement of the existing water delivery system. Information concerning changes in the irrigation potential of a system is conveyed to farmers who use this information to decide through their elected representatives in the irrigation association whether or not to carry out suggested improvements. If such improvements are made, desired changes in cropping patterns can be communicated to managers of the system. A new water delivery plan can be evolved through an iterative exchange of information between farmers and the managers of the irrigation systems.

5. Incentives

We have indicated that the management of irrigation systems in Taiwan appears to be responsive to the water needs of farmers and to changes in agricultural technology, as well as to the need for making improvements in the physical performance of the systems. These characteristics of the irrigation systems of Taiwan (and a few other countries) stand in sharp contrast to what one finds in most other countries of Asia. What accounts for these sharp differences?

A distinctive feature of the irrigation of Taiwan is that the systems are essentially owned and managed by the farmer-users of the water. Thus the managers of the irrigation systems work for the farmers. The irrigation associations, which are farmer cooperatives, can hire or fire managers depending upon their performance. Even when some members of management are appointed by government, they are expected to be responsive to the needs and desires of the members of the irrigation association.

The relationship between the management of the irrigation systems and the farmer-users found in Taiwan is markedly different from that which exists in many other countries. In most countries the irrigation systems are built and managed by the national or state (provincial) governments. The appropriate government unit hires and (rarely) fires management. The farmers who use or wish to use the irrigation water have little direct control over the performance of the managers.

This weak linkage between management and farmers can and does lead to inefficient distribution of water and makes it difficult to adjust water distribution to changes in technology or to changes in the design of the systems, which otherwise might be implemented to improve their efficiency.

In the case of Taiwan the rewards to management are determined by the elected representatives of the members of irrigation associations. And there is evidence that irrigation associations do reward good management and do penalize poor management. The reward structure includes financial returns to management, promotions, and nonmonetary recognitions such as prizes. In contrast, systems where management is divorced from the users of water have incentive structures for management which are usually not linked, or are linked weakly, to the operating efficiency of the irrigation system.

Emphasis on personnel efficiency and rewards is explicit. Irrigation associations are encouraged to have well-established personnel policies which provide job security, adequate financial rewards, and attractive retirement programs. Employees are also provided with considerable amounts of training to help them master the technical and managerial tasks they are expected to perform, as well as to understand the water needs of farmers [Tsui-Yuan, 1965].

Part of the incentive structure consists of a variety of contests in which employees of irrigation associations participate. These contests involve both financial and nonfinancial rewards and are interestingly symmetric in their reward structure. An example of grade evaluation and rewards is given in Table 1 [Joint Commission on Rural Reconstruction, 1968].

Another important aspect of the incentive system is the interrelationship between the collection of irrigation fees and financing the operations of an irrigation association. The operating budget of an irrigation association depends directly on the collection of water fees from farmers. In order to preserve their jobs, the technical and administrative staffs of an irrigation association have a strong interest in ensuring the collection of fees. If collections are poor, revenue will not be adequate to cover operating costs and will eventually result in a reduction in the size of the staff of the association [Wickham et al., 1974; Ko and Levine, 1972].

TABLE 1. Grade Evaluation and Prize and Punishment

Points	Grade	Action
Above 80	A	Award of prize in document, money, or souvenir.
70-79	B	Award of price in money or souvenir.
60-69	C	No prize (or punishment).
Below 60	D	Punishment upon consultation.

The willingness of farmers to pay their fees depends heavily on how well the irrigation associations are operated, i.e., the amount and timeliness of water received. The better the system is managed, the more willing the farmers will be to pay their fees. This is also true for voluntary farmer participation in certain operations of the system, such as controlling the release of water into fields, performing maintenance work on the portion of the system located near their farms, etc. Thus job security levels of remuneration for management personnel are tied directly to how well a system is managed.

6. Implications for Other Countries

We have tried to distill a set of economic and management principles which appear to explain the high level of efficiency of irrigation systems in Taiwan. However, we have not indicated the true complexity of irrigation systems and irrigated crop production found in Taiwan today with which the management of these systems must contend. One source of complexity grows out of the size of some of the systems. The Chainan Irrigation Association serves an area of approximately 150,000 ha.,containing probably about the same number of farmers. Another source of complexity is the complicated cropping systems that farmers follow involving several crops, each with a different length of growing season and with different water requirements. It should be obvious that the structure of management and the information required to run efficiently large irrigation systems like the Chainan system must indeed be very complicated.

The management of irrigation systems in Taiwan is often used as a model that other countries, particularly in Asia, might follow. However, it is doubtful that other countries could in a short period of time achieve anything like the level of technical efficiency one finds today in Taiwan. In most other countries, one or more of the four prerequisites for successful management discussed above is missing and could not easily be established. Creating strong and effectively implemented agricultural development policies that recognize the value of irrigation water will require substantial reordering of development priorities and strengthening of administrative services dealing with implementation of development plans and programs. These changes require a reorientation of national development policies and programs and will be fraught with all manner of political problems. The same can be said for providing legal and administrative bases for permitting centralized planning of investments in irrigation development but decentralized management of the irrigation systems.

The creation of information and incentive systems within the management structure of irrigation systems will require considerable research, training of management staff, and education of the users of water with respect to the benefits to them of improved management. These steps also require considerable time and effort.

There are also environmental, cultural, and political considerations involved in trying to transfer the Taiwan model of irrigation to other countries. The technical design of irrigation systems, as well as the development of certain management principles in Taiwan, were influenced by local environmental conditions, particularly with respect to topography, climate, soils, and crop technology. One would expect to find considerable differences in these conditions among countries as well as within certain countries. Design and management principles will have to be adjusted to specific environmental conditions.

The political institutional framework for the management of irrigation systems in Taiwan grew out of a particular political history and cultural setting. During the 50-yr. period of Japanese colonial rule and the subsequent 30 yr of independence, strong emphasis was placed on the investments in technology and infrastructure, including irrigation, required to accomplish rapid rates of growth in agricultural output. These achievements involved a combination of incentives to farmers and an ample measure of force. Furthermore, the institutions that were developed to implement agricultural development programs, such as the irrigation association, seemed to be politically and culturally acceptable in the sense that they elicited responses from participants that were desired by the governments. It is doubtful that direct transfer of the approach in Taiwan to the development and management of irrigation systems would yield beneficial results in other political and cultural settings. The Taiwan experience would have to be molded and adapted to conditions prevailing in other countries.

The relevance of the Taiwan experience to other countries lies in the recognition of the importance of the economic and management principles we have discussed and the key interrelations among at least some of them. The further development and formalization of these principles need not be limited to specific country situations. However, their applications will have to take account of the political, institutional, cultural, and technological circumstances that one finds in individual countries.

As was already pointed out by Levine and Wickham [1975], improvements in the design and management of irrigation systems will under the best of circumstances be a continuous process involving a series of numerous small but significant improvements. It might be highly worthwhile therefore to study in detail the evolution of irrigation management in Taiwan since about 1920, paying particular attention to each improvement that was introduced, the technical and economic forces that created the basis for each change, and the institutional response response required to make each change effective. This kind of detailed sequential history of the evolution of current irrigation management in Taiwan might provide useful insights as to how to proceed in other countries. One could compare the current state of irrigation technology and management in a particular country to a comparable period in the history of Taiwan. The focus would be on how the relevant principles of successful management in a particular period in Taiwan might be transferred and adapted to conditions prevailing in other countries.

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IV. GENERAL DISCUSSION OF ABEL'S COMMENTS ON TAIWAN IRRIGATION[1/]

ABEL: Someone raised a question about water allocation. The area irrigated may be divided into three parts. Area A has an assured supply of water while area B may get water some years and may not get water in other years, depending on the reservoir level, which is dependent on rainfall. They try to inform the peasants as much before planting time as possible concerning the quantity of water they can expect. Let us assume that area C will not get any water for irrigation. The important thing is that the peasant knows this before he plants his crop. He does not plant a rice crop in area C hoping to get water, because he knows there is no water.

The water fees are different between area A and B. Second, the land tax is different because the land value on which the tax is based differs from A to B to C. Area A would be taxed more heavily than area B either with a higher rate or a given rate applied to higher value, and B would be taxed more heavily than area C. As they have improved the supply of water and made other improvements these boundary lines have been changed.

WICKHAM: What I have observed in Taiwan is that the areas within the system receiving water are not static. There is a rotation of these areas.

ABEL: That is another aspect of their rotational system.

WICKHAM: The rotation gets around the objection that you wind up with farmers with a set management capability in one area with a given amount of water.

ABEL: In some systems they do follow a three-year rotation. Suppose there is enough water to irrigate 1/3 of the total area. In year 1, area A will get irrigation, B and C will get none. In year 2, B would get irrigation, and so on.

You may in many years have enough water for A, B and C to have a crop. In the next year you may have enough for B and C. In fact, there is very little area which never gets any water. In year 1, area A has enough water to grow a rice crop, area B does not have that much but enough for a crop of sugar cane. Area C gets a supply equal to 1/5 of the need for a rice crop which is enough for a few low-intensity crops.

GOLAN: How would these farmers compare under similar conditions with a farmer in the Philippines or Indonesia? I maintain that it is considerably better, so there must be something else besides this management system that explains why he gets higher yields.

ABEL: But that is not the question I am asking.

GOLAN: You are asking how come he is so much more efficient? I am saying there are many other things you have not discussed which will explain why he gets high

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1/ Since Abel's comments on Taiwan's irrigation were expanded and subsequently published and are reprinted in these proceedings, some of the discussion is omitted which is no longer relevant.

yields. It might be the price ratio between fertilizer and the crop.

ABEL: I am not using the term "efficiency" now in terms of cross-country comparison of productivity.

GOLAN: Maybe I fail to understand the point. This particular system gives you what?

ABEL: What I am concerned with is trying to determine what appears to be some of the important factors that explained why irrigation systems in Taiwan seem to work well. I am not saying that mine are the only four reasons.

GOLAN: Work in what respect? What do you mean when you say work?

ABEL: The system seems to work well in that given the technology and management they are going to maximize output in a command area from the amount of water they have available. That will not be the same level of output as you would get from a different set of plant varieties, and different levels of management practices.

GOLAN: Compare the Indian farmer who has a tube well where he is his own manager and makes all his own decisions, or take the Philippines where you have a communal system, 150 hectares, where they made their own decisions. They meet all your requirements and yet when you look at their output it does not approach the output of the Taiwanese. Why?

ABEL: You are confusing two things. The Indian farmer who has a tube well is probably using his water quite efficiently.

GOLAN: What is your definition of efficient use of water? I am not very clear. You have to measure it somehow because if you are talking about efficiency, you must have some yardstick of efficiency. What is that yardstick?

ABEL: I am using a command area because you can put a limit on the amount of water. The yardstick is to "maximize" physical output with a given amount of water and a set of production technology.

STATEMENT: I do not think Martin is trying to make a comparison of Taiwan and other countries. Clearly, there are other problems, the environmental questions, the temperature, and so on. All these questions are important, but that is not his point. What he is trying to do is to identify four points that seem to work in Taiwan and which while they might not work as well in other countries, might still be four important points.

GOLAN: But can we not ask what you mean by work? I am not impressed that they work; that is not the crucial issue. Are you saying in Taiwan if you give a farmer a certain amount of fertilizer, assure him a price, and give him a fixed amount of water, he will produce more rice?

ABEL: I am not talking about farmer efficiency. I am talking about the efficiency of a system. I am not saying that the Chinese peasant or the Taiwanese peasant is more efficient in his use of water or is a better farmer than the best Indian farmer or the best Philippino farmer. What I am saying is that for a given amount of water in the whole system that there is strong evidence that in Taiwan they have evolved a set of mechanisms whereby they achieved technical efficiency for the system.

GOLAN: Do you mean that it is technically impossible to grow any more by transferring any water?

ABEL: As a bold proposition, that is what I am saying.

GOLAN: That sounds like a very bold proposition.

ABEL: It is but I do not believe that I am exaggerating. Any other allocation within the system would lead to a lower level of agricultural output.

GOLAN: Could you not improve by lining canals, or making other investments?

ABEL: That is different. They know very well that they are not doing the best they can do in all the systems through lining, re-design and a variety of investments. What I am saying is that at any point in time if you take the physical structure the way it is and fix the technology and the management, then they are technically efficient. The whole history of Taiwan is continuous progress in improving the efficiency of these systems through re-design, changes in technology, etc. The interesting question is how they did it, what were the incentives, what were the signals they used.

TIMMONS: The system you have described gives the farmer more assurance of his water supply expected for use on his parcel of land. With this security, he would face less uncertainty because of less variance from the mean. But how do you achieve assurance of water supply? Do you get it by following a more conservative reservoir management system or by keeping a larger storage reservoir? What kind of flexibility do you build into the plan?

ABEL: As near as I can tell, the way they do it is by controlling the amount of water delivered to a farmer's field in any given period of time. The delivery schedule is adjusted throughout the season for variations in rainfall, If there is a lot of rain, they will deliver less water; if there is below average rain, they will deliver more. It is inherent in the delivery system, not in the reservoir capacity.

TIMMONS: Also, the information system is crucial in delivering accurate information to the farmer so he can plan his cropping system.

ABEL: As far as an individual farmer is concerned, I have drawn this in the simplest terms. An individual farmer may have several crops growing simultaneously, and only part of his land may be in rice, the remainder in other crops. This information is transmitted to management for calculating his water needs, and he will get so much for his paddy fields and a different amount for each of his other crops.

TIMMONS: Assume that the farmer decides to shift from rice into onions. Is he going to get docked for water because he has changed? He would be entitled to enough water for rice, but if he decides to go into something else, can he switch some of that water he saved into another crop or into another area?

ABEL: He can do whatever switching he wants to do. Each farmer would get the same amount of water. It may be that due to differences in soil characteristics, or whatever reason, they may get different yields. All I am saying is that they would strive to give each farmer the same amount of water per hectare of rice.

GOLAN: Any system that has storage can do it without difficulty and does do it.

ABEL: Any system can do it but not many do it. From the farmer's point of view, he knows prior to planting how much water he is going to get for his cotton crop. The same exchange of information takes place in the Turkish system as takes place in the Taiwan system. That is a terribly important element that is missing in most canal irrigation systems that I have seen.

When I was in India, there was a scandal in the Gunganauga area. There was a crop failure because the canal managers decided it was time to clean the canal. It turned out that this was before the last one or two critical irrigations for the crop. They shut down the canal, and there was a crop failure.

TIMMONS: I have reservations about the utility of taking these four points as verbatim truth of good irrigation and say that they apply anywhere in the world.

ABEL: The point to be made is that here is an example of a society looking at its water resources and it has come up with a systematic methodology for allocating the water. The Taiwanese would be among the first to point out the inadequacies of their systems. One thing is that there is now a real movement away from so-called farmer control and back into a more authoritarian system.

V. DISCUSSION ON THE ROLE OF U.S. UNIVERSITIES IN TRAINING FOR DEVELOPING COUNTRIES

ABEL: Suppose we want to train managers of irrigation systems to do a better job, any place in the world. What I am searching for is some principle that you could apply and begin to explain why particular systems work the way they do. But we are still faced with "What do you teach them?"

In the context of Taiwan this has two elements. Certain things are under the control of the system managers or the farmers. Certain things are external. The whole system of water law (and it is enforced as national water law) is an important piece of enabling legislation. No system wrote that water law. That was done by society. The question of policy (recognizing water as a scarce output) again is external to the system. There are things that the manager can do, but there are things that go beyond the manager, that society will have to wrestle with.

QUESTION: As a part of the training of the student who is going back to become a manager or watermaster would you teach him programming?

ABEL: That would not be my first priority. It depends where the student is going. I would teach a student going back to Taiwan some of the most sophisticated optimization techniques. For someone going back to another LDC, I would not bother even teaching linear programming.

QUESTION: What would you teach?

ABEL: If I were trying to advise a student who is going to operate at the managerial level, I would probably recommend not only programming, but also a variety of optimization techniques in a dynamic setting. If a student were going to go to work in certain parts of the Philippines or India, I would not stress linear programming beyond learning the basic concepts. There needs are more in the nature of elementary questions of organization, of simple management techniques, not the most sophisticated. If the student made some progress, I would suggest bringing him or her back for another year or two of study. We should not train people the same way for all countries.

STATEMENT: I was a little surprised to hear you say that you would train the one going to Taiwan in optimization techniques, because that would be most appropriate where your allocation decisions are centralized. If you have a more decentralized system where the individual operators are more involved, then the training may be more in organization and information systems.

ABEL: You have farmer participation, but at the reservoir level somebody decides at the beginning of the season how much water there is going to be. Under this kind of dynamic organization, you could use sophisticated techniques. But for systems in the Philippines it would break down because you do not have the grass roots responses to make it work. You do not have control of the water.

No matter how much assurance you give him, the farmer at the end of the canal knows he will not get water. If a manager came from India, I would train him in law and order. Then he can go back and make sure that farmers take only their share of the water. Go to most countries and you will find the farmer at the head of the canal gets all the water he wants, and the farmer at the end of the canal does not get any. Optimization is not going to do you any good. The first thing you have to introduce is law and order of an irrigation system.

As you read the history of irrigation in Taiwan, one of the issues that was of concern was farmers stealing water. They dealt with that within the incentive structure. In Taiwan rewards and penalties could be very great. Collecting water fees was another problem.

WICKHAM: In talking about types of training, the point seems to be, we do not have enough water control to use any optimization program. In such cases the most appropriate training would be to bring water under control. One thing that involves is measuring water, both the volume and quantity you have flowing at a given time. Until you can actually bring water under control and deliver it to the ends of the canals, you do not have to worry about optimization. Law and order is a further problem when we are being frustrated by farmers. To be able to control and measure the volume of water means additional investment in the system. Even without that investment, you could almost double coverage of an irrigation system by better policing the water.

ABEL: A geographer at the University of Wisconsin did an interesting set of papers on irrigation in Taiwan. One of the things that comes out of the Chinese experience is that stealing is a function of uncertainty. As the Taiwanese were able to build more certainty into their water delivery system, the amount of stealing went down. The stealing did not disappear but there was a positive relationship between certainty and less stealing.

STATEMENT: Stealing is a function of cultural background wherein one has a certain perception of property rights. The farmer at the head of the ditch who gets all the water may not view that as stealing at all. Indeed, he is probably one of the privileged members of society or else he would not be at the head of the ditch. If he did not start out at the head of the ditch, after five years he gets there because of his power. He does not call this stealing at all. He calls it getting his just due.

HOWE: I would like to come back to the set of points that Dan raised this morning in regard to intellectual imperialism. This becomes much more relevant when we start asking, "How are we going to train people?" or "What is going to be the content of the training?" I would illustrate this by the dilemma that we have all run across, where you are working in a country and the main obstacle to our particular perception of efficiency is clearly corruption. You know that people know how to run systems, they are highly trained technically, they can optimize and model, synthesize, simulate, but you know the reason things are not optimized is that somebody is getting paid off under the table. The consultant is always in a dilemma in facing these situations in the sense that his technical input can only be a marginal improvement in the situation, the really big changes relate to the whole value system. When somebody expressed great disappointment at the rate of progress in improving water resources and planning in a particular country, they said: "When they have been 200 years devising a system that is precisely designed to channel income into the pockets of the select few, how can you hope to reform it in six months of work?" How much do we have to get into the value system and how much do we have to adjust values? What is the possibility that the system is one in which the guy closest to the canal is a person perceived by society as being a person of merit who has worked his way up there? The minister or deputy minister is diverting resources in this particular way but after all he has worked his way up in the system, and now receives his just reward. Should we get into issues like this either as a consultant or as a person who purports to train people from these countries?

QUESTION: Chuck, are not you really talking about incentives? Where do the incentives lie for the people who are working inside the system. It seems to me these are just as important as market prices are when we look at market problems.

HOWE: I am saying we need to address these issues, but I do not know how far to push them. If you are afraid to confront the value systems or criticize the value systems that appear to be generating corruption or unequal distribution of income, then there is really very little you can say. All you can do is look at each system and say, "That is an interesting system but you really cannot say it is inefficient, because they have their own definition of efficiency and pretty soon you are reduced to complete inability to transmit anything. Education then is reduced to a very technical set of issues that the person regardless of his beliefs or values may find useful. But is that the only kind of education we can give or do you really have to address the question of value systems?"

I had dinner with Ralph Richardson from The Rockefeller Foundation a couple of months ago. He was talking about the long struggle not only with training people, but with identifying people who would go back and work as educators or agricultural agents who would maintain an objective, scientific approach and not enter into the system of being bought off. They felt that it was important to build up a cadre of experts who were not only technically expert but who had an interest in seeing that the information got carried to the people in the field including the small farmers. How important are those issues?

ABEL: I see a very limited role for foreigners. One thing we can do is try to understand better the behavior that flows from existing incentive systems, including corruption. I am very pessimistic about what foreigners can do in terms of changing the basic values of society. John Brewster and others who wrote about this suggest that these are things that the society is going to have to work out for itself. They are going to have to work it out in their own way. For example, some societies may decide to use a great deal of unceremonious vigor in getting things done. I do not see how we as outsiders really can play much of a role in transforming power relationships in society. From a training point of view, what we might be able to do is to work with people to make them aware of different ways, institutionally and politically, of dealing with a given problem. The Taiwan way or the American way or the Turkish way is not necessarily the best way for Indonesia or India.

STATEMENT: These problems should be kept in perspective because there is no system in which there is not some element of corruption from someone's point of view. Just keep in mind, "Hard Tomatoes, Hard Times". Can you teach anything about evaluating systems as institutional structures generating incentives which can be handled in a fairly positive way in teaching?

SCHRAMM: Mexico is notorious in that all public officials are on the make and yet we point to Mexico's progress in agriculture as an outstanding example of a country that has really done very well, not only in agriculture but in economic growth generally. Long ago in this country it was pointed out that the cities that were best governed were those which were most corrupt. I am not advocating corruption; I am just saying that it is not always clear that corruption in high places is necessarily inconsistent with rapid economic growth. It could probably be achieved more economically without the corruption, but these are not obviously inconsistent.

WICKHAM: Although I am pessimistic about the role that outsiders can play in trying to affect corruption, there is one area that does offer limited hope. It is not in telling governments what to do, but in building and operating pilot projects. A project can be implemented in the desired way and then evaluated in the light of other alternatives. It is not hard to find people who are more or less uncorrupted and a new project is not impossible to start off right. Abe and I have been working on such a project in central Luzon which I will discuss a little tomorrow.

BROMLEY: I would like to respond to Chuck's point because I am not convinced that it puts us in a corner and that we end up with paralysis. We do need to be careful how we define problems. A problem to us may be seen differently from their perspective. Our culture influences not only the definition of the problem but also the things that we cast up to be selected among in terms of solutions. There are two sources of bias. One is how we define a problem and secondly, in the case of policy or institutional changes, the dials that we suggest be turned and how far we turn them. The answer is not paralysis but caution and a bit of humility. We need a continual recognition of the absence of a reserve army of willing risk-takers to follow national leaders and pull up their roots to migrate to irrigated agriculture. Recognize that in a lot of traditional societies you do not have that kind of willingness to take risks, and recognize the profound implications this has for the kind of policy recommended. The more interesting question is why do you have this willingness in some places and not very much in others.

CROSSON: That is two different questions. The way you put it this morning, you seemed to be suggesting that even if the opportunity existed, you could not count on a response to take advantage of those opportunities. I would challenge that. There is a lot of evidence all around the world that, with real opportunities, small farmers will respond. There is evidence from land development or colonization in Latin America where the government builds a road and the people are in there right away! In the Philippines in response to the Green Revolution, there was an upsurge of marketing services both on the input and output side, all spontaneous and small scale. We make a mistake if we sell short the capacity of small farms or small businesses to respond to a real opportunity. Corn in the northeast of Thailand is another example. But it was the farmer who was responsible.

You could look at it the other way around. The consequences of making the jump if they fail are very great indeed, because their margin is so small. If you say that because the margin of gain is small, the effort is not forthcoming, I would agree. But that is not saying the same thing as the capacity is not there. It locates the limit somewhere else.

QUESTION: Are we talking about distinguishing between those aspects of the environment that a farmer can control himself or collectively through some group and those things that are really beyond his control? One of the elements of the whole developmental game, certainly not the only element, is to bring more and more things that affect the farmer's welfare either directly under his control (each farmer has a tubewell) or indirectly through collective action, under the control of a farm group.

BROMLEY: All you have to do is change the probabilities of pay-off. You do not have to bring it under his control, all you have to do is change the expected value of the gains.

STATEMENT: Dan's point is a very important one. What we want to do is reduce the variation and put the mean in the proper place. Control does not have to be given to the farmers to do it. All we really want is to improve the level of performance of some of those factors now not under the control of the farmers. Trying to put all these under the domain of farmers is not necessarily the right approach. Farm management economists have a tendency to think only in terms of farmer decision making.

The question that always comes up is, "Why do you invest in irrigation when you can increase the productivity on the rain-fed lands by applying more fertilizers, by using improved seeds, etc." This is one of the mistakes the outsiders make. If you look at the production response you are right, but when you look at the farmer's behavior, you find that he is trying to minimize risk and maximize profits. We need to look at the response from the farmer's point of view and not from the outsider's view who runs a computer analysis which shows the farmer will be better off even with a failure two years out of five. You cannot expect a small farmer in a developing country to risk crop failure.

Farmers want to minimize the maximum cost of loss that may ever occur. They have absolutely no ability to survive a loss beyond a certain point. We fail to make that allowance when we estimate the farmer's response from irrigation. Even if farmers have seen that 100 kilograms of nitrogen produces the highest returns, they only apply 60 or 70, because they are trying to minimize possible losses.

We are also talking about another class of risk in a system, the risk to the farmer that, even if he makes optimum decisions and takes optimum actions, the system managers will not take the actions that will make it possible for the farmers to reach the production possibilities. We are comparing systems in which there is information in the hands of two groups of decision makers. The system managers have economic information as well as information on what the farmer's response might be. There may be feasible ways to decrease the risk to the farmer. Even so, he may not go at once to the optimum response, but every time you help him do better, you are moving in the direction of the optimum. If there is anything in the Taiwan system it is that their management system gets them closer to the point you would reach if you had the same set of resources in the hands of a single entrepreneur. Information flows fairly well from the farmer back into the system.

SFEIR-YOUNIS: I would like to make a couple of comments based on my experience in Chile. One is on corruption. It seems that whatever the inefficiency it cannot be attributed 99 percent to corruption. There are other troubles that relate to the type of institutions and development planning process. There are some countries where you have a tremendous control from the center, applying to certain types of resources. In the first place there is a strong, national environment. They want to increase output and they recognize there is a scarcity. However, not every institution in the country which has responsibilities for natural resources understands what scarcity means. They also do not understand the difference between natural resource and other types of inputs.

Second, even with centralized decision making, you also see many institutions dealing with the same resource. What happens is that water is one input in farm production, but you have more than five or six important institutions dealing with other types of resources without connecting them to the water institution. The institutional set-up that farmers try to deal with is completely unorganized and creates risk. The farmer uses water at the level he believes to be most efficient, but the institutions may be more interested in their payoff than efficient water use. Corruption is a side issue in deciding crop efficiency. The main problem is that there is no understanding of how to develop a planning system that works. In Chile, for example, the output price system is completely isolated from the input price system. So you have an institution in the government that sets potato prices and the farmer will react to those prices and input prices. However, there is no relation between the output price and input price setters.

Finally what should you teach a person who is coming to the U.S. and will go back to Taiwan. The most important point is what are the problems and where and in what direction are the institutions being developed. This is more important than mastering linear programming.

TIMMONS: I would like to respond to two points. Different people view techniques differently. I never use linear programming as an end in itself, but as a means not only to help formulate the problem, but to try to get some quantitative measure on some important problem. There is nothing sacred about linear programming as a particular technique but as an analytical device it can provide valuable information such as shadow prices. It is useful to know scarcity prices for particular resources. If you want to determine how scarce water is and if you want to move to a more general equilibrium framework, linear programming can be a very useful device. It is not an end in itself, but we may be remiss in not emphasizing how the technique should be used and for what purpose, rather than stressing the technique as an end in itself.

You raised another point that is very interesting. This point embraces knowledge about the institutional structures that operate within the country. There exist certain external advisors who do learn enough about the institutional structure of the country to operate quite effectively within the country. The distinction at that point between foreigner and native begins to evaporate, at least in terms of knowledge. But most of us do not know enough about institutional complexities within a particular country. Hence we are faced with a particular dilemma; do we become country specialists or do we continue as subject matter specialists? We experienced a movement towards country or regional specialists in the 1960's but this movement has declined in recent years. If, in fact, the kind of problem situations that we are dealing with differ so much from country to country, do you train a person from Taiwan interested in irrigation the same way that you would train a person from Bangladesh? If so, what is the role of U.S. educational institutions? You can broaden the question to include foreign assistance institutions and educational research institutions outside the U.S. What role do they have? One choice is to become an expert on Bangladesh. That is a valid choice and you work only with the problems of Bangladesh, but that amount of country specialization may not be acceptable or possible for most water specialists. So we have this dilemma of how do we accommodate whatever it is we have to offer to the location-specific needs of people in different countries?

The solution probably lies in a mixture of the two. In a graduate seminar--or in any particular university--there are some real advantages in having students from a number of different countries. There surely must be a common core of economics which would be applicable to many countries. The specialization has to come in terms of students doing thesis research in their countries where they take the tools and knowledge that they learned and apply them to their own conditions. And to do that, the students and their advisors must be sufficiently literate regarding country conditions, to make adaptations suggested by country conditions in keeping with the general body of theory in the dissertation research.

SFEIR-YOUNIS: John, does that imply that given departments would then be fairly well specialized even though they have a general body of methodology and tools?

TIMMON: My reaction would depend on the department's resources. We have had a technical assistance program in Peru since 1962 and whenever we had as many as 16 to 18 students from Peru on campus at Ames we would organize special seminars for those students in addition to their regular courses. We try to get them to identify the kinds of problems that they face in their own countries which inhibit development. They describe these problems in terms of the effects on productivity and income distribution, primarily, and then they identify their institutional structures that lead to these problems. Also they investigate alternative institutions for achieving their objectives. They are not going to make the choices; the leaders of their countries are going to make the choices. But without this problem identification within their own countries there is a real danger of the students becoming technicians in particular methodologies, without recognizing institutional differences among countries where the problem exists. So we train only mechanical robots. They can carry out all kinds of methodologies very effectively, but they do not know why they are doing it unless the methods are applied to a problem within a particular country. And it seems to me that this mix between an understanding of problems within a country and the applications of the appropriate research technology is what is needed.

WICKHAM: At IRRI we consider the field work as the important part of the graduate research. International Rice Research Institute obviously is not in the position to provide classroom experience, but to a limited extent, we can be a vehicle, essentially for foreign students studying in America to come back to their country to do their research. I am not making an open offer, but we are always looking for these kinds of students and if we could play a modest role in this respect we would like to.

TIMMONS: We are probably getting into part of the discussion for tomorrow, but for some time I have felt that individual universities are not going to be able to become specialists in all the 150 countries of the world. Although students may come to a particular university from any country, I would like to see us try to work toward a sort of pooling of our university talent to work with these students. For example, if I knew you were in the Philippines and we have students returning to the Philippines to do dissertation research, I could check with you concerning high priority problems the students might work on in the Philippines. It would be helpful to our Philippine student if I could phone you concerning his or her training and interest to see what you think. And then possibly the thesis research could be done under your direction. It saves us resources and provides a means to pool our university resources. Right now we have very imperfect information on who from our university staffs, foundations, and AID are in particular countries for certain periods of time. We worked out arrangements a few years ago in Peru for North Carolina State University's graduate faculty members in Peru to be on our graduate faculty and vice versa. With assistance from North Carolina we gave final graduate exams in Peru. There is no point in just coming back to the U.S. to take the dissertation exam. In some instances we had qualified members of the Ministry of Agriculture sit in on examinations. These members could ask more incisive questions than we could about what the student was doing and what would be the use of the dissertation in the country's development. This is the direction the universities should move. Economists are scattered around in the world in many countries and major professors of foreign students should try to take advantage of the competence of these scholars in assisting foreign graduate students with research in their native countries.

ABEL: In preparation for tomorrow, I would like to suggest a couple of things. First, we should go around the table tomorrow and ask advice on what we as resource people can do and what our universities and the technical assistance organizations can do. Are we thinking about what would happen if we turned all of ourselves into consultants or are we thinking about training graduate students to work on their countries' natural resource problems? Are we thinking about eventually establishing their capacity to train their own people, which would include not only people who do research and training, but short courses and things that might improve decision making. Are we thinking about doing research and helping build up LDC's own research capacity? As a lot of Dan's questions suggested, we ought to try to give some indication of how we expect advice to be given. There is in the U.S. and elsewhere in the world so much economic rent connected with ownership and use of natural resources that we are in a much more politically sensitive area than we are when we just deal with production functions and give advice to farmers on fertilizer, pesticide, and seed varieties. If we could get the countries to do all we want them to do with natural resources, we would really be pulling away at the foundations by which control over society is exercised. This makes it a little different proposition from programming ourselves into our country to do the research. Gunter and the people who have been connected with Mexico can testify that it is a lot easier to become personna non grata if you are advising people on these questions than if you are advising them on simple, sectoral agricultural planning.

I would like to add another question for us to be thinking about tomorrow. We went through a period in the 1960's where there was a great stress placed upon crop technology. The results were very salutary in a number of places. But what was not realized at the time is that our technology was being applied in resource environment favorable to the technology. We began to see that favorable environments were limited in supply. While I would be the last person to downplay the importance of crop and livestock technology, there is a growing realization that there is a very important interaction between the resource environment and the performance of technology. Randy Barker and Bob Herdt have a project in the Philippines which is beginning to show how important the environment is in certain situations. There ought to be much more emphasis placed on problems of improving the resource environment as a way of more fully exploiting some of the biological and chemical technology that exists and that will continue to be created.

QUESTION: What do you have in mind to increase the resources?

ABEL: You can do two things: (1) you can develop technologies which are adapted to the resource conditions that exist or (2) you can do things to change the natural resource conditions. These are not mutually exclusive and you could follow a mixed strategy. We are learning there is a lot of interaction between the potential gain of a given technology and the quality of the resource environment.

QUESTION: How do you define quality of resource?

ABEL: Let us take a simple example, rice. We can find varieties that in a particular area may be suited from the point of view of disease and insect resistance. It has experimental station yields of 6.2 and 6.5 tons per hectare; but farmers are getting 2.5 tons per hectare. Some experiments in farmer's fields show that possibly 2 tons of this difference may be due to the quality of the irrigation system (the control of water). Some other place it may be something else in the resource environment. The other 2 tons may be explained by management practices and a number of other things. The early spread of the Green Revolution was on the best irrigated areas and went like wildfire in the Indian wheat areas, until you ran out of irrigated areas and the effective constraint became how fast you could expand irrigation.

In the eastern Indian villages where Bill Easter was studying village irrigation, water control was the key. In the winter (dry season) where you had less water than in the summer (wet season) farmers on some soil started growing wheat while still growing paddy in other fields. But they could do it because they had individual control over water in the fields. On lighter soils on the higher lands, it made sense to grow wheat since you got about the same gross value for the wheat as for the rice. It made sense to do it because wheat requires less water, but they could not do this until they got control over water in the individual fields.

These are just some isolated examples of what I mean by the interaction between the quality of the resource environment and how much of the technological potential can be exploited. You still have the other two options open. We should not ignore this middle ground. In other words, if you have a lousy irrigation system maybe you should breed the best variety you can for that lousy irrigation. If we can improve the quality of the irrigation system, that is an even better alternative.

STATEMENT: What you are really talking about is not just the resource base but improving the farmer's access to the resource base.

ABEL: I define resources and the quality of the resource environment to include access. An example would be Southeast Asia where many of the original irrigation systems were not designed for irrigation in dry seasons but were designed to supply supplementary water in the monsoon season. But with a little bit, or sometimes a whole lot, of tinkering, you can redesign a system that will irrigate part of the command area in the dry season and will produce very high yields because of high solar radiation combined with irrigation.

STATEMENT: As we continue our discussion we have to recognize that just as the agriculture of a country does not exist in a vacuum from the other sectors, the use of natural resources does not exist by itself, but has to be intertwined with other resources and institutions.

VI. SOME CRITICAL ISSUES IN IRRIGATION PLANNING FOR SOUTHEAST ASIA

G. Levine and T. Wickham [1/]

The design and management of irrigation systems in Southeast Asia is largely based on past experience and resulting conventions, or rules of thumb. Even where project proposals are made for international funding, most of the important relationships follow closely these rules of thumb, or those transferred from other parts of the world. This practice has had mixed results, and we believe this is because a number of important issues are not adequately or explicitly considered in the process. This paper attempts to analyze several of the more critical issues relating to the design process of new systems, and several more relating to system management. It outlines what we believe are low efficiency practices and suggests alternatives based on our experience and, where available, on data from pilot projects.

By critical issues we mean those choices which can have a major impact on the success or failure of an irrigation system. Some of them are frequently overlooked, or not really considered a matter of choice. Others may not be included in project statements or management guidelines, but are nevertheless decided informally. Each critical issue can have a marked effect on the performance -- measured in engineering, agricultural or economic terms -- of irrigation systems in Southeast Asia.

The paper is directed to Southeast Asian irrigation systems because our experience is primarily in that region. Many of the issues, and perhaps the conclusions, apply to other parts of the world, however, where the context of irrigation is similar to that of Southeast Asia. This context can be described briefly in terms of environment -- humid tropical with pronounced wet and dry seasons; of agriculture -- almost exclusively lowland flooded rice; of past water use -- largely supplemental during the wet season, but recently extended where possible to dry season plantings; and in terms of farm organization -- many small farms between 1 and 4 ha. in size, each dependent on the system as the source of water and on neighboring farmers in its on-farm distribution.

Finally, the paper focuses on design issues and on management issues. Irrigation design usually specifies the location and size of the system, the dam and canal layout, the nature of farm level distributaries, if any, the expected volume of water, and a recommended cropping pattern throughout the year. An economic justification of the design is also provided, usually based on one or more criterion such as benefit-cost, internal rate of return, or net farm income.

Once designed and built, a system must be managed. Management, often called operations and maintenance (O&M), refers to the routine allocation of water within systems and its distribution to and among farmers. It therefore involves scheduling of cropping seasons, of reservoir releases where applicable

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and of water deliveries to the farming areas. It also includes repair and maintenance work on canals and structures, and administrative responsibilities.

Design and management influence each other. Management must be organized around the physical components of a system, which are specified by design. Certain management practices are precluded by some design choices while others are favored. Rotational irrigation at the turnout cannot be practiced if farm ditches are not provided in the design. Management's influence on design is less obvious but equally important. Shortcomings commonly attributed to poor design can sometimes be alleviated by intensive and dedicated system management such as is sometimes found in smaller community run systems. No design can be considered ideal in a permanent sense, and an evolving management program is necessary to continually bring out the fullest potential of a system, and to identify appropriate changes in the physical system. Evaluations of different management practices in existing systems will also provide excellent information to serve as a base for design choices for future systems.

While design is normally a prelude to management we have deliberately placed the discussion of management of existing systems before that of design issues because large numbers of systems are already in place. We feel that significant improvements in irrigation for large areas are possible with improved management.

A. Management Issues

1. Priority in Improved Water Management: Farm Level *vs*. Main System

New higher yielding varieties and greater population density have combined in recent years to increase the demand for irrigation capability. New varieties of rice can produce about twice as much grain per unit of water as traditional varieties, provided water (and other inputs) are supplied dependably throughout crop growth. Even more important to some farmers, the newest varieties of rice mature in less than 100 days from seeding, permitting a better chance of double cropping in areas of marginal water supply.

The increased demand for irrigation is being met through new system construction (discussed later), and through improved management of existing ones. The need for improvement is apparent in studies from Malaysia showing up to 30 days of lag between first release of water and the date it reaches the last farm, and those from the Philippines showing mean water use efficiencies at the farm level of only 38% in the wet season, and 68% in the dry. In the Central Plain of Thailand farmers sometimes do not use water intended for them during the dry season. These and many other examples reflect the need for more intensive use of water at the farm level in the larger systems of Southeast Asia.

Efforts to improve farm level management have included a number of pilot projects ranging from complete land consolidation to limited farm extension programs. The physical improvements of land consolidation, including land leveling, redistribution of landholdings, and construction of roads, canals, and drains, probably costs over US $1,000 per ha. at today's prices. Its rationale is that major improvements in farm level water use cannot be achieved without these large expenditures on physical extensions of the system into the farm level environment.

Pilot projects intermediate in intensity between traditionally run systems and land consolidation have been tried in many countries. They have had varying degrees of success, the reasons for which could be the subject of an interesting research undertaking. But one of the most common shortcomings of pilot projects is their inability, where successful, to serve as a model for widescale improvements beyond the pilot area itself. This is not surprising, for very few pilot projects are actually planned for that purpose. Most of them are small in area -- a 300 ha. project is a relatively large one -- which limits their applicability for systems of ten thousand to several hundred thousand ha. Furthermore, in efforts to ensure their success, pilot projects are almost always located in highly favorable portions of the system, typically near the beginning of canals where water can be supplied dependably. They are also usually provided with abundant inputs, both budgetary and in terms of personnel. While such projects may tell us something about what may be achieved at considerable expense, they cannot be expected to serve as a vehicle for broad on-farm water management improvements.

Up to this point we have discussed on-farm, or farm level improvements, but there is also the network of canals and structures between the dam and the turnout releasing water to the farmers, which we call the main system. Construction of main systems accounts for the major expense of new systems because of the earthmoving and hardware involved; it is also the focus of most traditional engineering design attention. But once constructed, main systems have not usually received much further attention except through routine maintenance, which we discuss in the third issue of this section.

A Philippine study of a form of on-farm rotational irrigation brings out the importance of improved management in the main system. The purpose of the project was to implement a rotational schedule based on a five-day recurring cycle, in three 50 ha. blocks. It involved building all the farm level canals and structures to permit the rotation, advising the farmers of the new pattern, and then carefully measuring and controlling the water releases into the blocks on the basis of a rated unit flow. The project was successful in that the scheme worked satisfactorily after a few false starts. But as a standard of comparison, three other 50 ha. blocks were also monitored in which the only modification was to measure and control the rate of water supply in an amount equal to that of the nearby rotational blocks. The mean grain yield, water use efficiencies, and dates of planting and harvesting were not significantly different between the two forms of irrigation indicating that there was no additional benefit to all the on-farm development associated with rotational irrigation. But the measurement and control of water releases, a function of the main system in that project, resulted in remarkable performance improvements for both forms of irrigation relative to traditionally operated systems. Although the study covered only one season, there is no reason to expect the conclusion to differ with experience over more years. Evidence exists of similar type effects even in arid zone irrigation (Dez Pilot Project, Iran).

It is often a surprise to find that many on-farm improvements cannot be made until some basic improvements have been implemented in the main system. This is the reason most pilot projects are located near the headworks, to reduce the chances of disruption caused by main system breakdown. Even the simple concept of distributing a given rated flow through a turnout - a single turnout - produces very stringent demands on how the system is operated upstream of that turnout. It is even more complex when several turnouts would be controlled in this manner. Relatively minor adjustments of the gate settings at the headworks of each canal, or of checking heights (to partially obstruct the canal in order to raise the elevation of water in it) can easily cause 50% - 75% over - or under-irrigation at the further turnouts.

Proponents of farm level priorities in management improvements often point to the farmer as the basic person responsible for conserving water. There is no question that large quantities of water are lost at the farm level, but if too much water is released from the canal onto farmers' fields there is no alternative to its being lost into drains. Flooded rice fields can hold only a given amount of water beyond which all excess will drain from the lowest fields. Farmers often take steps to divert excessive water to their fields, but this reflects a breakdown of management at the main system, not the farm level. Rather than concentrating on tertiary farm ditch construction, we should give priority to tighter main system management. Some suggestions for appropriate technology in this connection are offered in the next section of the paper.

Of course there is an important need to bring farmers more fully into the decision-making process regarding water use, and programs to that end should be encouraged. But who can carry them out? If their purpose is to improve the climate of cooperation and shared responsibility between the farmer and the system ditch tender or water master, it is most unlikely that agencies other than the irrigation agency could carry them out successfully. We should work with farmers by training main system personnel to do their jobs as well as possible, and to better relate to farmers.

In conclusion, the effects of poor management may be reflected at the farm level, but most of the causes are found upstream within the system. We believe farmers act generally in their own best interests in the use of water, and to urge them to change their practices on behalf of distant farmers, distant tomorrows, or distant concepts such as national production targets, is not likely to be successful. Farmers continue to expect major improvements in the way traditional systems are being managed, and while many of their expectations are excessive we believe that the systems should take the first step in managing their domain more intensively. As these improvements are gradually realized, farmers should be brought into the program. The best way to help the small irrigated farmer is through the large system which serves him.

2. Sophisticated vs. Simple Management Technologies

In the simpler diversion systems of Southeast Asia water flows more or less freely through the canal network and onto farmers' fields. Most of these schemes have evolved as supplemental systems for the wet season crop, when mean expected rainfall is almost equal to the total crop requirement, although its distribution is uneven throughout the season. Irrigation water is in relatively abundant supply, the systems are managed rather extensively, and water control is relatively weak. Flooded rice, which dominates irrigated land in Southeast Asia, illustrates this point well. While it requires perhaps 50% more water than the average upland crop, it does not require great care in water conveyance and distribution among farms. Upland crops need channels to supply and drain water at periodic intervals, keeping the soil moist but not flooded. Rice thrives on modest depths of flooding which can usually be achieved by a continuous supply of water to terraced and bunded fields. Field-to field irrigation is not satisfactory for upland crops.

Now that double cropping is becoming increasingly important some of the more intensive technologies developed for arid areas should be examined for their applicability in the humid tropics. But first we should see how well existing technologies perform under today's conditions.

The question of management technology for the farm level usually focuses on tertiary distribution systems. In very flat flood plains and where irrigation canals have relatively few and well controlled turnouts, such as in Kedah, Malaysia, farm ditches appear to be necessary in distributing water quickly and equitably. In the Philippines where land slopes are greater and the points of water release from the canals are numerous, overland or field-to-field water movement seems to work quite well. Studies in that country have not found significant difference in grain yield or in the incidence of drought between farms located close to supply canals and those located far from them. One reason for this is the orientation of landholdings. Farms tend to be very long and narrow so that the maximum number can have direct access to the canal. Thus, field-to-field irrigation is largely confined to one's own farm. Less than one-third of the farms served from several Philippine systems received water passing over more than two other farms. There is no evidence that fertilizer nutrients move with the water from one field to the next provided that the rate of flow is slow enough that soils are not carried with the water. It appears that this form of on-farm management is satisfactory for most diversion systems.

Storage projects are justified primarily on the basis of area double cropped, and this means storing excess river water during the wet months for use in the dry season. This is different from the diversion situation, for now farmers are called upon to economize in water use during the months when it is plentiful. Water savings are important in these circumstances, but it is not easy to motivate farmers to make them in view of their past experience with diversion technologies. Since the overall storage system will benefit from economical water use, it is more likely that main system technologies will be more appropriate than on-farm technologies such as rotational irrigation.

Several techniques have been used for many years to allocate water in the main system during periods of scarcity. One of the most common methods is to suspend deliveries into a whole canal or set of canals and continue supplying another set. After about a week the canals which were closed are provided with water and another set is closed. This rotation continues until the drought period is over.

Another form of rotation within systems which appears quite promising is the sequencing of water availability in sections along a canal. Although water must be supplied along the entire canal in order to irrigate the last portion, it may not be of high enough elevation to freely flow onto the fields along the upstream sections. Checking, or obstructing the flow is the usual way farmers near the beginning of canals increase the water height to the point where it can command their fields. Pilot work in restricting checking to scheduled periods in each section of a canal appears to be a simple and useful management technology.

In terms of hardware, perhaps the most important need at the present time is for structures to measure the flow of water at the major branching points or gates of the canal network. These devices are well known and need not be expensive, particularly if designed and built with the original canal construction. Accuracy of ± 10% is adequate.

Another important device would be gated turnouts with measuring capability. Some forms of this structure are found already in Southeast Asia, although they are often not used and sometimes unusable. It will be very difficult to avoid over-irrigation by some farmers unless the turnouts serving their fields can be closed.

Finally, a means of transport is necessary for systems personnel to monitor the canal and meet with farmers. Motorbikes for selected personnel are becoming valuable acquisitions for many systems.

Technologies for better managing main systems are badly needed. They need not be highly sophisticated, and in fact must not if personnel with modest training are to interact with them and explain them to farmers. Implementing a comprehensive package of management practices specifically for the farm level does not appear justified at the present time where flooded rice is the only crop grown.

3. Operations vs. Maintenance

We often refer to operations and maintenance (O&M) as a single concept. A strong case can be made for divorce of the couple based on mutual incompatibility.

Operations generally refers to the allocation of water in the system, the collection of water rates, if charged, and other administrative matters. Water management is the main field operation.

Maintenance of systems is the routine care of embankments and structures, and the occasional rehabilitation of badly deteriorated systems. Rehabilitation can be considered deferred maintenance since well maintained canals do not usually need periodic renovation, while badly neglected canals do. An economic study comparing these two maintenance approaches would be interesting.

Incompatibility of maintenance and operations stems primarily from conflicts in allegiance of the personnel called upon to do both. Maintenance is carried out almost exclusively along canals, and those doing it have no reason to get onto the land to see how adequately the water is irrigating the command area. Maintenance functions require essentially no contact with farmers except possibly where farmers have broken embankments. Many maintenance activities can be done by groups of men working collectively.

Operations, or management, calls for a very different person. He must be able to relate well to farmers and solicit their feedback. He must have the opportunity to assess the adequacy of irrigation throughout his area of jurisdiction. He must know something about agriculture, for farmers expect him to and ask him technical questions. Although the system authorities in the Philippines do not endorse this idea, many farmers there reported that they even prefer that ditch tenders assigned to their areas farm their own parcels of land in order to better understand farming and irrigation problems.

Under financial duress, most irrigation authorities are asking their O&M men to undertake both functions. Maintenance activities almost always predominate in their day-to-day work, however, because accomplishments in that field are more visible. The system of rating ditch tenders in the Philippines is based largely on the extent of grass cut along canal embankments at certain times of the year -- a criterion which is at least easy to measure. The distribution of water from several hundred turnouts over a season could not be rated in that way.

We would recommend a separate labor force for routine maintenance. This force could be recruited from the farming community and be paid on a piece work basis. Operations personnel could then be recruited more carefully, trained, and given more responsibility for improved water management.

4. Water Rates: Farmers vs. Society

The two reasons usually advanced for farmers paying a substantial water charge are (1) it helps allocate water more efficiently, and (2) farmers achieve higher yields and higher net farm income with irrigation which justifies their paying something for the water.

Water rates can serve as an allocative device only if they are based on the volume of water used. At the present time this is not the basis anywhere in Asia, including Taiwan where water management is relatively sophisticated and efficient. Rates are imposed instead on an area basis, which probably tends to worsen allocation equity since farmers then have an additional incentive to get the highest production from each hectare they can regardless of the water used. In the Taiwan case, control is sufficient to maintain allocation equity.

Under present circumstances it is impossible to measure water to every farm, and it is unlikely that this will change in the foreseeable future. Even if each farm had its own supply turnout at the canal, practical instrumentation to measure that flow is not available. Laboratory-type devices could be tried, but the annual costs of these instruments, using a nominal interest rate, would far exceed any reasonable fee which farmers might be expected to pay.

A somewhat more promising alternative is to measure the water passing a certain point in the main system, and charge the group of farmers to whom it is supplied. This could theoretically be done in the 50 ha. rotational units being built in the Central Plain of the Philippines. However, there is wide variation in the amount of water needed to supply a rice crop even within nearby areas, due to variable water losses to seepage and percolation. Would it be fair to charge farmers on lighter soils more in view of the fact that their input costs, such as for fertilizer, are also likely to be higher? And assuming that water was measured accurately throughout the season, what adjustments would be made for farmers who were supplied and charged for more water than they needed, but whose supply was critically short during a key period, resulting in reduced yields?

It appears to us that control of water flows at the turnout or within the canal is the best means of water allocation now available. The fact that it is not now being done very equitably does not mean that this system should be replaced by a monetary charge system, but rather that water control should be improved.

The second argument, that farmers get higher yields and net income from irrigation, also deserves deeper analysis. It is not difficult to quantify the yield increase resulting from supplemental irrigation to a previously rain-fed farm. This can in turn be converted to net farm income and used to justify a substantial water fee. There is no question that the first farms to receive irrigation have higher net farm income and can afford to pay for the water. But as the proportion of farms under irrigation increases there is real question whether spreading water to more new farmers will mean greater income to them. Since the demand for rice is highly inelastic, farmers as a group stand to have higher net income by producing less grain, and lower income from more grain. For each additional ha. receiving irrigation there would be more production, with disproportionately greater downward pressure on prices. Over the long run farmers are not the beneficiaries of yield-increasing irrigation; society is.

Perhaps a better approach to the question of water rates would be to assess the true beneficiaries of water some fraction of the cost of providing it. A most obvious beneficiary is the landowner whose property suddenly doubles or triples in value when irrigation is extended to it. An effective land tax is a rational and administratively straightforward way to recapture part of the costs of irrigation. This is being done on a limited scale in some states of India as a "betterment levy".

Another approach follows from recognizing that increased production results in reduced costs of rice in the general economy. Even if the price does not go down, increased production stemming from irrigation would keep it from going as high as it otherwise would. The beneficiaries of this are the rest of society -- everyone except farmers who presumably do not buy rice at all. The fact that general tax revenues are frequently used to build and operate systems is an indirect acknowledgment that society does have a stake in increased food production.

Finally, to the extent that increased production through irrigation results in conserving, or even earning, foreign exchange, some way should be found to tax a portion of that income. Export taxes are one way if there are exports.

The argument for farmers to pay water charges is, in short, more conventional wisdom than economic or logical wisdom. One even wonders if the farmer should not receive a rebate for all the extra work of planting the second crop, for attempting to maintain a stable insect, disease and fertility environment in spite of much greater ecological threats, for preventing his fields from deep flooding due to occasional oversupply from the system -- and then quite possibly for incurring a major crop loss due to brief but critical water shortages in the system over which he has no control.

The most important point in the water charge issue is the need for adequate and sustained support to extend and intensify irrigation capability. Where the funds come from is not as important as their availability year after year. New research initiatives are needed to identify the true beneficiaries of irrigation if it is accepted that the beneficiaries should bear the major part of the cost. Recent events affecting water fees in Taiwan also suggest that the specific circumstances, e.g. relative importance of the agricultural and industrial and service sectors, make one form of fees or taxes more appropriate than others.

B. Design Issues

The increasing focus on more irrigation, particularly in the form of large scale, capital intensive projects suggests that issues related to system design are becoming increasingly important, and in our opinion are becoming critically important.

1. Optimism and Uncertainty

If economics is the "dismal science" then engineering must be called the "bright technology", because it is evident that in a large number of projects a high degree of optimism must have been operating during the evaluation of potential resources and in the estimates of the effectiveness with which those resources could be used. It is not generally appreciated by many in the planning and decision-making hierarchy associated with irrigation projects that there often is a high degree of uncertainty incorporated into the physical and biologic design values that are the basis for the system. Frequently, this uncertainty is of such magnitude as to make many other project questions, e.g. what is an appropriate discount rate, almost irrelevant.

As an example: the most important single set of data relating to the physical environment of an irrigation project is that which defines the basic water resource. A variety of statistical and hydrologic techniques are available for arriving at the critical design parameters (long-time average flows, low and high flows of specified recurrence probabilities, etc.) and many of these techniques are elaborate and sophisticated. The validity of the answers derived using these techniques, however, is a function both of the extent of the input data and of the quality of that data. In many projects, both the quality and the duration of record are such that major variance is associated with the answers and significant errors have resulted.

The estimates of flow in the Colorado River that formed the basis for the interstate allocations of the flow were sufficiently in excess of actual flow that major reallocations have been necessary. These were partially responsible for the large investments in the California Water Plan. In more recent years, the estimates of average flows into Bumiphol reservoir, in Thailand, have been found to be approximately 30% in error, with almost one-third less water entering the reservoir than had been indicated in the original design.

A second example of a major design parameter, the estimated life of reservoirs on sediment-laden streams, has recently been in the news. Notwithstanding a sophisticated understanding of sediment transport dynamics, large errors were made in the projections of sediment accumulation and subsequently in the design of the Big Sanman Gorge dam in China. This resulted in the need for complete redesign and reconstruction after only five years of operation.

Clearly, the influence of errors of these magnitudes in single important design factors is so great that many other potential issues pale by comparison.

Other examples of uncertainties in the physical design parameters can be cited easily. While they may be of smaller impact than those indicated previously, their cumulative effect can be of major importance. The evaluation of soil suitability for irrigation, for example, provides estimates of susceptibility to salinization or other drainage problems. Frequently, susceptibility is grossly underestimated.

These types and magnitudes of variance are not confined to the physical environment evaluations. Errors in expected yields frequently are on the order of 25% or more. Estimates of plant disease impacts, of irrigation related human health problems, and similar problem areas are little more than guesses.

Unfortunately, the current design process does not encourage, nor usually permit, a depiction of the uncertainty that might provide a more accurate picture of the proposed project to the appropriate decision makers. During the critical feasibility stage the typical design procedure includes: the accumulation of available data, most often in secondary form (primary data collection is usually limited to potential major construction sites; occasionally crop field trials are used if a major crop is planned), the evaluation and rationalization of the data, and the determination of the "best fit" relationships based on the data. Once a specific relationship is determined, e.g. the "average" flow hydrograph for a stream (discharge vs. time), this relationship is assumed to be correct. All further calculations are assumed to be starting from zero error.

As successive relationships are utilized, the resulting "best fit" relationship is again assumed to be correct. Ultimately a set of "design" values are arrived at which are treated as if they are true. The area that potentially can be served from a water source is a typical answer derived from the successive utilizations of different sets of physical data inputs.

The final answers might not be too far from a reasonable estimate of the real world if the errors associated with the various "best fit" relationships were randomly distributed. Experience suggests, however, that an "optimist" tendency biases the results toward an overestimation of project capability. Whether this optimism (and it is not limited to the engineers in the design teams) is the natural bent of "doers", by contrast to "thinkers", or is enhanced by the potential benefits to the designers (and related agencies and individuals) from project implementation, separate from the benefits to the project beneficiaries, is an interesting question.

The entire problem of uncertainty in design is compounded further by the almost complete exclusion of the human factor in the derivation of design parameters. As suggested earlier, rules of thumb are used frequently in design, and nowhere more frequently than where the human being is operatively linked to the project activity. For example, in systems where the on-farm water distribution is other than flooding, the "design" water use efficiency assigned to different types of distribution methods (furrows, borders, etc.) is a "rule of thumb" efficiency. Where the rule is obtained in a cultural context different from the proposed project it will only be fortuitous if it is reasonably accurate. Rarely is there any attempt to derive more site specific criteria based upon direct contact with local farmers.

In summary, the uncertainties in many areas of project design are much greater than assumed; these uncertainties are found in the physical and biologic aspects of project design, as well as in the more generally recognized uncertain economic areas, the uncertainties are masked by the design process; estimates are biased toward an optimistic view of the proposed project; many issues are irrelevant in the light of these uncertainties; any realistic evaluation of a proposed project must explicitly consider the critical uncertainties.

2. The Decision Stage

The design process for a development project usually proceeds sequentially from a pre-project to the pre-feasibility, feasibility and finally to the detailed design stages. Usually, the decision on the type of project that is most appropriate is made early, often at the pre-project stage, and frequently without serious consideration of other alternatives. The Mekong development is an example where *a priori* judgment was made that the key to the development of the region was the large scale exploitation of the Mekong River, without explicit considerations of other development alternatives.

In a similar way, decisions about alternative irrigation projects, e.g. small-scale supplemental irrigation projects, small-scale reservoir projects, large-scale year-round irrigation projects, etc., are made with minimal critical comparisons.

In part this is due to the ways in which project objectives are specified. If, for example, a development objective is stated as the increasing of dry season production of rice by 1000 tons, the alternative types of irrigation projects that can be considered are very limited. An alternative objective, the increase of rice production by 1000 tons, opens the way to a much broader consideration of alternatives.

A recent pronouncement from India illustrates the point. It has been stated as policy that India will plan to increase the proportion of its total rice production derived from the dry season by a specified percentage, to reduce the variation in annual production. A policy stated this way, automatically limits the project alternatives to irrigation projects, probably with reservoirs, either surface or groundwater. The more basic objective, to stabilize rice production, would permit a much wider consideration of alternatives, with a much higher probability of arriving at economical and appropriate projects.

In addition to type and degree of project objective specification, the information about available resources plays an important role in the selection of project type and specific project locations. These decisions frequently are based upon preliminary information of questionable accuracy, as suggested in the discussion of design details in section 1. The information most readily available tends to emphasize the resources most prevalent. Constraints in resources are not obvious, particularly as they relate to proposed changes in the agricultural system of an area. Where there are attempts to identify resource constraints at a relatively early stage, the resources or environments that are emphasized almost always are the physical and biological. Economic considerations are secondary, and social constraints are rarely identified. Yet, the phrase "the system is perfect but the people are lousy" (or, more euphemistically, "we have trouble with the human resource") is commonly heard in "modern" systems in developing countries.

It appears to us, that in the pre-detailed design period the development objectives should be specified in such a way as to leave maximum flexibility for project type and site selection, and that the decision relative to both type and site should be delayed to the feasibility stage. We recognize that this requires a proportionally greater investment before decisions are made, because more alternatives will be carried through the feasibility study process. This process, however, may tend to minimize or at least to counterbalance some of the tendency to be overly optimistic.

We also suggest that increased attention be paid to the human capital resource available to both the prospective project clients and to the government which frequently is an active participant in irrigation projects.

3. Idealism vs. Pragmatism: Phasing and Staging

Partly as a result of educational philosophy and partly as a result of the availability of a number of "laws" that define behavior of the physical world, engineers and scientists involved in design frequently use the "ideal model" as the design goal. This "ideal" system is modified in the planning and design process as constraints of various types are identified. For example, a water use efficiency of 100% while still meeting crop needs, is a theoretical achievement, but design efficiencies usually are approximately 60%. The design process starts with the theoretical value and proceeds through successive reductions as water losses are identified. However, if the losses become "excessive" the design is modified to reduce them, e.g. by including canal lining, providing for control gates, etc.

The definition of "excessive", however, is more often based upon a feeling that certain levels of losses are acceptable and others are unacceptable, rather than upon a balancing of the relative costs of achieving a specified efficiency vs. the costs of not reaching that level. Rarely is a project designed for 30% efficiency, yet many are actually operated at that level. In particular circumstances of available water supply, limited management resources and minimal adverse effects from over-irrigation, a design value of 30% might be the most economical and most effective way to achieve project objectives. But it goes "against the grain" for an engineer to design an "inefficient" project. The concept of total efficiency, which integrates environmental, economic and social efficiencies is not effectively utilized.

Related to the focus on an ideal model is the degree of "modernization" incorporated into the design. Systems are almost always designed with the most modern features currently available and theoretically appropriate, almost irrespective of the current level of agricultural or irrigation practice in the area. Direct service to individual holdings, on demand, with volumetric metering and with high efficiency is considered to be the "ideal", providing the farmer with maximum decision-making independence, and reflecting modern approach to design. While this is not always achieved in design, and rarely in practice, it still reflects the ideal. In striving for this, as suggested in the discussion on operation and maintenance, measuring devices, control gates, modern institutional structures, etc. are incorporated into the design, even when the prospective clients have no experience with these components. The modern project design, however, includes provision for training and for extension efforts to insure that the system personnel and farmers will learn to use the modern facilities and institutions.

Where the proposed system is large, the design frequently incorporates a staging of development in which a portion of the area is completed in accordance with the modern design and operated, in principle, with training and learning objectives in mind. While these areas typically are larger than the "pilot" projects described earlier, they suffer from similar problems. The resources available to them, and their favored locations make them unrepresentative, though not necessarily without significant value. A number of major problems in the Muda River Project were identified in the first stage development with important changes in the design resulting. In other cases, however, when problems are identified in this first stage of development, especially when those problems are related to the ways in which the clients are utilizing (or not utilizing) the project resources, there has been a radical redefinition of project objectives rather than project redesign. Perhaps the most significant of recent examples is the Dez Project in Iran.

We would like to suggest that the concept of phasing be considered, in which not only the size of the initial area is staged, but that the degree of progress toward the "ideal" is staged. Thus, a project would be planned and executed to combine successive degrees of modernization, feedback, learning (by clients, operators, and designers) and where appropriate, expansion.

The obvious objection to this approach is an apparent increase in project cost and an increase in the time to achieve the "final" state. We argue, unfortunately without specific supporting data, that in reality if any realistic discount rate is used, costs would be lower. The system would be more appropriate to conditions, percent utilization of current investment would be higher, and the probability for making serious mistakes would be reduced.

Obviously, there are aspects of systems which cannot be staged or phased. Where the basic design calls for a major reservoir, this cannot be staged. However, the operational technology and farm practices anticipated to be used with the more stable water supply might be tested and evolved on a relatively small area, using modest storage development and/or wells to simulate the projected reservoir operation.

4. Large vs. Small Projects

For a variety of reasons, many external to the real needs of the farmers, there is a growing emphasis on large project development. A sense of urgency about the pace of development and about food production contributes. The attitudes of major lending agencies, of within-country development agencies and of political figures all add to this emphasis.

Significant problems can be expected. Large-scale projects usually involve high per hectare investments concentrated in a limited region, frequently resulting in reductions of development funds available to other areas; inter-regional disparities may result. Large-scale projects frequently require external consultants and design teams, especially where the major lending agencies are involved. The problems of uncertainties, emphasized earlier, are exacerbated in this situation. The terms of reference and the time scale associated with the use of external consultants are such that serious problems with the basic premises for the projects can be expected.

On the plus side, it is argued that large projects make more effective use of the limited local design and managerial resources. While there may be some justification to this argument, it is not entirely valid. In mobilizing local design and managerial talent for the Upper Pampanga River Project, the Philippines scoured its existing systems for the highest quality talent available. These individuals have been concentrated for the 80,000 ha, $80 million project, but no evaluation has been made of the impact of this mobilization on the many systems from which they were drawn. It is at least arguable, that an intelligent, vigorous and knowledgeable (about a specific locality) individual can make a more valuable contribution in a position of major individual responsibility in a relatively small project, than as a member of a team in a larger project in an area different from the locale of his experience.

It is also argued that large projects are necessary for the effective utilization of relatively large, but variable water supplies. A large reservoir is necessary to stabilize the supply; reservoir projects have higher per hectare costs; the area that can be served adequately is increased greatly over that which can be served by a run-of-the-river project. Accepting this as valid, an unresolved question remains. Can the potential benefits of small-scale projects -- the utilization of local experiential knowledge, the feedback and response speed, the involvement of the clients be achieved within the context of a large-scale project? Is it possible to develop a large project that represents, at the field level, an agglomeration of small projects, even though the major facilities are designed and operated as a large project?

The suggestions made for the operation in our earlier section represent a potential analogy, though at a smaller scale. What might be appropriate institutional mechanisms for achieving this mode of operation, and what might the costs (financial and other) be are unanswered questions that have major importance for many countries, at this time.

In summary, the major points we are trying to make in this entire section on design are that:

(1) In the context of the developing countries, especially the humid tropics of Asia, it is essentially impossible to design an effective appropriate project before implementation. The design must explicitly include an extended period for feedback and revision.

(2) The effective utilization of relatively radical departures from traditional practice, on the part of farmers, will take place only over an extended period of time. Phasing of changes may permit a smoother transition at lower real cost though at an apparent higher initial cost than the abrupt introduction of new methods.

(3) There is a need for evaluating the relative impact of investments in large and small projects, and for methods to gain the relative advantages of small projects within large ones.

(4) Given these uncertainties and extended requirements for design and implementation, new techniques must be developed for providing realistic information to policy and project decision makers.

VII. WICKHAM'S COMMENTS AND THE DISCUSSION DURING HIS DELIVERY OF THE LEVINE-WICKHAM PAPER

Scientists try to develop the relationship between water use and yield without measuring water, if you can believe it. But the curve itself, the reason it has developed better for rice, I assume is because of the nature of rice. For other crops, the timeliness of applying water really affects that curve. I have worked a great deal on potatoes and with potatoes timing is more important than the amount of water. The time element leads to a number of curves and there is a lot of work being done all over the world on estimating these curves. Timeliness mixed with amount is a very technical problem.

It is amazing how few devices we have to measure the amount of water. These measuring devices need not be expensive and they need not be all that numerous. We just need them in a few strategic points in a canal so that we can have some idea how much flow we have. To farmers the option of closing water off to a field is a necessary condition for good water management. The best would be grated turnouts with measuring capability and when open you could measure the volume of water flowing into the field. This is certainly a technological possibility but is scarcely ever done.

Finally, we need transport for the people managing the irrigation system. Water has to be allocated in different parts of the system. Managers need some way of determining if the water is reaching the desired area. Motocycles or some form of communication are needed to know how the system is performing. We had an aerial surveillance program over part of our irrigation area and I was impressed how much you can see (and how cheaply) from light planes. We need some system of movement and feedback to see how things function.

Technology for better management of main systems is badly needed. They need not be highly sophisticated. In fact, they must not be if personnel with modest training are to use them and explain them to farmers. Implementing a comprehensive package of management practices especially for the farm level does not appear justified currently, where flooded rice is the only crop.

We often refer to operations and maintenance (O&M) as a single concept. A strong case can be for divorce of the couple based on mutual incompatibility. Operations generally refer to the allocation of water in the system, the collection of water charges and other administrative matters. Maintenance is how you clean out canals, paint the structures, clean the grass from along the canals and generally keep the canals in shape. When maintenance is not done on a regular basis, rehabilitation is required. Rehabilitation can be considered deferred maintenance. In fact, the amount of money spent on rehabilitation might be more or less equal to the maintenance costs. Why are these two functions (maintenance and operations) in conflict? Maintenance is carried out almost exclusively along the canals, and those doing it have no reason to get onto the land to see how adequately the water is irrigating the command area. Maintenance functions require essentially no contact with farmers except possibly where farmers have broken embankments.

Management and operations, on the other hand, calls for a very different person. He must see what is happening in the fields. Is water reaching the farmer's fields? Operations requires very intimate knowledge of farmers and communications with them. Maintenance does not require any knowledge of agriculture but with operations you need to know something about farming.

One of our research projects in the Philippines discovered that many farmers prefer that their ditch tenders be farmers who would better understand farming and irrigation problems. Under financial pressure most irrigation agencies hire one person to do both. The problem is that promotions are based almost exclusively on the most visible performance and visibility means cutting grass and cleaning up debris along canals. There is no comparable means of measuring and rewarding excellence in water management. We would recommend a separate work force for maintenance. This work force could be recruited from a farming community and be paid on piecework basis. Piecework is quite acceptable in Asia and there is no reason why it could not be done this way. Operational personnel could be trained for agriculture and for water management. This training could not be crammed into a construction type who has no appreciation of agriculture. Therefore, these people must be recruited very carefully and be given more responsibility for improving water management. I cannot overemphasize the importance of the human resource now available in the terms of ditch tenders, water masters and many others. What we need to do is strengthen their relationship with their farmers and give them more training and responsibility.

QUESTION: Are you referring to separating operation and maintenance all the way up to the reservoir, or are you talking about the ditch tender level?

WICKHAM: Primarily the ditch tender. I have not had much to do with the other levels such as gate keepers, water masters and higher up. Even at that point, the maintenance should be done by a maintenance crew and the distribution of water among the canals should be separate.

QUESTION: Why did you not say anything about communication in your discussion of transport?

WICKHAM: Of course, it would be nice to have a nice communicating network, but I do not give it as high a priority as transport. Communication does not have to be emphasized. Half a day is enough, or even a day is enough lead time.

The last question I want to talk about is water rates. The two reasons usually advanced for farmers paying a substantial water charge are (1) it helps allocate water more efficiently and (2) farmers achieve higher net farm income with irrigation which justifies their paying something for the water. Water rates serve in terms of allocation only if they are based on the volume of water used. At the present time nowhere in Asia, including Taiwan where water management is relatively sophisticated, is water sold by volume. Rates are imposed, instead, on a per area basis which probably tends to worsen allocation since farmers then have an additional incentive to get the highest production they can, regardless of the water used.

Under present circumstances, it is not possible to measure water to every farm and it is unlikely this will change in the foreseeable future. I have spent over a third of my last five years working on the measuring of water and unless some new technological development occurs, it is impossible to measure water reliably. I am concerned that the yearly cost of any device which could be tried would be two or three times the amount of any reasonable charge that the farmers might be expected to pay. A far more promising alternative is to measure the water passing a certain point in the main system and charge a group of farmers to whom it is supplied. This could theoretically be done in the 50 hectare rotational units being built in the central plain of the Philippines. Here we have measuring devices that could work and the instrument cost could be allocated over 50 hectares. But let me point out a few rights that are exceptionally difficult to handle.

Farmers on light soils are going to require a lot more water since there is a lot more water loss due to seepage and percolation. These farmers are going to have to pay more since they require more water to grow a crop. These farmers are also going to have to use more fertilizer if they are going to get the same yields as farmers on heavy soils.

But, even more important, what happens if the farmers were supplied and charged for more water than they needed? Given the tremendous variations in the amount of water delivered, can we control the volume of water so that the farmer really gets the amount he needs when he needs it with any assurance and not supply him 100, 200, 300% more than he needs for perhaps weeks at a time. Suppose we do supply him with much more water than he needs except for a critically short supply for four or five days when the crops desperately need water and his yields are reduced 1/3 or even 1/2. He was supplied with abundant water, more than enough for the season so that his fee on a volumetric basis may be high. The tolerance in our ability to control the delivery of water is nowhere near in balance with the benefits that come out of a volumetric measure.

In a system where it takes three to five days from the main storage to the diversion dam, it is difficult to regulate flow based on farmers' requirements. For example, after three dry days water is released, but by the time water gets to the diversion dam three to five days later, it has rained and the farmer really does not need the water. If you charge on a volumetric basis, he is going to say, "do not let it through my outlet". Who is going to pay for the water? We are dealing with a monsoon system where, by the time the water is delivered it is not needed in many cases.

Where the water just goes into the drain and out, because it is not needed, it is almost impossible to talk about volume education. Volume education could be talked about under arid conditions where the irrigation is the sole source of water because their is no rain.

<u>EASTER</u>: Would you make that statement for both wet season and dry season or are there any systems where volumetric measure is practical?

<u>WICKHAM</u>: The irrigation system is designed for the wet season and being used in the dry season. It is going to be a very long, difficult process for farmers to think in volume terms but one is justified in trying. The point I want to make is that the government is not going to be able to measure the volume used in big areas.

In the case of the Philippines the difference between the wet season and dry season water supplied is about .8 of a meter with .8 of a meter in the wet season and 1.6 during the dry season. This is 2.4 meters for the year. It appears that the control of water flows in the canals is the most important need of water allocation. The fact that water allocation is not now being done very equitably does not mean current methods should be replaced by a monetary charge but rather by better water control.

The second argument for water charges is that farmers get higher yields and income from irrigation. It is not difficult to quantify the yield benefit due to irrigation. Even wet season supplemental irrigation increases yield very significantly and you can attribute all of the yield in the dry season to irrigation. There is no question that the first crops to receive irrigation produce higher net farm income. But as the proportion of farms under irrigation increases, there is a real question hether spreading water to more and new farms will mean higher farm incomes. Since the demand for rice is highly inelastic, farmers as a group stand to have higher income by producing less grain, and lower income for more grain. For each additional hectare receiving irrigation there would be more production with lower prices. Over the long run, farmers, as a group, are not the beneficiaries of yield increases. Perhaps a better approach to the question of water charges, or water fees would be to assess the true beneficiaries of irrigation and try to charge them something rather than charging farmers on the assumption that they are the beneficiaries. The most obvious beneficiaries are the consumers.

The land values begin to rise even before the irrigation project is in full operation. Therefore, an effective land tax, with which we have had a great deal of experience, is a much more positive way to approach the problem. Another approach which recognizes that increased production has reduced the price of rice is a national subsidy. Even if the price does not actually go down, it will not go up as much as it otherwise would. Clearly there is a benefit to the national economy and this has been recognized by the fact that many governments pay irrigation subsidies directly or indirectly. We ought to recognize who benefits and be quite open about the subsidy.

STATEMENT: This is an approach that we typically take for food crops and usually for agricultural output in a country. What you are saying for most of Asia is absolutely right. However, I would like to point out one important exception in other places in the world. There are commodities, whose demands are very large either domestically or because they are a small part of international trade. This is particularly true for a lot of commercial crops that are produced for export such as cotton in Nicaragua or Brazil. For these commodities it may be that nearly the full benefit is captured by the producer. One wants to look very carefully at the nature of the demand and the price elasticity.

In fact, if you are growing something like strawberries, can you really justify using national treasury receipts for irrigation? This really opens the gates to all kinds of subsidies for projects with national benefit. You could start with a basis of levying charges by means of fixed rates that would absorb the cost, or you could make your rates reflect the productivity of water. You have two basic contexts from which to start. Have you assumed that the cost of the system would be borne by a combination of operators and owners, so that you would reduce the amount capitalized into the land values? Otherwise, you will have to have some kind of a capital gains or an increment tax after the increase in land values.

WICKHAM: You mean, having a tax high enough to capture the increase in net incomes?

STATEMENT: No, having a way of pricing it high enough to minimize the capitalization of income into increased land values.

WICKHAM: Let me explain what I think has been done on a particular project in regard to taxing farmers.

The Philippine government charges the beneficiaries X kgs. of paddy in the wet season and a higher amount in the dry season for water. This is based on net returns without trying to say whether the cultivator is a tenant or an owner. But for irrigation in the Philippines, where the cultivator is very poor, you have to do something.

STATEMENT: What you are saying is that because the poor farmer or the lease holder cannot afford to pay for the water, we should not charge anything, but what about the large land owners? You have to do something and then hope that you are going to have a mechanism to insure that the lease holder can make a living.

WICKHAM: Why do I think that the farmer is not the beneficiary in irrigation? My thinking goes back to rice and what has been done with HYV's. We produced the highest yields with good irrigation. We then ran into disease and insect problems which not only affected the IRRI farm but all neighboring farms. You will find it in the IRRI annual report. We found some very serious virus diseases which we had absolutely no control over. All of these are related to an unstable environment which is much more adverse to high yielding rice. We have to recognize that farmers gain from high production only in the short run because of drops in prices. The true beneficiaries are society not the individual farmer who, in fact, might deserve a rebate for all additional expenses he has not only this year, but also in years to come.

STATEMENT: Large price fluctuations would hold only in a case of a commodity like potatoes where you have large fluctuation from year to year. In most countries like the Philippines you have a minimum price. You cannot show that for a long, long time you have fluctuations downward. You have tremendous fluctuation upwards where you can make a real killing.

STATEMENT: Tom, this is too simple a view of a very complicated problem. Actually, there are some farmers that have done very well. The same is true of the whole technology area. And some farmers will really gain from irrigation. What happens then, if the price goes down, there are farmers at the margin who are going to be driven out of the industry. What you are saying is that if you look at the whole net social benefit across all farmers, it is close to zero. But that does not mean that there will not be large groups of farmers who have captured a permanent gain in income.

WICKHAM: I would agree with that except for one point. That is that I am quite concerned about the problem of maintaining production environments over long periods of time. The environment is going to become so sensitive that the net benefit to all farmers is not going to be positive. All the expenses of new technology or irrigation are not really embodied in the supply curve.

STATEMENT: Tom, what you are saying, then, is that whoever evaluated this project failed to take into account the cost of double-cropping. Presumably, whoever did the evaluation took into account that as one moves into double-cropping, you will have to mechanize, use higher fertilizer inputs, pesticides, etc. All this should have been taken into account.

VIII. DISCUSSION OF LEVINE AND WICKHAM PAPER BY EASTER

EASTER:

I had a chance to read Tom's paper last night but his notes from Levine are new, so I will not comment much on them. Although I agree with a lot of what Tom said, I will point out some of the basic differences between irrigation systems that I looked at in India, and the ones that he has talked about in the Philippines. These differences lead me to some very different conclusions regarding the need for field channels or laterals on farm plots.

My research was primarily in eastern India in Sambalpur district on the western side of Orissa State and in Raipur district on the eastern side of Madhya Pradesh. In this part of India you can usually produce one rice crop a year based on the monsoon rainfall but during the rest of the year you do not produce anything without irrigation. The large system in Sambalpur is for both power and irrigation. With adequate rainfall, there is enough water to irrigate two crops. During the rainy season irrigation supplements rainfall but the dry season crop is completely dependent on irrigation. The system was completed in the middle 1950's but many farmers did not start using the water until the early 1960's.

The point that Tom makes on main canal controls and improvements is an important issue. Improvements are needed in the Sambalpur system, particularly on the canals near the farms. The control question the engineers are aware of, but I do not know what they are doing to improve control. Our major concern was with improving water distribution at the village level.

The most pressing need was for on-farm improvement of irrigation systems. There are, at least, two essential components. One is technical assistance to the farmer and the other is a total village commitment to the program. You also need coordinated assistance from the Irrigation Department and the Agricultural Extension Officers, which was occurring in Sambalpur. Most of the villages we investigated were at the end of a canal although farmers near the outlets were getting excess water even in some of these villages. The critical reason why the field channels and improved water control were so important, in contrast to the Philippines was the large number of farm plots irrigated from one outlet. Tom talked in terms of one and two farms irrigated from an outlet. We found ten to twenty farm plots served by one outlet. One farmer may even have two or three plots scattered in the 25 to 125 acres served by one outlet.

The farmers near the outlet definitely received more irrigation water and had a lot to say about who obtained water below them. If the farmer near the outlet wanted to stop water from flowing through his fields so that he could fertilize he closed the outlet and no one below him got water. The farmers did not want water flowing through their fields while fertilizing since they were afraid the fertilizer would wash away. Tom argued that there is no evidence that fertilizer is lost by water flowing from field to field. This may be true. However, the real question is what the farmers believe and they believed they would lose fertilizer.

Our analysis of the water management program found net annual benefits of 150 rupees per acre. This is obtained with an average expenditure of about 34 rupees per acre for construction and a 6 rupee per acre annual expenditure for maintenance.

If our figures are anywhere close we are talking about a net present value of 578 rupees per acre using a 20% discount rate and a project life of 10 years. A very profitable kind of project. Judging from the way farmers are responding to this project and demanding technical assistance, the benefits must be transferrable to other villages.

The District agricultural extension people started out with just two villages. When we did our investigation four villages had been completed and they were in the process of doing nine more villages. Given their staff size, they could not handle more than nine villages a year. In addition to the villages they were working in, there was a waiting list of villages wanting technical assistance to install field channels. So, at least in this case, it appears that the field channels were doing a real job for the farmers. I was very surprised at the magnitude of the benefits. When we started the survey and analysis I was not expecting anything of this magnitude.

TIMMONS: Could you explain a little bit more about what you mean by field channels?

EASTER: Each village has 5 to 10 canal outlets, depending on the size of the village. These outlets were designated by the irrigation authorities and serve anywhere from 25 to 125 acres. What you have is a large area with a number of small plots, most less than an acre, and farmed by different farmers. The field channels that the district agricultural extension staff installed go right on top of or right next to the levees. Channel placement is such that the levees are reduced in size rather than land being taken out of production. The field channels allow each farm to control the water going to his fields. If he does not want any water he can let it by-pass his fields without shutting it off to the next farmer. You do not run into the problem of the fellow at the top shutting water off and depriving other farmers of water. You also get a better distribution of water throughout the area irrigated by each outlet.

The system of field channels includes some drop structures and some pipes to prevent erosion. The engineers working with the farmers design the channel placement so that water goes down hill. If some farmer does not want a channel in his field, the engineer determines how best to go around him. However, all farmers generally cooperated since the whole village agreed to the project.

The extension people realized that they had to keep the system very simple and low-cost. On the average, the agricultural extension spent only about 28 rupees per acre for construction of which about 18 rupees was for technical assistance and 10 rupees was for materials, structures and pipe. Farmers are responsible for digging the field channels at an average cost of 6 rupees per acre and for the maintenance. The technical input is not really sophisticated but it requires some engineering training. The farmers tried to do some on their own and ran into some real problems, such as getting the channels going up hill.

I would like to comment on one point Tom made, on the non-use of water by Thai farmers and Tom's example of some of their problems. This could be a question of farmers not knowing how to irrigate. I do not know if this is the case, but in Sambalpur they did not irrigate for about five or six years because of a lot of beliefs about the use of this water. One thing that happened was farmers from Andra Pradesh, who were traditional irrigation farmers, moved up, bought land and started irrigating. How much this contributed to the education of the rest of the farmers in terms of irrigation, I do not know, but it appeared to be an important factor.

Another thing we talked about earlier was putting in a system without properly educating the farmers and expecting them to adopt irrigation right away. At least in the Sambalpur case, it did not work for about five or six years. Now, they are clamoring for more water, particularly during the dry season. One reason the field channel program has gone so well is because the farmers at the end of the canals were not getting enough water. The field channels allow for better water distribution within the villages that are not obtaining enough water. The program does not solve the problem that villages near the head of the canal are getting more than enough water and the ones at the bottom not enough.

We have already said a lot about water pricing and what we talked about can be divided into three pricing functions; the repayment function, the allocation efficiency function and the income distribution function. In the case of allocation efficiency, you might want to think about using the village as the measuring point. On the average a village covers about a thousand irrigated acres in Sambalpur. Water would be delivered to the village and the more water the village farmers used, the higher the water volume charge would be. The village charge would then be allocated to the individual farmers based on acreage owned. If the farmers are more efficient in their use of water, their overall acreage charge would be less because the village volume charge would be lower. It might work, since the village is still an important institution in India.

The second point I would like to make is about the role of water pricing in income distribution. The income distribution impacts of irrigation depends on the ownership of the land. Is the land concentrated in a few hands, or is it distributed among a large number of small owners? This is an important question in whether we charge and what we charge the farmers for the water.

On the ownership point, I would like to go back to the experience we had in the small Raipur irrigation project. The project is irrigating only about 26 acres. But when we surveyed the village after the project area had been designated, guess who owned that 26 acres? Most of it was owned by two of the biggest farmers in the village. This was a project funded by the Ford Foundation and the Intensive Agricultural Development Program (IADP), but no one seemed to know its distribution implications until we did the survey. This points out that tion project benefits can go to a few land owners and can be very concentrated. In such cases the income distribution impacts of low water charges become important.

Finally, in the Sambalpur case, with net returns of 150 rupees per acre per year, government should begin to charge these farmers for the project costs. They could pay the cost and still have quite a surplus left over after just the first year. Some allowance would have to be made for bad crop years so that farmers could defer payments. Farmers' payments would help reduce project funding restrictions and allow the district extension staff to expand and work with more villages, and would reduce any income distributional effects.

<u>TIMMONS</u>: Bill actually introduced a fourth function in his pricing system which is ability to pay.

<u>EASTER</u>: The second recommendation which I would make concerns the need for technically trained people to work with farmers in improving village irrigation. This appeared to be the bottleneck in Sambalpur. If I were advising the government on this project I would say, "Train about 20 more of those engineers and get them out in the villages". In addition, you would need two or three helpers for each

engineer, but they would not need much technical training.

There are 400 or more irrigated villages, but at nine villages a year it will take them 40 years to finish. On the other hand, you can go too fast and do a sloppy job. Unless they get the extra technical help, they should not try to do much more than nine villages a year. I would emphasize the importance of keeping the irrigation improvements simple and cost low. At a later stage, one can bring in more sophisticated technology, but under current conditions the district extension people should slowly expand their program.

Finally I would like to stress a point Tom made in the latter part of his paper, that is the importance of considering alternative designs and the whole question of looking at alternatives. This is very, very critical in our work with irrigation projects.

QUESTION: Bill, do these costs reflect the cost of training these engineers?

EASTER: The costs included are just the wages paid.

General Discussion

GOLAN: If you are going to try to do the survey through crews out in the field it becomes almost impossible to cover large areas. So, you have to go into aerial photography in order to do it. For example, the Indians want to do 4,000,000 hectares in five years. Now, you just figure how many people you have to send out into the field to do the survey if you are going to put field channels over that size area.

ABEL: There are two things that are very important. First, you could not do with aerial photography what was done in these villages, because you are working with very micro units, and a small difference in elevation can be terribly important. Second, Bill mentioned that you had to get the whole village to agree. What he did not say was that you do not get the village to agree without spending some time in the village. You reach a critical mass, like, maybe 60 or 75% of the villagers cooperating and it is amazing what influence they will have in getting the remaining villagers to agree. We saw the social dynamics working and the survey engineer played an important role in knowing the village and planning and helping to facilitate this social change.

GOLAN: Maybe you misunderstand me. All your aerial photography is going to give you are contours in order to do the survey.

EASTER: This information was already available in Sambalpur.

ABEL: Let me make one other point. If you look at this training program, it cannot be classroom training. These people have already been trained in the classroom but they need training in the field. With a well structured program, in several places in India, you could proceed in a geometric progression. There is no reason why you cannot build into the village work the training component which is going to create the next group of trained people. The point that Bill made is very important: If you are going to just routinely expand the numbers, and forget about the quality, you are going to have a disaster on your hands.

<u>WICKHAM</u>: We have used aerial photography a great deal in our research, and I am very grateful for having it available. They make very good base maps. The problem with aerial photography is that we almost inevitably are tantalized into using it beyond this purpose, and we begin writing in the boundaries based on the photos. If we could restrict it to providing contours for the field survey, they should be used. But it would be too big a temptation for people in India to do what they did in the Philippines, which is to write in all of the boundary lines in the office in Manilla, and then give it to the people in the field. Nobody in the field dared to argue with these maps. The result was that when we tried to find six 50 hectare test areas where we could actually carry out irrigation comparisons, we could not find six that worked out of hundred and hundreds. The aerial photography was misused and in an area where people are not highly trained, there is a high probability that aerial photography will be misused. But, I agree in principle, for without aerial photography you cannot go very rapidly.

IX. PROSPECTS FOR IRRIGATION DEVELOPMENT IN NICARAGUA

Curtis L. Larson

As in many other Latin American countries, rural poverty is a major problem in Nicaragua. The rural poor include a large number of campesinos (small farmers) living at the subsistence level and also a large number of farm laborers. The annual income of the latter is typically very low for two reasons: low daily wages (U.S. $1.50 to $2.00 per day in 1975) and seasonal employment of as little as 100 days per year. The living standards of most campesinos are not much better since their farms are typically very small and the crop yields low, due largely to their inability to utilize current agricultural technology.

Nicaragua has substantial land and water resources, though it is not a large country. In 1973, the total areas of cropland and pasture were 803,000 ha. and 38,824,000 ha., respectively. Crop production is concentrated in but not limited to the Pacific plains where there are extensive areas of productive soil. Livestock production is important in both the Pacific and Central Zones. The area devoted to pasture includes not only hilly land but also large areas of level land with black clay soil (known locally as sonsoquite) which can be used for growing rice and could be used for other crops by providing proper drainage during the rainy season and irrigation during the dry season. In 1973, only 5.2 percent of the cropland (41,500 ha. and 7,400 ha. of pasture) was irrigated, with most of the cropland producing rice and sugar cane. This is a very small area in relation to the potential area of irrigable land and the available water resources. With a climate that is suitable for multiple cropping, Nicaragua has a considerable potential for increasing food production and national income through expansion of irrigation.

1. Potential Yields With Irrigation

Annual rainfall in the Pacific and Central Zones varies over the area from about 700 mm to 2500 mm. The precipitation is concentrated in a 6-month period (Figure 1) during which a single, annual crop can be grown quite well. Corn and cotton are the two annual crops commonly grown without irrigation, corn by the small farmers and cotton by the "commercial" farmers. In most cases the land lies idle during the dry season.

Differences in average yields for single crops, with and without irrigation, range from 56 percent on cotton to 400 percent on pasture (see Table 1). Only a small part of the large differences between rainfed and irrigated yields can be ascribed only to irrigation since, as shown in Figure 1, the wet season rainfall is nearly adequate, although this varies with location. The most important factor is the low level of agricultural technology utilized by most nonirrigation farmers, many of whom are subsistence farmers. Thus, there is potential for increasing crop production by improved farming practices and by irrigation.

Multiple cropping is clearly feasible in Nicaragua with irrigation, and has been used to a limited extent. With cotton as the rainy season crop, corn, beans or sorghum are grown under irrigation during the dry season. In this way, production and gross income per hectare can be increased several times by irrigation combined with agricultural technology.

Pasture yields are of special interest and are important in view of the large area of pasture. The fivefold increase in pasture production (in animal units) with irrigation is due to the fact that pasture is needed year-round and its livestock carrying capacity is, therefore, determined by the dry season forage production. In Nicaragua, beef animals on unirrigated pasture typically lose 45 kg. during the dry season! This loss has to be regained during the rainy season which is, of course, very inefficient. Nevertheless, raising cattle extensively can be profitable, if done on a large scale, thanks to low land costs and low labor costs.

In general, the precipitation is inadequate for growing paddy rice. Multiple cropping of paddy rice is common with irrigation. Perennial crops (bananas, etc.) require irrigation and so does sugar cane, although some is grown at reduced yields without irrigation (Table 1).

2. Soil and Water Resources for Irrigation

The area of potential cropland in Nicaragua is estimated at 1.5 million ha., almost twice the present amount. The land suitable for irrigation was estimated by an agency of the Nicaraguan government[1/] as follows:

Suitable for most crops -	418,400 ha.
Suitable for selected crops only-	426,900 ha.
Total considered irrigable -	845,300 ha.

More than half of the land suitable for irrigation is designated for selected crops such as rice due to poor internal drainage (mostly sonsoquite soils).

The total land area suitable for irrigation is more than 20 times the area presently irrigated. However this does not give any consideration to the water for irrigation. Because water resources for irrigation have been investigated mainly on a project basis, enough information is not available for an estimate of the total irrigable area where water is the limiting factor rather than the land.

The major water sources for irrigation in Nicaragua are groundwater, natural lakes and reservoirs. Nicaragua has extensive groundwater supplies at reasonable depth (less than 30 m.) in many areas that are well suited to irrigation, mainly in the Pacific plains north of Managua. It is estimated that about 70,000 ha. can be irrigated profitably by groundwater in the areas studied so far. Projects totaling 45,000 ha. have been proposed for irrigation with water from Lake Nicaragua, which is quite unique, being an unusually large source of good quality water. Lake Managua water is not suitable for irrigation due to high boron content. Current proposals for construction of reservoirs for irrigation total about 19,000 ha.

1/ "Posibilidades de Riego on Nicaragua," UNASEC Informe Tecnico I-1 (1973)

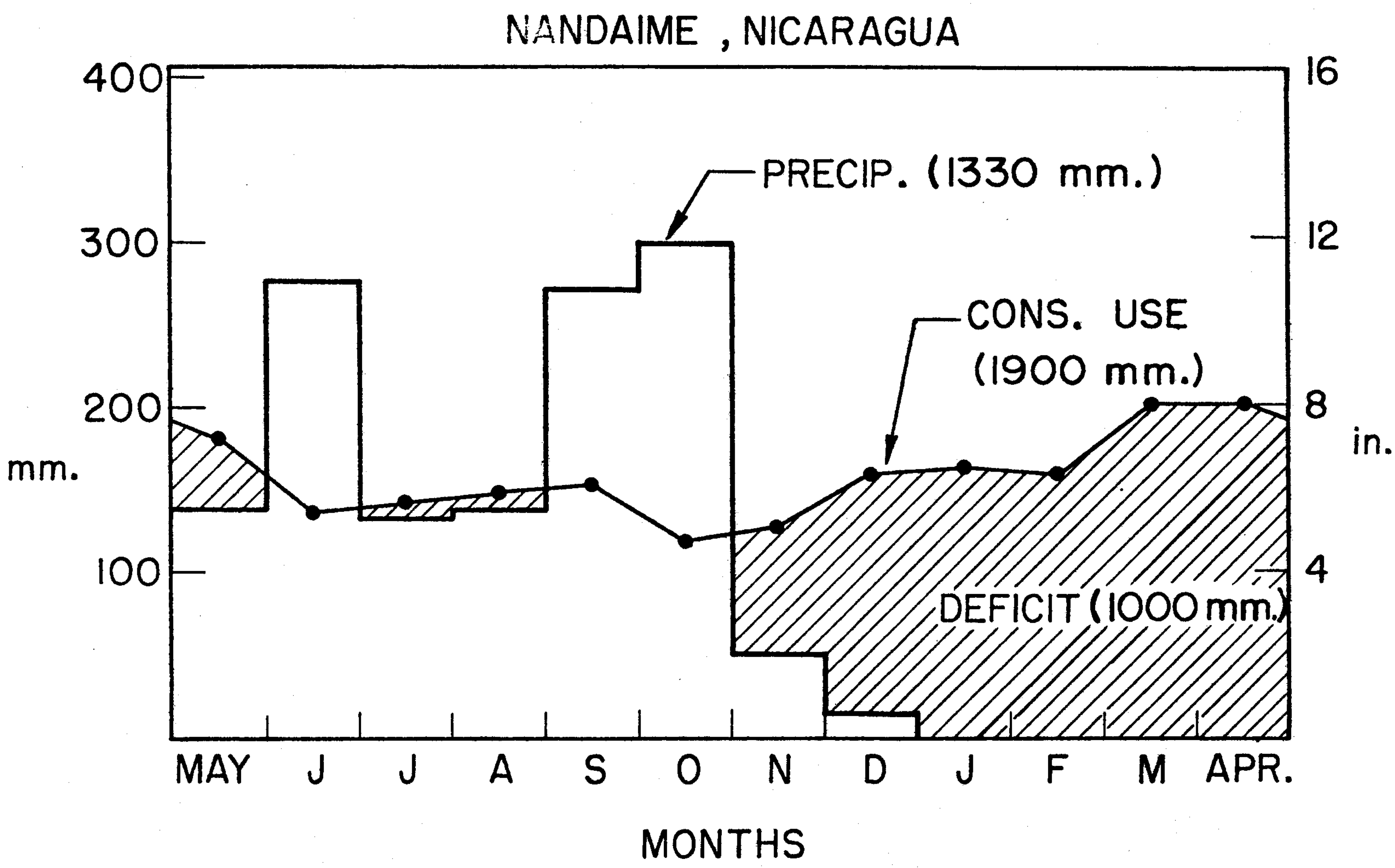

Fig. 1. Monthly distribution of precipitation vs. approximate consumptive use (0.7 x pan evaporation) at a location in the Pacific coastal plain near Lake Nicaragua.

Table 1: Average Yields for Rainfed and Irrigated Crops, Pacific Zone of Nicaragua

	Approximate Growing Period	Yield		Percent Increased in Yield
	Months	Rainfed[1/]	Irrigated[2/]	
		--------t/ha--------		
Cotton	6	2.50	3.90	56
Maize	4	1.40	3.90	179
Beans	3	0.80	1.60	100
Sorghum	4	1.50	4.20	180
Sesame	4	0.40	1.00	150
Sugarcane	12	55	100	82
Upland rice	5	1.00	-	
Flooded rice	5	-	2.60	160[3/]
Pasture	12	1[4/]	5[4/]	400
Tobacco	5	0.50	1.90	280

1/ Approximate national average (in some cases without fertilizer and other improved practices.

2/ Irrigated yields are with fertilizer and good management.

3/ As compared to rainfed upland rice.

4/ In animal units per ha.

Table 2. Approximate Costs of Gravity Irrigation in Nicaragua for Alternative Water Sources, 1972-1973.1/

	Available Streamflow	Groundwater, Tube Wells	Pumped Lake Water	Reservoirs, Gravity Delivery
	$ per hectare			
Investment Costs2/				
Total	653	449	755	1,428
Annual basis	65	57	84	147
Operating Costs2/				
Energy		45	25	
Maintenance	4	4	6	8
Administration	6		8	6
Labor	16	16	16	16
Total operating cost	27	65	55	30
Total Annual Costs1/2/	92	122	139	177

1/ Land preparation costs not included.

2/ Based on 1972-73 prices.

Source: "Diagnostico de las Posibilidades de Riego en Nicaragua," UNASEC (Nicaragua) Informe Tecnico I-2 (1974).

The total area of proposed projects from all water sources is about 150,000 ha. This is almost four times the area now irrigated but much less than the area of soils suitable for irrigation. Thus, although potential water supplies, both groundwater and surface water, undoubtedly are well in excess of those identified to date, water supply appears to be the limiting factor for ultimate irrigation development in Nicaragua.

3. Costs for Alternative Water Sources

A somewhat unique aspect of irrigation development in Nicaragua is the alternative water sources in certain areas. In addition to the three major sources mentioned above, there are small amounts of streamflow available to a few locations. These supplies are quite small, however, since the prolonged dry season reduces most streams to little or no flow.

Comparative costs of irrigation development and operation for the four water sources were determined in 1972-73 (Table 2), all for gravity irrigation. In terms of investment cost, the use of tube wells is lowest in cost. One reason is that the well depths are relatively low, usually 10 to 30 meters. Another is the small area (as small as 100 ha.) that can be irrigated economically by a single well. Thus, an extensive canal system and series of control structures is not needed, in contrast to the other sources.

Even the use of available streamflow has a higher initial cost than tube wells, since either a pumping plant or a diversion structure some distance above the irrigated area is needed along with a long delivery canal, and smaller canals to distribute the water. Likewise, the use of lake water (from Lake Nicaragua) entails a substantial investment cost for a pumping plant and a canal system. This is true even though the irrigable land is close to the lake and the maximum pumping lift is about 25 meters. As usual, the investment cost for reservoirs is quite high in relation to other water sources.

In terms of total annual cost, including operating costs, the lowest cost is somewhat different. The major difference is due to the cost of energy for pumping (which has increased in importance since the study was made). Consequently, the diversion of available streamflow is the lowest in total annual cost and tube wells second. In these terms (total annual cost), reservoirs are still the highest cost but the differences are reduced considerably in comparison to other water sources.

4. Government Involvement in Irrigation Development

Most of the irrigation development to date in Nicaragua has been done privately, mainly by sugar cane plantation owners and by rice farmers. Government involvement in irrigation is relatively new, and has occurred mainly in two forms. One involves financial assistance to a semipublic corporation providing and applying irrigation water (pumped from Lake Nicaragua) to an area of about 1000 ha. The principal crops of the project area are sugar cane, bananas, and pasture. Another form is a program of technical and financial assistance for tubewell irrigation of units of about 100 ha. The program is voluntary and the units are, therefore, dispersed throughout the good soil (cotton growing) area. Multiple cropping is, of course, practiced on these units, in the manner described earlier.

Until recently, there has been no government agency charged with or capable of planning or implementing irrigation projects. Project studies have been carried out mainly by consulting firms. Project implementation, however, requires government involvement. In the case of the program irrigating 100 ha. units from wells referred to above, the program is handled by the Central (National) Bank of Nicaragua, with help from a consultant on technical assistance. At present, a government agency for implementing new irrigation projects is being developed. Eventually, this should make it possible to implement larger scale irrigation projects.

Another government agency, known as INVIERNO, has been established for providing various types of assistance to campesinos, including extension, technical assistance and credit. It is partially supported by AID and, according to recent reports, is already providing positive results. Although the agency has much to do in areas that are not irrigable, subsistence farmers are also found in the irrigable areas with good soils. These farmers are limited by the lack of land (often less than 5 ha. and sometimes less than one ha.) and by shortages of education, capital, etc.

Extensive irrigation development in Nicaragua would relieve rural poverty in several ways. First, very small farms could be farmed intensively, with multiple crops, with adequate fertilizer use, etc., enabling the campesinos to produce some crops for sale. Secondly, multiple cropping on commercial farms would approximately double the duration of employment annually for farm laborers. Finally, irrigation development could facilitate land redistribution by making smaller farm units profitable. Thus, a landowner with several hundred hectares of cropland, now unirrigated, may be willing to sell a portion of it if assured of irrigation for the remainder. The portion sold would then be used for development of new family-sized irrigated farms and for enlarging farms that are too small even if irrigated. This would be an equitable program if executed properly. At the same time, it would lead to much more efficient use of the country's land and water resources.

X. SOME AID SPONSORED WORK IN WATER MANAGEMENT

COREY: I will start with explaining what some universities are now doing for AID in water resources. We have 211(d) grant programs with a consortium of five universities in the area of soil and water managment. This concept, I guess, was developed about six years ago in the AID's office of agriculture and started with three universities but is now up to five. These universities have formed a consortium called the Consortium for International Development. They have tried to break up different phases of what they refer to as the water chain. Each of these universities is involved in a different part of the water chain. The University of Arizona is working on watershed management but not necessarily agriculture watersheds. Utah State University's area is management of water on farmers' fields. Colorado State University is concerned with water delivery to the farm and removal of excess water from the farm.

The extension of these three grants are quite specific in the way these universities are linked with LDC's or with international centers or with each other. We are asking the universities to do some studies called "state of the art studies." "State of the art" is a critical review not only of literature but also of the actual practices being used. These studies are used to help identify problems. What Martin discussed yesterday with the Taiwan situation is a state of the art study.

The other two universities in this consortium are University of California at Riverside and Oregon State University. One grant was just made a year ago, and one of them is just in the process of being granted. The University of California at Riverside has a 211(d) grant in the area of dry land and summer rainfall agriculture. Oregon State University just negotiated a grant in dry land agriculture and the associated animal management, and for winter precipitation agriculture. The five institutions are all involved in water management principally at the farm level, including agronomic and engineering aspects of the management. They are going to do some studies together in countries where AID wants help such as sending a team to Kenya. We contact the executive director of the consortium and he gets maybe one man from each of the universities, or maybe all from one university. They may also get one from two consortium universities and one from the University of Florida or some place else.

QUESTION: Are all of the basic disciplines such as engineering, agronomy, soils, animal science, economics and sociology going to be involved in these studies?

COREY: I cannot say that all of these disciplines are involved in each of these institutions, although the economics, engineering and agronomy are.

The two research contracts given to Utah State University and Colorado State University are probably more important and more interesting to you. These contracts I am fairly familiar with because I worked on Colorado's contract for the past four years before I came to Washington. The universities were to do research on farm water management which would lead to greater production in LDC's. Utah State concentrated its efforts in Latin America while Colorado State concentrated principly in Pakistan. I really do not know why these concentrations, other than Utah State was involved in Latin America in other programs and Colorado State had been involved in other Pakistan programs.

Utah State has put a lot of effort in developing production functions for fertilizer, water, and for various crops. Their lawyers gathered together the water laws for a number of countries in Latin America. They had a rather large seminar last summer and published the results of their work. Utah's contract is a little different from Colorado's. Universities cannot go into any country without being sanctioned or commissioned. However, Utah State has been responding to mission requests to send people to Latin American countries so they have been in all these countries for various reasons. What research they do in a given country is dictated by what the mission and the ministry of agriculture wants done in that country. Generally, some institute will want technical help to do research in irrigation practices, irrigation methods, or production functions, and will ask us if Utah State can do the work within their contract. However, I would rather see them get involved in some things like Tom talked about this morning, namely, making some of their irrigation systems work better.

These two University contracts will run to 1976 and now we are trying to decide where we want to go next. This was one reason I was very happy to come to this meeting and hear your points of view, which I have to admit, I do not get enough of in our group. The Economics and Sector Planning Division sits down on the next floor and we sit up on our floor and we do not get together enough.

The program in Pakistan started out to be a program where we worked with various research institutes to do some specific studies such as managing saline water. Managing saline water is important because a lot of the underground water is quite salty and by mixing it with canal water it can be utilized. After I initiated these projects I found I was not being used full-time, so I developed another program. A pilot study on how to make these systems work better, was also developed. This was a system very similar to what Bill Easter described. For those of you who are familiar with the irrigation system in the Punjab in Pakistan, you know that there is not a headgate in that system which runs out to 50 farmers. The water flows all the time when there is water in the canal. If it rains and the water is up to the farmer's knees, he still gets water from the canal system if in fact the canal has water flowing in it.

There are now five men working on three projects, an economist, two agriculture engineers and two agronomists. This really has not been as successful as it could have been if we had gone there at the outset to set up a pilot study. The idea had to be first promoted with AID and then the government of Pakistan, because no university was working on these problems and we could not work within a country without having a project agreement. Much time was spent finding agencies who wanted to do something to improve irrigation. Then the agreement had to be moved up through the bureaucracy. But something significant has happened in Pakistan. There is now a concern in the Pakistani bureaucracy for doing something about their water management problems. Just going out and measuring water was a big eye-opener for them. They had read all the reports and the manuals which consultants had given them to help design their system. They said, all their reports and design manuals say that the losses in the ditch system is 10 percent. We measured the losses at 50 percent to 100 percent. They did not believe this. In fact, one of the chief engineers argued that it could not be because the system was designed for a 10 percent loss. Once they realized the magnitude of the water loss, they became concerned.

There is a great need for training in the field at a rather low level of technology. More is achieved than just learning how to measure water and how to survey fields. Once they see and understand why they are doing it, it is really thrilling to see them operate. They become just as enthusiastic as we do. If we just give them the manual or the mechanics of doing it, they do not have any trouble with it, but their understanding and incentives are not there.

In the fall of 1973, a seminar was held at Utah State called "Research Needs in Soil and Water Management." The results were put out in a rather neat package and some worthwhile concepts were developed. There is a great need to train technicians in the field where they will be working. Time is an important input to a training process. To actually get started requires people in a given place for quite a time. There also needs to be some concern by government at high levels. What Martin said yesterday is important. You need a concerned government. Many of these people who become good government planners pass through your institutions. I have seen several people who have gone through our universities and in a few years are in very significant places in government. We should also be thinking of seminars directed at rather specific topics such as how to improve or how to manage irrigation systems.

HAGEN: Part of our chief concern in the division of economics and sector planning is project design analysis. This means developing a logical framework with basic project goals and objectives along with outputs and assumptions. The function of our particular division is largely to fill the critical economics gap in AID. Existing divisions have a great many technicians in the physical science, soil and water, for example, but there is a serious economic deficiency in these divisions. For example, the lack of consideration for water pricing and the economic analysis of irrigation projects.

X. CONCLUDING DISCUSSION ON THE ROLE OF U.S. UNIVERSITIES IN TRAINING FOR DEVELOPING COUNTRIES

BROMLEY: It seems to me we are talking about training and education and research on two different levels. Tom's talk and Bill's discussion are really sort of at the manager level. Another kind of training and education is for the highly trained person who is going back to developing countries to play a role in natural resources management in general. I was wondering, do we dare consider splitting the group into two pieces and to talk about them separately?

ABEL: I think we have to. We really have two kinds of education roles. One level that we might call the field manager and the other level might be the research economist, university professor or high-level advisor in the government agency dealing with resource economic questions. Each person might want to address both levels of training in your comments.

CROSSON: Of the two categories of people, I am very skeptical that universities have much of anything to do with respect to the type of training Tom and Bill have discussed. It sounds as though the kind of training that is needed is for people who are going to actually manage the distribution of water at the system and subsystem levels. Some valuable things can be done, but I do not see the U.S. universities or other kinds of institutions playing an important role.

Let me say a little bit about the kind of involvement Resources for the Future has had. In one part of our program we put people in various places to work at a host institution, a university, where that person was expected to cooperate with host colleagues to develop a research program. In this way we hoped to stimulate interest in resource economics. We did this for three or four years and are no longer pursuing that phase of our work. I would have to say that on the whole we did not accomplish very much. The reasons are variable, but one of them is that we did not concentrate our efforts. We put one person each into several countries and that probably was a mistake. It probably would have made more sense to put two or three people in one country. Since we did not do that, we are now in another part of that program in which we work with essentially post-doctoral people in a number of Latin American countries. We encourage them by providing financial incentives as well as intellectual inspiration to do work in resource economics, specifically water and water management in agriculture. The first phase of that program has been completed and has some potential for showing results. The main problem for this program has been finding people with backgrounds in resource economics and water and it has turned out to be a major problem. I am not that familiar with other parts of the world, but in Latin America resource economics as a field of study does not exist. In order to find people to work with, we ended up working primarily with engineering types who had some economics background. They were not really economists and this has been a problem for us. We feel that the intellectual tradition these people have prevents them from seeing the problem the same way we do. Their approach is different and not really the most appropriate in the present circumstance. They emphasize technical aspects, the highly mathematical model building kind of an approach to problems with a heavy emphasis on hydrology. All the kinds of problems we have talked about the last two days tend to be overlooked and not even seen as problems.

Another major problem is keeping people interested in working in research. Because of the demands on their time to do other things either in government or in the private sector, it is hard to keep them on research projects. The U.S. universities might be able to stimulate and build an enduring capacity to do work in the field of natural resources in Latin America, but to do it we will have to think of a way to make it financially attractive to professionals, once they go back, to be involved in research. The fact is that at the present time there is not much individual pay-off to research in Latin America. We may have to train enough people so that we could lose a lot of them early because they are very valuable to government in decision making roles. If we really get enough people to serve in research positions, we may have to institutionalize the research so that when a person takes a job at the university, research institute or government institution, it is really understood to be a research job.

This is the way we at RFF have been trying to operate on a small scale. The small scale may be one of the reasons why we have had problems with it. People will, in all honesty, say "Yes, we are going to spend this much of our time doing this," but the fact is that they do not. Because of these various pressures that I am talking about, you need a university or special institution where people can go because they want to do research and there has to be a financial incentive to stay. Right now, that kind of situation is rare.

ABEL: Your observation about the lack of people trained in resources in Latin America would also hold for most of Asia. The economists are not trained in resource economics. The people we found that had some resources background were primarily engineers.

We have to think about training people in the context of working with a government, trying to get government to recognize the importance of the area. Just training a bunch of people and sending them home is disastrous, but the idea of training people systematically as part of some larger relationship could pay off. There are a couple of Asian countries that would hire resource economists. The ministry of agriculture would hire them and the national irrigation administration would too. In some places all you would need is to get them into government while they are being trained.

BROMLEY: I do not have anything terribly profound to say on the education. I am impressed by this group and my interest would be in getting this group together again in six months. The paths we have been going on are sort of independent of one another and we have not worked very closely. Here are three universities, Wisconsin, Minnesota and Iowa State, which are within a stones throw of each other. We do not want to exclude Washington, D.C. and Colorado from this little discussion, but with the proximity of these three schools and the history of our work in developing countries and in resource economics, it is a crime that we just never talk to one another. I do not know what else to say about it except that we should find some way for this group to stay in touch. We have had these ridiculous regional research projects sponsored by the Agricultural Experiment Stations for fifty years and I am not sure what they have done. If this group could get together once a year, we could outstrip their performance.

ABEL: There is a problem developing in regard to where the 211(d) grants are moving. It is now very difficult to obtain AID funds for graduate training of students from LDC's for research in their own country. Did your students all go back to their countries and are they now engaged in research?

BROMLEY: Most of them have gone back and in some cases there were no casualties at all.

ABEL: The Ford Foundation put an enormous amount of money in training people. There is a difference in return rates and it relates to how the universities select their students. We try to select students who already have established themselves in their country. Many times they are selected for us. The Agriculture Development Council and Rockefeller Foundation do an excellent job of selecting, so it is not "we". We gladly take the students they select.

How you select the student seems to me a very, very important step and this is the point I was making earlier. The linkages to an institution are more important than the training.

HOWE: I do not have any new insights to share, I am afraid. In terms of training, I certainly see these two levels of training in different countries depending upon their own heritage, training and background.

There is a need for people at lower managerial levels. People are needed who know how to organize repair facilities for tube wells or who know how to keep records for the geological survey. There are just many levels of technical skills that are terribly needed. The higher skill levels are also needed, but in a country which has very little in the way of educational institutions or training programs, the emphasis should be on technical skills. In all of their systems, agriculture, range management, water programs, transport and everything else, trained manpower is needed.

A country like Kenya, with a stronger educational structure and which has benefited from a lot more technical training inputs from many countries, needs people who have the capability of heading up planning teams: the kinds of people who would form a team to look in an integrated way at land and water resources and not formulate just a program, but make studies and continue an on-going evaluation of resources management. This requires a team approach and a set of people, each of whom has expertise in a particular area, but who can communicate his or her discipline to the engineer or economist or rural sociologist. Unfortunately, most developing countries seem not to be interested in this kind of education. For example, Kenya has rebuffed a number of times the efforts of foundations to improve their educational institutions and to provide a new program for training.

We cannot do things greatly differently than we have been doing. We have been giving them a solid background in theory and methodology and we can permit them to return to their countries to do their research. As John and several others brought out, the research should be relevant to their own continuing interests. We do have a fairly large number of foreign students at the University of Colorado, but many of them are sponsored in such a way that they cannot return to their own countries for research. Once in awhile you will get someone who does a thesis in theory and that is fine, but most do not have that interest nor should they. The student needs someone he can work with in his or her own country after going back. The students should be supported to do a meaningful piece of research that provides them with an entree into the profession in their own country.

We are not an agriculture school, but we do offer natural resources as a field of specialization at the Ph.D. level. But most foreign students do not take resource economics. A lot take economic development which of course deals with some of the same issues but certainly not totally the same. They also take macroeconomics, theory and policy control and monetary theory. Most of them leave without getting a good background in project analysis, let alone, resource development.

BUTCHER: I do not have the overseas experience to tie to, but I do have some experience in training students from LDC's. I discovered I have another relevant experience, I grew up on a farm that was at the end of the ditch. I know something about that phenomenon. We used to get an awful lot of irrigation water on Sundays and holidays and when it rained. A lot of water came down the ditch during those times. I also thought I observed in the discussion some similarities between some of the fundamental problems and principles that occur in irrigation and water control in developing countries. The rules of thumb that we have come to apply would not be appropriate. But if you get back to some of the fundamentals such as the incentives and the breakdown in the benefit and cost linkages to the person who is making the decision, they are very similar across countries. I see quite a bit of opportunity to help solve these water problems in LDC's and quite an opportunity to transfer experiences between countries. Linkages with programs and with institutions in these countries are very important to the efficient operation of an institution and in helping LDC's both in terms of the training of students and in LDC based research. Some of the topics we might look at include the pricing issue and the whole question of financing and repayments. These might be areas where some basic research could be done.

One of the real questions is the basic trade-offs between irrigation and other kinds of investment including the real uncertainty as to irrigation's actual value to a developing country. When I think back to the comments about environmental quality and some of the pollution problems, I do not have a very good idea of how important they are. What kind of trade-offs ought to be made between environmental quality and other resource uses? The trade-offs are likely to be different because of the different income levels, kinds of technology and cultures. It is a place for some basic investigations.

WICKHAM: I would like to comment on what International Rice Research Institute (IRRI) is hoping to do. To begin with, I want to explain some of our plans in the water field. First, one of our ways of operating is to try to have a pilot project which actually implements some change in the field. We then assess its impact both in terms of inputs and outputs to estimate the costs and benefits. The first part is really a training program at the lower level. The second part is tied to research and a training program at the academic level. The way we operate, it is hard to distinguish between the two types of training. We would tend to use graduate students doing thesis research on the academic side. We would tend to use local people, employees of the area or employees from the irrigation agency to do the other training part of it. There is a great deal of overlap and it is hard to clearly differentiate these two training roles.

In the past, the water management work has been a part of the economics department and that is why we can say a little about resource economics. I am sure that it will continue, although I suspect in the future there will be a little more separate focus on the engineering and economics. I do not think this will create any problems as long as Randy Barker is there to direct the economics.

In the future, there are two or three new developments that I hope we can achieve. One of them is to begin studies roughly comparable to what we are doing in the Philippines in some of the following countries: Thailand, Indonesia and India. I am thinking in very modest terms and am quite attracted to Bill's comments on trying to train 25 people and being a little bit unsure if even that was pushing it. In a lot of discussions, if you say 25 people, they kind of ignore it as being out of the question. When I look back on two or three years of my own experience at IRRI, I cannot even say we trained 25 people. Therefore, I am quite mindful of the limited volume of people who can be trained if you are really going to try to teach technological skills and get competently trained people. We hope to start pilot field projects over relatively wide areas looking at different levels of intensity of water management, highly intensive water management, moderate levels of intensity and low levels of intensity. We would look at the investment costs for each.

Another idea we would like to try would be to demonstrate to irrigation agencies the feasible improvements to existing management. You can talk all you want and write articles about it but until you can demonstrate improved management in the fields, they are not going to listen to you and they should not. We have collected quite a bit of data the last couple of years, partly from the water response model that Martin discussed yesterday and some other distribution work we are doing along canals. We would like to try to construct this water response model, not out of research data, but from field data. However, there are a great many impediments in doing that. This model hides a tremendous number of assumptions which we sweep under the rug but they have to be swept out again. Our possible involvement with other agencies includes quality graduate students to help us do this work.

One thing that bothers Randy Barker and myself is that we are not always able to get the highest quality graduate students to work with us in our research. Consequently, one area of possible collaboration between ourselves and universities might be good graduate students who are looking for opportunities to do research in Asia. We could handle a quite limited number of students. We would not, generally, be able to help them in their course work. The course work would presumably be done in the U.S., although there is a university right next door to IRRI with a number of people who have done or are doing their Ph.D. work. One qualification is that we would find it very difficult to support American graduate students. What we would look for would be Asian students studying in the U.S. who might be looking for an opportunity to go back to these countries to work. If we would start these projects in Thailand, Indonesia or possibly India, citizens of those countries would be the most logical people to invite. And at the present time, we do not have a good supply of trained citizens from these countries.

We are now trying to establish a network in Asia to consider irrigation problems. We will be having a seminar in April or May next year. We hope to have a regular system of communications in the region. There might be a way to relate the communications network with some of the things we have talked about.

There is one other angle I ought to mention: the institutes really do not do very much in trying to implement our research ideas through national programs. We do not feel we are in the position to do it. This might be a role for AID or maybe a university which would go the next step.

GREGERSEN: I see three levels of training based on my experience with forestry in Latin American countries. The management technical level is not very important in forestry. Then there is the higher level of training, and here, again, at this stage this kind of an individual is not needed in forestry. The area in between is the most important in forestry and I am trying to aim my program at this level. We need project analysis but not at a sophisticated level. The person has to know how to do simple things. Thus far, we have had four students go back to Latin American countries and they are all working with U.S. industry. One of them has just gone with FAO. The point that Abel made earlier is important. These students did not have the government affiliation to go back to and do research. I have a student from Ecuador who is tied very closely to his forestry agency or institute and will be going back, I am sure. I just returned from Guatemala where they have very capable management technicians and very sophisticated planners in the forestry institute. But in between the project level and project identifying, there is nobody in economics in Guatemala who is doing or can do the project analysis.

TIMMONS: First I would like to identify the changing environment in which the universities are functioning today and which may well persist in the years ahead. I jotted down seven points which I have thought about off and on over the years when I have been in other countries. One is the need for our courses to shift their content very definitely to the LDC's problems, particularly if as many as 48 percent of the graduate students in certain economics departments are from other countries which is the case in several U.S. universities. Second, we have to give more attention to the applications of our knowledge to problem solving and less to elaborate national and sectoral models which we are trying to force upon a number of countries. Third, we are going to have to put much more emphasis upon institutional change. This we know dangerously little about, because the kinds of institutions being formed in developing countries are quite different from what we have. People who take preconceived concepts of private property or family farms,as we know these concepts, to the LDC's had better stay home because they are going to become frustrated and possibly neurotic. Fourth, there are increasing numbers of agencies, universities and countries working in less-developed countries today. You go into a country and there will be representatives of numerous other countries working there. We rank about 16th among the countries of the world in terms of the proportion of gross national product devoted to constructive technical assistance abroad. Amounts of U.S. assistance we see in the Federal reports and news media include the destructive technical assistance. The armaments component of U.S. aid is difficult to disentangle within the total aid package. But we rank very low, and we are going to get lower the way things are going.

The fifth condition I sense as part of this changing environment is that we are going to have considerably less funds and fewer foreign students to work with in years ahead. We are going to have to adjust to these kinds of conditions. Sixth is the tendency for U.S. universities today to turn away from LDC's and to work more on domestic problems. This is going to be all the more true if the financing drops. Professors are going to research topics and teach courses in subject matter areas with financial support for their research and graduate students. Seventh, there is a latent although very fundamental U.S. trend toward recognizing the importance of natural resources in developing food, fuel and shelter, and in helping satisfy balance of trade problems. Given these conditions, the need for trained people remains the scarcest resource (even including water) in the LDC's today. Relevant knowledge and its adaption to local conditions in LDC's also remains an extremely scarce resource.

I become bothered when I hear the AID regional bureau chiefs and country directors refer to such things as 211(d) grants as university handouts. I am also bothered by the university's failure to adjust to the realities of the situation that exists today and into the future. Looking at this matter more positively, the university's mission remains basically (1) generating knowledge, (2) communicating the new and the older knowledge, and (3) within a framework we have never really done much about--"science with practice". We do a lot more with the science or research part of the motto than we do with the practice or utilization part, although our experiment stations and extension services are involved heavily domestically with this practice or utilization area. These are concepts that AID personnel have been voicing lately, although I am not sure how well they comprehend what is meant by utilization and linkage modes. But these are important concepts.

How do we start reorienting ourselves to serve these three missions or functions? Are we going to continue our on-campus training and research of foreign graduate students within an essentially national mold? Or are we going to adjust to the needs of foreign students or else discourage their admission? In terms of courses we have set up so many prerequisites that students cannot take the courses they need because they are cluttered up with prerequisites. We are going to have to follow a model some of the universities tried to follow in the water resource program financed under the 1964 research and training act. I was on a committee that abstracted courses from twelve different departments. We took the parts out of these courses and made them into a series of three courses which do not have very many prerequisites. A very interesting thing happened when we took the hearts out of all those courses; there really was not much left for the prerequisite. Some of these sacred courses have to be redone.

The off-campus training, research, and application can still be served to a degree by students working together with professors as teams. But we have another task of back-stopping the students who have returned home to the less developed countries and who urgently need help occasionally but do not have access to it. Our students in the U.S. can telephone us or see us at professional meetings or see other people in other institutions, but this does not happen in the LDC's. This is quite a serious problem because they are isolated and require further help as needed.

We still have a job of assisting the universities in LDC's but I am becoming somewhat dubious about the success of these efforts particularly in Latin America where I see a fine institution grow up and develop, and then be dispersed and neglected. In some of these countries we have to recognize that the place to help and work is not necessarily in the universities. The governments themselves provide opportunities for us to make our contribution, particularly in special educational training for middle-management and research.

I might conclude my comments with six recommendations. Do not take these very seriously but I always like to end on a positive note. One, I certainly agree with Dan, I found this conference extremely exciting and informative and I have gotten a lot out of it. These are the kinds of stimulations we used to get from the old regional committees. Second, we have to expand this kind of a dialogue process we have been going through here in a seminar environment to some of our colleagues in the developing countries. It is a little bit strange, here we are, essentially a group of U.S. citizens talking about the problems of the developing countries and only one person here is from an LDC. There is real danger in relying on the second-handed facts which we have gathered while wandering around the world for the past two decades. Third, our universities might start specializing a little more on problem areas or geographic areas, although I would not neglect the virility of the basic disciplines and the open-door policy of admissions. This is what helps make a university, the universality of students from different countries, a world on the campuses. But, we are probably going to have to specialize more. Fourth, I recommend that universities work together in resource economics, although there might well be a division of this specialization by countries. Fifth, the U.S. and state extension services should be used to a greater extent in educational efforts within the LDC's. Finally, if the U.S. universities are to continue their teaching and training of LDC's students, funds must be made available by the federal government. Assistance to LDC's is more of a national than a state funding responsibility albeit the nation's most valuable education capabilities reside within the universities of the states.

GOLAN: There is a wealth of things that U.S. universities can do. While they can not provide people from LDC's with everything they need to know about particular jobs when they go back home, they can provide them with knowledge of specific facts relevant to their particular countries. Learning experiences which help them learn how to think about problems and judge which facts are relevant to particular situations are very important. Some basic theoretical concepts are also useful. Students should also learn how other countries have dealt with problems similar to theirs. There are really a lot of things the university can do. The main problem is not what can they do, but how are you going to finance such training?

I noted several speakers saying something about training people to go back to their countries to work. When you talk to officials from LDC's, they want more positions for their nationals in international organizations. They think that not enough staff from LDC's are presently serving in international organizations. So, it is not only the individuals that want to work overseas, their country too may encourage them to do so. It is not too bad because they get good training and quite often go home later. We need people from LDC's in international organizations and, therefore, you are not doing a disservice to people if they stay here after you have trained them.

International lending institutions like the World Bank look to universities, Rockefeller Foundation, IRRI, etc. to develop the ideas. What the World Bank can do is pick up ideas that somebody else has developed and then put some money into developing and expanding them.

What Tom was telling you about the water management projects is a good example. The minute we are convinced something like the water management projects make sense, we are willing to help train the staff required for the projects. At the same time, Bill was talking about his experience in India which highlighted some of the problems we have to face in constructing projects which are often large projects. We have to try and find a way to rebuild these projects in the quickest and most feasible way. Maybe we are picking the wrong projects. However, once they have been picked, the best possible project design should be adopted, and for that we need a large amount of training built into the project. We can set up technical training for the implementation stage.

The resource economist will be needed before the project has been selected. You need him to force the engineers and the agronomists to look at alternatives such as different construction methods and different implementation techniques. Once the project has been selected and the implementation starts, that is when you need the technically trained people to make the project run. The resource economist still has a role in the implementation stage, but the technical people have a bigger role. You in the U.S. universities have collected a tremendous pool of valuable information. The studies and the training that is provided is appreciated in most places. We at the World Bank definitely realize it. One of the reasons I am here is to find out what is available so we can make better use of it.

One of the problems that the universities face, and it is not a new problem, is that many people from LDC's want to take advantage of the facilities being offered but do not have the funds to pay for such training. This is not limited to the universities and is an increasing problem around the world.

MARTIN: Nobody has really gotten out of the lip service stage in looking at income distribution. It seems to be a bigger problem for the resource economists and agricultural economists. For example, what does it mean for income distribution if we build a big irrigation project and let the present land owner capture the benefits? Will we make the assumption that we will get efficiency first and then straighten out the income distribution? It may be easier to buy up the land before the irrigation project and design the whole project in 10 hectare farms. Otherwise you have a hard time ever getting the land into the hands of the small operator other than the small tenant. There is a great deal of foundation work that needs to be done by resource economists on these income distribution questions. If we do get together again, income distribution is something to put on the agenda. It is different than anything else because we are not going to get a chance to go to Thailand or the Philippines and study income distribution. The most we can do is train some students to go back and work on the problem.

COREY: The workshop has been very productive. If there is another one, I would suggest bringing in some more problems from other LDC's. I know that a number of AID people in our programs would have both benefited from and made some valuable contributions to this workshop.

ABEL: I would strongly endorse that idea. We need to both expand the scope of people from the U.S. and bring in people from LDC's. Furthermore, I hope we will have the opportunity to continue this kind of interaction. We owe a special appreciation to Chuck Howe and Gil Levine and Tom Wickham for taking the time to prepare the papers. Having the papers was a very useful way to structure and focus our discussion. We thank you all for coming and making the two days extremely interesting. John is absolutely right, it is going to be hard for those of us interested in resources to find money even for small programs. However, one gets the impression that each of us here somehow or other will be involved, whether it is in India, the Philippines or someplace else. I would hope that we can stay in touch and bring more people into this kind of network.

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