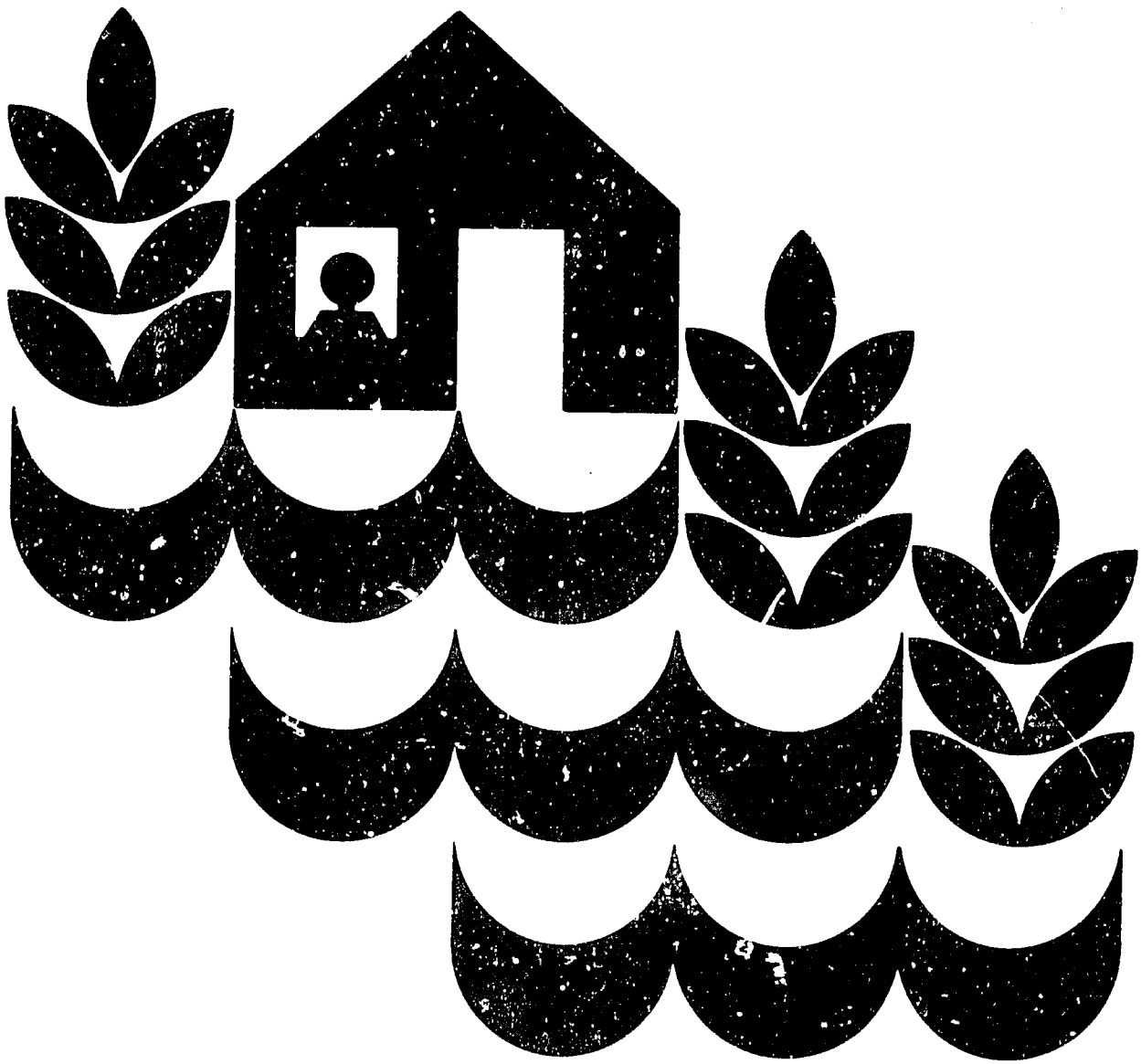
- PN-AAT-992

SMALL FARM, SELF-HELP IRRIGATION PROJECTS

HANDBOOK NO. 4

Water Management Synthesis Project



SMALL FARM SELF-HELP IRRIGATION PROJECTS

Bertis L. Embry and Nancy L. Adams

HANDBOOK NO. 4

Prepared in cooperation with the United States Agency for International Development, Contract AID/DSAN-C-0058. All reported opinions, conclusions or recommendations are those of the author (contractor) and not those of the funding agency or the United States government. Mention of commercial products in this publication is solely to provide information. It does not constitute endorsement by AID over other products not mentioned.

WATER MANAGEMENT SYNTHESIS PROJECT

Agricultural & Irrigation Engineering
Utah State University
Logan, Utah 84322

Engineering Research Center
Colorado State University
Ft. Collins, Colorado 80523

December 1983

FORWARD

Small Farm Self-Help Irrigation Projects is the fourth handbook in a series for the purpose of improving water development and irrigation water management. Emphasis is on the developing countries.

This handbook follows the history of development of a successful small farm, self-help irrigation program currently being carried out in Guatemala. The principles and procedures which resulted in project success are presented along with the actual experiences from the Guatemalan story, as narrated by Dr. Bertis L. Embry, Project Advisor, to illutrate them. Next the tasks or elements which must be considered at each phase of development are presented to facilitate the application of self-help principles by the users of the handbook. Finally, possible resources that may assist the developer in carrying out the tasks are suggested for each of the principles discussed.

The handbook is written as if certain principles or steps must be completed before the others are begun; however, as with all guidelines, the ones suggested here must be creatively adapted and fitted to the existing environment. Thus, the handbook is designed to be of practical use to anyone wishing to promote a successful self-help program.

We would appreciate hearing from you concerning your experiences in using the handbook. Information about other technologies that have been successful under the particular conditions in your country are welcomed, also.

TABLE OF CONTENTS

INTRODUCTION

In 1976, what turned out to be an extraordinarily successful, USAID-assisted, Small Farm, Self-Help Irrigation program was started in Guatemala. The Guatemalan Agricultural Development Bank made loans to organizations of farmers for the purchase of materials. All labor was furnished by the project farmers. Engineering design, construction, supervision and instruction on system use were furnished by the Extension Service of the Department of Agriculture through loans made to the Guatemalan Government.

By 1981, 40 small irrigation projects serving 2000 farmers had been completed. Of these 40 irrigation systems, 17 also provide potable water for the water users. Most of the projects are gravity operated sprinkler systems constructed at an average cost of 600 to 800 dollars per hectare for the main line and all on-farm irrigation equipment. These projects promoted crop diversification, with fruits and vegetables augmenting and replacing production of the traditional corn and beans. Average farm incomes increased two to five times and more.

In the highlands of Guatemala, farmers can raise three to four crops of vegetables per year under irrigation but only one crop under natural rainfall farming. Production of tree fruit and small fruits such as strawberries or blackberries can also be improved by irrigation. With diversification into fruits and vegetables in addition to the traditional crops of corn and beans, the farmers reported increases of their income from the land by two to five times and more, provided labor opportunities for themselves and their families and decreased the necessity of going elsewhere to work.

An added benefit, where the source of water permitted, was potable water for the farm home. Where the water was potable, a faucet was put in each family's patio within the project. Pure water, as well as the added nutrition due to crop diversification greatly improved the general health of the communities served.

The funds for the Guatemala program came from a loan from the U.S. Agency for International Development to the Guatemalan Government. The Guatemalan Agricultural Bank of Development made the necessary small loans at low interest rates to the groups of farmers. The Inter-American Development Bank is interested in making loans to continue and expand the development in Guatemala.

Experience indicates that similar farmer self-help projects are possible in many parts of the world. On that basis, this Handbook has been prepared to share the concepts and techniques that were successful in the Guatemalan experience. The hope and expectation is that the material in the Handbook will prove useful and beneficial in guiding others who are developing similar programs throughout the world.

PRINCIPLE 1: IDENTIFY THE WATER AND LAND RESOURCE AND DETERMINE ITS POTENTIAL FOR INCREASING AGRICULTURAL PRODUCTION

"While working in Guatemala on a research project with Utah State University, I was asked to visit various parts of Guatemala to learn if it would be feasible to build small irrigation projects for the farmers who have small holdings. In the course of these visits, I saw many places where it would be feasible to provide water for the farmers to irrigate. The farmers themselves were irrigating in very few places in the country, and based on the observations I had on sources of water and location of the water with respect to farms, we decided that it would be feasible to build irrigation systems for these small farmers."

To Be Found

One or more areas of the country, if any, which are suitable for such a project.

Elements to be Considered

1. Check potential sources of water for quantity, reliability, and availability.

2. Check the water supply for excessive salts. This can be done with an electro-conductivity meter. If there is any question or if the preliminary check has a very high reading, the water should be sent to a laboratory to determine the quality. Usually, in mountainous areas where most of the water comes from rainwater that has been stored underground, there is little problem with the salt content, but if the water does run through a

salt bed or place with various problem salts, it is important to know before any development starts.

3. Study the weather patterns, including rainfall and temperatures, to determine the suitability of year-round irrigated agriculture and/or cultivation of higher value crops.

4. Determine whether land is available for use under irrigation.

5. Carefully study the soil types and the topography to see if the soils are suitable for irrigation.

6. Determine what crops can be cultivated, the time of year they can be cultivated, and evalute the possibility of shifting to a more intensive agriculture under irrigation. A change in cropping patterns, including a change in crops grown, or a change in time in which the crops are grown, or both, may be possible.

7. Identify possible benefits and interests of farmers in participating.

8. Check for possible drainage problems that may affect continuous agriculture under irrigation. Projects have been built which have been rendered useless for agriculture within a very short time because of the accumulation of salts. If there is a problem to begin with, it can often be solved by installing a drainage system at the same time the irrigation system is built so the excessive salts can be leached out of the soil and disposed of.

Possible Resources

1. Topographical maps including contours and showing features and streams.

2. Land ownership maps or plats, if available.

3. Soils maps and other soils data.

4. Climate maps and other climate data.

5. Interviews with experts acquainted with the country.

6. Field visits with farmers and local officials.

7. A similar, successful project near the proposed area.

PRINCIPLE 2: IDENTIFY POTENTIAL BENEFITS TO FARMERS, LOCATE FARMERS WHO CAN PARTICIPATE, AND STIMULATE ACTIVITY!

"Small farm irrigation development must be done with the farmers themselves. Every village or area will be different, so it is difficult at the stage of the preliminary investigation to find out just how widespread these developments might be. We found in Guatemala that most of the villagers were so negative toward the government assistance that very little could be accomplished until one pilot project was built to be used as a demonstration.

"Farmers may have a negative attitude toward any kind of development if they have been disappointed previously by inadequate or inappropriate governmental assistance.

"In later stages of the work done in Guatemala, the farmers came to us asking for the projects. Almost invariably, they were the community leaders, the ones the farmers looked up to. If the farmers voted or asked a committee to ask for a project, the leaders in the community were always chosen to do this."

To Be Found

One or more groups of farmers who are interested in participating in a self-help irrigation program.

Elements to be Considered

1. Check whether the development seems feasible from an economic viewpoint: Are markets available? What is the likely income from the crops? Are there storage facilities and transportation available and adequate? Can the farmers get credit if and when needed? Are other inputs available when needed and at prices farmers can afford?

2. Determine the probable costs and benefits to the farmers.

3. Find and interest the community leaders in participating in the project. It will quickly be apparent who the leading farmers are. They are normally the spokesmen for everyone else. They are the ones to whom the others look up and follow. If you ask somebody who their chief is, they will usually tell you who the leading men in that community are.

The leading farmers may or may not be the political leaders in their own communities. Sometimes they are because they are the ones who get designated as the auxiliary mayors or representatives of the next level of government above them. Usually, these people have had more education than the normal person in the community, but not always.

4. When going into a village to start a project, it is usually best to call a meeting and have people tell you who are the ones in their community who get things done.

5. Enroll the leading farmers in participating in the project. Talk to the farmers and explain the program to them. "In the case of Guatemala, it was explained that money was being loaned to the Guatemalan Government for the express purpose of improving the irrigation and the cropping patterns for the small farmers in the country. The farmers were also advised that the irrigation water was to help them raise crops that they had not ordinarily produced and was to allow them to crop their land the year round. It was also explained that the money would be loaned to them for periods of one year up to 20 years and that they would be required to repay the money in yearly installments after their project was in operation. Also explained to them was the fact that they would have three years of grace, during which no payments would have to be made although the interest

would begin at the time the money was borrowed. The interest rate was set at two percent per annum.

"The farmers were told that they would have the services of engineers to make the surveys and make the designs, to prepare the bill of materials, and to supervise the construction, but they would have to do all the work themselves and no money would be loaned for labor in any part of the project. This was to let the farmers know that it was their project. They would have to build it, and after it was built, they would have to manage it. They would have to repay the loans that were made for the purchase of materials for the construction and maintain and operate the project on their own.

"The farmers in Guatemala were used to planting corn and beans, and they realized that with the crops that they were then growing that the income, especially the cash income from those crops, would not be sufficient to repay any loans. They were very dubious about borrowing money. They were especially afraid that if some kind of mortgage were put on their land and they failed in their payments, their land would be taken from them. This is always a problem with small farmers, especially in areas where no titles are recorded, and it is difficult to get people to change what they have been doing for years because of fear. Another fear is that if they should have a crop failure in a new cropping system, they wouldn't have food for their families. They know that what they have been doing works and at least they have some food.

"We discussed with the farmers the potential benefits of using the new system. We also discussed with them the idea that they should not change their traditional cropping patterns immediately--that they should change

gradually, that only as they learned should they change over completely to an irrigated, year-round agriculture instead of the traditional crops that they have been growing.

"The farmers had very small holdings of about one-quarter hectare, and it was recommended that they start out with one cuerda[1] or a half cuerda for their first cropping season and then gradually increase as they learned how to farm successfully with irrigation."

6. Have farmers choose to participate in the project. "We estimated the change of crops and what the value would be. For example, we took some base figure like 20¢/doz for carrots and 10¢/head for cabbage. We used the values that were common for these crops. However, since the farmers could grow the crops in the "off seasons," they almost always have earned much more than we estimated."

7. Proceed to obtain funding for the project.

Possible Resources

1. Any organization already in use for communicating with farmer groups, such as the existing extension service, traveling schools, religious leaders, radio, etc. Choose to communicate through the network the farmers trust most.

2. Groups of farmers which are already organized and working together.

3. Farmers who are already irrigating and realize the benefits and requirements of irrigation.

---

[1]Land in Guatemala is measured in cuerdas. A cuerda is approximately one-twentieth of a hectare.

4. Review the project plans and purpose with the leaders of local governments. They may be able to influence the higher levels of government if there is really a need for, and an interest in, irrigated agricultural development.

Finding Participating Farmers

"In Guatemala, we had the most success in contacting farmers when we attended what they call traveling schools. In the traveling schools, we were given a block of time of 15 to 60 minutes to explain the program offered. Often we had a lot of inquiries after the school was over from interested farmers. In many cases they did not have much confidence that anything would be done, so it was very difficult to get the people interested. It took six months to locate the first group that were really interested and ready to go. This group represented some 17 farmers in the village of Santa Rita in the municipality of San Marcos. This group of farmers had already obtained the right to the use of the water by buying the right of access from the land owner to go on his land to take the water."

PRINCIPLE 3: DETERMINE A SOURCE OF FUNDING WELL IN ADVANCE OF ANY FIELD WORK

"The initial proposal for the small farm, self-help project to AID Washington contained designs of several different types of small irrigation systems based on actual field observations. On the basis of those designs and the other material furnished by AID Guatemala, the project was approved in Washington D.C., and about a year and a half later the project was ready to start.

"The irrigation project was combined with a soil conservation project and a conservationist was assigned as advisor for the project's soil conservation program. I was assigned to be the advisor to develop teams: (a) to build the irrigation projects, and (b) to teach the farmers how to use them."

To Be Found

A source for financing to pay for all technical assistance plus monies for loans to farmers as needed.

Elements to be Considered

1. Check whether the farmers are able to finance their own irrigation system if technical assistance is provided. This usually is not possible for farmers having very small holdings, so other sources of financing will probably be needed.

2. Check whether the national agricultural development bank has funds available from the national government or may obtain loans from other countries for short-term and long-term financing. Arrange to have the

funds be made available on a longer term basis, because the cost of an irrigation system is usually too much to expect the farmers to pay off in one crop season. This is especially true where most of the farmers have not used irrigation previously.

3. Keep searching until a funding agency is found, in most countries various groups are already operating, and one only needs to find them. Institutions such as churches, the Rockefeller and Ford Foundations, other large charitable institutions as well as the government and international donor agencies have funds available that can be used for imporving the lot of the small farmer.

Possible Resources

1. Government support is usually needed to find or develop sources of funding and to insure the funds reach the farmers.

2. Various sources of funding may be explored including:

--Farmers' personal resources

--Private banks in the project area

--Government development banks

--World or regional development banks

--United Nations

--Foreign government assistance

--Foundation, church or other philanthropic organization assistance.

PRINCIPLE 4: DEVELOP A PRELIMINARY PLAN INCLUDING COSTS ESTIMATES FOR PRESENTATION TO FUNDING AGENCIES AND FARMER PARTICIPANTS

"In the Guatemalan project, we were putting in irrigation systems in mountainous terrain, so we used gravity-operated sprinkler systems. The pipelines, sprinkler pipes or hoses with sprinklers were all part of our cost, and we found we could do this for 600 to 800 dollars per hectare which was quite reasonable in light of all the estimated returns. This did not include the cost of labor, because the people supplied their own labor to do the job.

"A typical farm in the highlands of Guatemala is approximately one-quarter hectare. Many families do not have that much land, and a few, of course, have quite a bit more.

"In areas that had a limited water supply, the resource was distributed so that each family was allowed to irrigate the same amount. The shift to irrigated agriculture, with fruit and vegetable crops, enabled the farmers to pay for the system in a relatively short period of time. On no project in Guatemala, did the farmers ask for more than a seven year loan."

To Be Found

Availability and adequacy of resources needed for project success, including an estimate of the costs and benefits for participating farmers.

Elements to be Considered

1. Carry out preliminary engineering surveys.

   a. Engineers involved in system design should walk over the proposed project and make a preliminary evaluation of feasibility.

b. Check in detail the suitability of the soil for irrigation, the mircoclimate of the area involved, the possible crops that can be grown, and investigate the marketability of those crops.

c. Determine the location of the water source, along with its route of delivery to the area to be irrigated. Determine the quantity and quality of the water--consider seasonal variability.

d. By observation and study of available maps, the design engineer should determine the kind of conveyance system and structures and the proposed method of irrigation. Steps 1-4 may have all been done in the preliminary visit as outlined in Principle 1; however, unless the design engineer was involved in that first visit, the design steps should be repeated.

e. Study the best time of year to do the work and estimate when the project will be ready for use. Time is required for surveys and designs and for construction.

If detailed maps of the chosen site are not available, a survey will have to be made. The size and complexity of the project will dictate the extent of the survey. Usually, both horizontal and vertical control will be necessary. If it is a very simple project, finding the differences in elevation with a hand level may be sufficient. If the project is quite complex, a complete map of the area may be needed, together with a line for the canal or pipeline.

2. Develop preliminary designs and cost estimates.

a. Base the estimates on similar projects that have been built. The estimates are needed so the farmer participants can choose whether to supply the money themselves or to borrow in order to complete the project.

b. Include estimates of the materials and labor costs, although the latter is to be supplied by the community. Obtain community acceptance of preliminary plans and cost estimates before going into a great deal of trouble to make a complete design. By studying existing projects and the costs they incurred, and checking the availability of materials required for the proposed project, one can usually arrive at a cost estimate within 80 or 85 percent of the actual cost. It is better to over-estimate the cost because farmers will accept a reduction much more easily than an increase.

c. Include the following in the proposed operation plan: specify the crops that can be grown; the advised cultural practices, types of fertilization, and pest control. The proposed irrigation schedule should always take into account the farmers' current practices. A gradual change from current practices to irrigated agriculture may be an advantage. Sometimes this is impossible, and a complete shift-over is required when the irrigation is started.

d. Anticipate potential problems as well as benefits so the farmers can know about them and have a sound basis for deciding whether to approve or reject the project. It is essential that the farmers themselves approve what is to be done, because without understanding they will not be nearly as willing to build the projects as planned.

3. Carry out a market survey and analysis.

a. Study the available market before the preliminary plan is presented to make sure the farmers will be aware of what produce they can sell, where and for what prices.

b. Study the road conditions and transportation facilities for

taking the products to market. Under an irrigated economy, especially in newly irrigated areas, the amount of production may be a lot more than the farmers are used to, and their traditional method of transport to market may not be adequate. There may also be instances where new or improved storage and processing facilities are needed. Again check in enough detail so some idea can be given to the farmers of what they can do with their crops.

c. Determine whether the farmers can sell their products at wholesale to a jobber for transportation to and sale at retail markets, or the farmers may want to take over the whole marketing process themselves and sell directly to the ultimate consumer.

d. Determine what crops the farmers are cultivating and the time of year they are planted and harvested. Evaluate the possible outcome of shifting to more intensive agriculture under irrigation and of changes in cropping patterns, including changes in crops grown and changes in times of planting and harvest.

4. Check the farmers' property and water rights.

a. Determine whether the local farmers own or rent their land.

b. Determine whether the farmers have titles, and if not, whether they are long-term residents. Unless the farm community does its own financing, some kind of land registration or recorded land titles will be needed. Titles or deeds may not be recorded, so some system of a written record of ownership may have to be made. In Guatemala, the farmers were asked to register their property rights with the nearest municipality. In this way, if there were any question, at least some form of property ownership had been recorded.

c. Determine what the water law is and if farmers' rights have been or can be established. If no prior rights can be determined, be sure to obtain permission from the local authorities to use the water source for the project. Do this well before the project is started. Make sure this permission is recorded, possibly in the minutes of the local municipality, so a permanent record of the date of water use is established.

d. Identify any prior rights to the water, and either purchase or satisfy these rights by delivery of water or by some other means.

5. Develop a linkage with the extension service, because the farmers will need education in the new practices. Extension staff are needed so the education program in each participating community can be undertaken simultaneously with the engineering and construction phases of the project. Where these two phases do not take place simultaneously, the farmers will be ill-prepared to use their system once it is completed.

6. Involve participating farmers in the planning process. The leaders need to know what is being planned. It is advisable to obtain their advice and consent before the planning has gone too far. If the leaders have participated in the planning and are convinced the planners are doing the right thing for the community, it will be much easier to sell the project to the members of the community. If the leaders are not convinced, it is very unlikely the project will ever have any measure of success.

7. Check the farmer attitudes and the possibility they can and will work to improve their farming practices.

8. Determine: (a) whether this group of farmers qualifies and (b) whether it chooses to participate by supplying the labor for construction and by borrowing money or otherwise obtaining money to pay for the materials.

9. Identify a sponsoring organization in which the administrative and technical functions of the project can be housed.

Possible Resources

1. Local, regional, and national agencies may have resource information including maps, soils and climate data.

2. Appropriate government ministries and local offices.

3. Farmers and local officials.

4. Local businessmen, perhaps also national and international business enterprises, depending on the crop and the anticipated market.

5. Agencies which record water rights and property rights.

6. The Extension Service.

7. Where some farmers already irrigate, a reasonable evaluation of the likely success of an irrigation development can be made by visual inspection and by talking to long-time residents. Where there is no history of irrigation, it may be very difficult at first to evaluate exactly what a new development might produce. With irrigation, the whole agricultural pattern may change, and a previously unproductive area may become productive. A change of crops should bring beneficial economic returns, especially in areas that have desert-like conditions. Benefits should also accrue in areas having a distinct dry season during which the climatic conditions are such that crops can be grown.

"For example, in the highlands of Guatemala, the traditional crops are corn and beans. Most of these are used for local domestic consumption in the homes of the farmers themselves. Farm plots are usually so small that there is very little production to be marketed. By encouraging the farmers

in those highland areas to shift from the traditional corn and beans to a vegetable and fruit economy, it was possible for them to have two to four crops per year on the same land. In some instances, they were able to raise the net return from their crops grown as much as five to fifty times over their return on the traditional crops. Climatic conditions, availability of markets and the interest of the farmers themselves in intensive agriculture will determine the return. Therefore, investigate these factors first, so the planners and farmers will know what to plan."

PRINCIPLE 5: IDENTIFY A SPONSORING ORGANIZATION WHICH IS COMMITTED TO WORKING WITH FARMERS TO IMPROVE AGRICULTURAL PRODUCTION AND MARKETING

"The irrigation team was under the Agricultural Extension Service, primarily for administrative support. The staff members were assigned to that office, but specifically they were assigned to the irrigation group. The Extension Service was chosen because they had the most contact with the farmers. They supplied logistical support such as offices, payroll services, gasoline dispension, vehicle repairs, supplies and equipment.

"The members of the irrigation team were usually hired for their specific jobs. Clerks, secretaries, and others, who worked only in the office, were transferred between the irrigation teams and other functions in the extension offices.

"Irrigation teams were organized to work with the farmers. An irrigation team was to be comprised of either a Civil Engineer or an Agricultural Engineer capable of making hydraulic designs for canals or pipelines or other means of conveying water, a draftsman, secretaries and other support people capable of makng surveys or helping with drawing the maps after surveys were made by other groups. The people working on these teams were assigned to the extension service office to work with the small farm irrigation projects. All personnel hired or assigned, whether they were engineers, draftsmen, secretaries, chauffeurs, or agronomists were members of the team. There was a job description for most of the positions, and people were hired or assigned on the basis of their ability to do the job."

To Be Found

An organization which will provide administrative support (a home for the personnel working on the project).

Elements to be Considered

1. Evaluate the organization's commitment to the welfare of the small farmer.

2. Determine the organization's commitment to self-sufficiency for the small farmer.

3. Investigate the organization's flexibility in adapting to the requirements of the project administration.

Possible Resources

1. Extension Service.
2. Irrigation Ministry or Institute.
3. Private voluntary organization.
4. Religious organization.

PRINCIPLE 6: COOPERATE WITH THE SPONSORING ORGANIZATION TO PROVIDE TECHNICAL ASSISTANCE TO THE PARTICIPATING FARMERS

"Administrative support to achieve the technical objectives was provided through the cooperation of the Agricultural Extension Service. Of special concern in Guatemala were the purchase and maintenance of vehicles and obtaining survey teams. Payroll and secretarial help, as well as draftsmen with the necessary equipment and tables to draw maps and diagrams were required. The extension personnel who assisted the farmers with their new irrigation systems also needed support. One of the greatest problems we had in Guatemala was not having enough extension people who could teach the farmers how to use their systems and get the most out of them."

To Be Found

What is needed in order to provide technical assistance to the participating farmers.

Elements to be Considered

1. Determine what technical assistance is currently provided.
2. Establish what additional technical assistance is needed to achieve project goals.
3. Schedule the technical assistance.
4. Determine the number of employees needed, and establish procedures for hiring them.
5. Define the skills needed for project personnel, and write job descriptions.

6. Clarify the logistical support needed--transportation, office space, office equipment, etc., and agree on who will provide what.

7. Determine what information is needed and formulate a plan for obtaining it.

8. Establish how long the project will be located within the sponsoring organization and whether it will ever become a separate entity.

9. Make the financial arrangements for paying the staff time, office space, supplies, equipment, vehicles, etc.

Possible Resources

1. Similar agreements which have been entered in and proven workable in the past.

2. Expert advice of those who had had similar past experience.

3. Expert legal or managerial advice regarding such agreements, including consultations.

PRINCIPLE 7: LOCATE OR TRAIN TECHNICALLY COMPETENT PERSONNEL WHO ARE WILLING TO WORK IN THE FIELD WITH THE FARMERS

"It was very difficult in Guatemala to employ trained personnel to work on the teams, especially away from the capital. Those who had enough training and were willing to work, usually had two or three other jobs, and sometimes it was difficult to keep them working on a government assignment. Part of the problem was that government professionals received lower pay than employees of private organizations.

"The government method of assigning people to rural areas did not contribute to employee satisfaction. When our personnel had some choice of where and for whom they worked, they had a lot more commitment to their jobs. For example, when we employed people from Quezaltenango to work there, we got a lot more done than when we assigned someone from the capital or from other parts of the country to work there. An associated problem was that the government assumed any graduate engineer from the University could do anything. Ordinarily this was not true, and we found few engineers trained to design irrigation systems. We found a great lack of facilities adequate for training irrigation specialists in the country, and the government had not taken advantage of the available scholarships to train personnel.

"Not enough people were ever assigned to the irrigation teams. Frequently, only one person on the team could calculate the hydraulic designs. When that person was on vacation, or doing something else, the designs did not get made. One person dependence leaves a very vulnerable organization. The present engineers are now adequately trained to do the work, but what will happen when they are assigned elsewhere, and new personnel are hired?

If we had a full contingent of people on the teams, there would be more trained personnel ready to carry on, and the project would not be subject to disaster when one key person leaves."

To Be Found

Capable or trainable persons to be professionals and technicians for working with farmers.

Elements to be Considered

1. Building small and medium-sized irrigation systems requires engineers with interest and training in irrigated agriculture. If technical people are not available in the country, identify capable individuals either to be trained in the country or to be sent to other countries for additional training.

2. Find or train people who are skilled in the use of irrigation water for crop production. Have them train locally respected farmers who will then help their neighbors.

3. Find or train competent advisors who are willing and able to get out on the farms and work directly with the farmers. These can be short-term or long-term assignments of engineering, agronomy, and marketing experts, especially important is expertise in fertilizers, herbicides, pesticides, irrigation and working with farmers.

4. Utilize trained professionals to maximize quality of crops grown. If quality is emphasized and realized, markets can be found. Once quality is ensured, increase quantity.

5. Place emphasis on training young farmers on how to produce (hands-on training). Farmers can teach other farmers much better than any foreigners

or experts from the city. Farm boys speak the native dialects and hopefully have the confidence of the people at home. Let them do the day-to-day instructing while backing them up with the best specialists available.

6. Train farmers who show aptitude in surveying and construction to supervise the construction work by farmers at new sites.

7. Carry out the tasks in the field.

Possible Resources

1. Training facilities within the country, existing or to be developed.

2. Special project short courses for both professionals and technicians.

3. Four-year degree programs for professionals. If these programs are started at the beginning, by the time the initial phases of the program are under operation, these people will be back working while foreign advisors are still available to give them training in the field.

4. People could be sent out for short course training or for practical training on farms in developed countries, and then these people could be integrated back into the program.

5. Practical on-the-job training by experts for professionals and technicians can be an on-going part of the project.

PRINCIPLE 8: CARRY OUT THE FOLLOWING SEVEN BASIC TASKS IN THE FIELD

--Enroll farmer groups to participate

--Organize farmer groups into legal entities

--Perform survey and design functions

--Assist farmers to arrange financing for their project

--Supervise and train farmers in the construction of their system

--Train farmers to maintain and operate their system

--Train farmers in agricultural and marketing methods needed for new crops.

"The farmers had to be convinced of the value of the projects; most of them were skeptical that anything would come of them. At times we felt the same way because things moved so slowly. We kept any appointments we made because the farmers did not have much confidence in the government programs. It took almost six months of traveling and talking to various groups before we found a group who was willing and able, who had the land, and who had access to the water to build a project. Then it was almost another year before we were able to actually construct that first project.

"In the fall of 1977, we had some definite applications for projects. There followed several months of frustration before we got the funds in hand so construction could begin. We tried alternate sources of funds, such as special projects in AID or direct loans from the Agricultural Bank, even to financing the first projects ourselves to get things moving. Finally, the loan details were worked out with the Agricultural Bank and construction on the first small-farmer irrigation project was started in Santa Rita in February, 1978. The project was a gravity-operated sprinkler system that

worked on stream flow without any storage; and since the water came from a spring, it was potable and a faucet was placed in each yard. The project was inaugurated in May, 1978, and became the model for many such projects which were to follow. The project also supplied 3 of the 5 field foremen that are now in charge or building other projects."

To Be Found

Opportunity and means to accomplish each of the tasks.

Elements to be Considered

Task 1: Enroll Farmer Groups

"A group in Santa Rita, San Antonio Sacatepequez, San Marcos, first heard of us in one of the traveling school sessions. They had been working on their own to get an irrigation project but could not find financial or technical help. This was an ideal location for the original project. It could be a gravity-operated sprinkler system with no pumping costs (many Guatemalans insist that you cannot have an irrigation system without a pump and a tank). Also, the main highway between Quezaltenango and San Marcos runs through the project, so everyone could see the sprinklers operating on both sides of the road."

1. Be sure the farmers understand the benefits and requirements of irrigation.

2. Be sure the farmers understand that their responsibility for building and paying for the project themselves.

3. Be sure the farmers understand the technical assistance and training that will be provided.

4. Be sure the farmers understand their responsibility for operating and maintaining the system once it is built.

5. Find out whether the farmers are willing to provide the labor necessary for construction.

6. Find out whether the farmers are willing to obtain financing or use their own resources to purchase the needed materials.

7. Determine whether this group qualify for financing.

Task 2: Organize Farmer Groups

"Most of the irrigation systems were built by informal groups that we would call mutual companies in the United States. These groups organized themselves by electing a president, maybe a vice president, a secretary and a treasurer. Thus, there was somebody in charge of having meetings and discussions and someone to whom we could talk about how their plans were progressing. The organization was sometimes recorded in the minutes of the municipality; however, when the loan applications were made, the farmers had to record their organizational structure with the bank. The organization was responsible for the loans, but the bank required everyone to sign the loan papers so that as a group they were responsible for paying the loan and no one individual was responsible for paying the whole thing. This worked out quite well."

1. An irrigation project is usually much cheaper and more satisfying when one large unit is used to deliver water than when each family has its own little individual system. This is especially true if the source of water is a long distance from where the land is to be irrigated. Therefore, work with the farmers to establish some kind of organization to borrow the money instead of their doing it on an individual basis.

2. This organization may be an existing cooperative; it could be a village government; it could be a larger municipality-type of government; or it can be a farmer's organization. The farmers can organize themselves into a mutual company. These can be formed and legalized to borrow as a group.

3. The company should be registered with some legal entity such as a municipality or department. Small groups may have an internal agreement among themselves, but they should be registered so that legal rights to water may be established.

4. The organization, whatever it may be, files an application for a loan as a group rather than making individual applications. Then the group as a body is responsible for the repayment of the loan. The group must have made its own bylaws and provide for each member to pay his or her share.

Task 3: Survey and Design

"After a site had been identified and the people became interested, we determined the amount of land to be irrigated and the water needed, selected a method of irrigation, made a survey, made the designed, calculated the costs, and finally obtained a loan from the Agricultural Bank of Development."

1. Estimate the amount of water needed for the irrigation project. Many factors will determine the water needs, the climate, temperatures, hours of sunshine, relative humidity, the kind of crop, and the irrigation efficiency, which will be greatly affected by the method of irrigation. In some countries water use is estimated at one liter/sec/hectare. This is more water than is actually needed by the plants in most areas, but may be

required if irrigation efficiencies are low. If no other information is available for the area being studied, water depths of 4 to 7 mm/day can be estimated for the necessary consumptive use of the plants. The delivery and application efficiencies will have to be applied to these figures to get the total amount of water that needs to be diverted.

In general, first determine the amount of land that is desired to be irrigated. Assume a 5 mm evapotranspiration rate if no better data is available, apply estimated delivery and application efficiencies, and one can have a good estimate of the amount of water that will have to be diverted for the project. If this amount of water is not available, then one will have to ration the water to those who want the project, allowing each family a proportionate share.

If the amount of water available is known, the amount of land that can be irrigated can be determined. If the water source is the well or a stream that is lower than land to be irrigated, some kind of pump will have to be used. Pumping will entail much more expensive installation and continuous cost for power, and should be avoided if at all possible. Certainly, if water is to be pumped, the value of the crops grown must be enough to pay for the additional costs involved.

2. Choose the method of irrigation. Several methods of irrigation are available. These may be divided into three main categories: a) surface irrigation; b) sprinkle irrigation; and c) micro-irrigation. All have advantages and disadvantages.

Surface irrigation may be accomplished by wild flooding, or more controlled flooding using border checks or basins. The later will require quite level land. Furrows may be used, especially for row crops.

Corrugations, which are a form of furrows, can be used in crops that are sowed by hand or drilled in closely spaced drills.

Sprinkle irrigation is accomplished by impact sprinklers that rotate. On steep, pervious soils water is conserved and drainage problems are minimized by using sprinklers or micro-irrigation, because the water application can be more accurately controlled than with surface irrigation.

Micro-irrigation may be done by using pervious hoses and pipes or by using controlled drippers placed close to each plant. For areas with difficult irrigating conditions, and when the value of the crops is high, drip irrigation may be considered. The high cost of installation may make some farmers hesitant, even though by proper management irrigation can be very well done with drip systems if they are properly installed and maintained. The maintenance in terms of clogging of filters and nozzles may preclude the use of some waters in the systems.

Whatever method of irrigation is used, the purpose is to maintain sufficient water in the soil to sustain plant growth. Too much water may be worse than too little, so attention must be given to application methods and rates so that damage is not done to the growing plants. In some areas and climates, overhead types of irrigation may keep the plants too wet and cause various kinds of fungus diseases.

3. It is impractical to supply enough water to irrigate all of the land at the same time; therefore, some system of allocating water to different farmers and parcels will have to be worked out. Experience has shown that where water is abundant, the farmers tend to overirrigate, often to their own detriment. Water should be delivered at regular times or in regular quantities so the farmers can plan for the time and amount of their

irrigation ahead of time. Provisions can be made for the farmers to interchange their turns when circumstances prevent a farmer from using his or her turn at the regular time. Harvesting, sickness in family, or emergencies may make it necessary for a farmer to trade turns with a neighbor.

A convenient way to allocate is to allow a certain quantity of water to flow in a pipe or lateral canal on a continuous basis, with that amount of water being divided among a given number of farmers in the area.

In any kind of irrigation project that depends on spring or stream flow, the design should be made for continuous operation. Otherwise, a large part of the available water will be wasted. Getting farmers to operate on a 24-hour a day, 7-day a week schedule is sometimes difficult, but this type of schedule is necessary where water is scarce. If there is excess waters or if water is pumped from a lake or well, more flexibility may be allowed for night irrigation. But even then, the extra cost of the equipment needed for irrigation only during the day may preclude the luxury of only irrigating in the daylight. Most large systems are designed for full-time operation.

4. A survey of the distances and slopes will have to be made so design engineers will have the necessary data on which to base their water delivery calcualtions. If a project is small with short distances and few people involved, a main line survey with a hand level and a measuring tape may be sufficient. Record the location of each parcel to be irrigated. For larger developments, make a more detailed survey with accurate horizontal and vertical measurements. If detailed maps are available, plot a tentative line on the map and obtain actual field measurements later. Also,

make a detailed plan and profile plots of the proposed main line and laterals from the survey notes.

Show the location and elevation of each turnout or valve on the map. When all the maps and other information have been assembled, the engineer can begin the calculations for the design, which will include canal and/or pipe sizes, kind and capacity of gates, valves or other control structures for the main line, for any laterals, and for the individual fields. Record the information from the calculations on a copy of the detailed map or maps. Considerable technical engineering work is necessary to obtain a workable design that serves the users equitably. The larger the system, the more detailed the necessary calculations. Commonly several different designs will have to be made before one is finally chosen for construction.

Prepare a complete list of materials needed, along with actual or estimated cost of those materials. The materials of construction are the main cost of a project, since the farmers are providing all of the manual labor, and maybe some of the supervision. Some details of how to make the design and a sample bill of materials are given in Appendix A.

Task 4: Assist farmers to arrange financing

"Before a loan was submitted to the bank, the farmers had to have their right to the water certified by the municipality. This was to protect their water right in the future should water laws be established by the Guatemalan legislature. The bank required that each farmer have a certification of property ownership recorded in the municipality, because the titles to property, especially small holdings in the highlands, were not recorded.

"In the final paper, the only security written into the documents for the loans was the honesty of the people who were borrowing the money. This made it possible for owners of small farms to borrow the money without having to mortgage their land. Very little of the small farmer's land in Guatemala was actually registered with the government, so it was almost impossible to assign any kind of title or to put mortgages on the property."

1. Project staff may need to work with the bureaucracy of the funding system so the money will be made available and the guidelines will be established for loaning money to the farmers for purchasing the necessary materials. Considerable time may be required if the bank has never done such a job before and they have to write a complete new set of guidelines for their branch bank in order to make these loans.

2. Technical personnel should help the farmers estimate the loan repayment period, but finally, the group should make its own decision. The group knows its own situation best, and it is better to have a little longer time to make repayment than to have it too short. Then, if the farmers can and are willing, they can pay their obligations off early and save the interest which might accrue. The bank or other lending agency will work out an agreement with the farmers on the repayment of the note, the interest rate, and the terms of the payment of that interest. They will also specify the time for final repayment of the loan.

"In Guatemala, the loans to the farmers could have been extended for as much as 20 years. The farmers often chose a much shorter term, and practically all of the loans made for the irrigation systems were for a seven-year period. The farmers felt that within that time they could complete the payments without any difficulty. The first group that obtained a

loan and was able to make a payment the first year, even though it was not required."

Task 5: Supervise and train farmers in construction

"The first project was supervised daily by the advisors, because no Guatemalan engineers were working. Subsequent projects were supervised by field foremen, who were farmers themselves. These foremen lived in the community where the project was being built, and the local farmers supplied their food and a place to sleep. The engineers visited the projects under construction at least once a week, and oftener if necessary, to check on details and to see that the work was being done according to the plan. We insisted that several farmers on each project learn how to install the equipment so they could make repairs or extensions in the future without needing outside help. The system has worked very well in Region I; but Region V, as yet, does not have a pool of trained people to supervise the construction, so every project in Region V has been handled by hiring, as necessary, to get the work done."

1. First, someone has to be responsible for scheduling the farmers' work, including which days they will work, how long they will work, and making sure that everyone does their share. "In the Guatemalan experience, there were always some differences, but normally it worked out well and the people were quite willing to do their share of the work. Nor was there much trouble getting workers when construction work had to be done. The group's officers made the assignments, so everyone knew which day he was supposed to work. In smaller groups everybody was there every day unless they were sick or had other business."

2. Send advisors daily, or as needed, to supervise the farmers' work.

3. Train farmers who have helped build an irrigation system and who have land of their own and thus experience in working with irrigation, to become construction foremen. At times when no construction is being done, encourage some of these people to teach other farmers how to use the irrigation systems and how to plan crops. "It very quickly became apparent who would be the best foremen and the best agriculturalists for teaching others, and so we would send the people to the areas where they could do the most good."

Task 6: Train farmers in operation and maintenance

"After the projects were built, the officers were also responsible for making rules of operation of the system so the water could be divided fairly and so everybody understood when they could and could not irrigate. In many projects they could take it most anytime they wanted to."

1. As the system is being built, establish a method of operation for the distribution of the water. If there is an excess of water, people can be allowed to specify how much land they want to irrigate. Then payment can be made on that basis. If there is insufficient water, then one way is to allow each family to irrigate the same amount of land and pay the same amount in the repayment of the loans.

2. The sustaining function of the officers will be to manage the system, to make sure the system is operating, and to see that any faults in the line are repaired. If extensions are to be made, the officers should approve these and see that they are installed properly. The officers are the ones responsible for collecting the money, paying for any needed repairs, and

recommending that the repairs be made. In the Guatemalan projects, most of the organizations had some construction funds left over which they could use for repairs.. Later they could make an assessment to their people in order to have some funds available in their treasury.

4. The time needed to work with the farmers may vary considerably, because some of them may know what needs to be done, while others do not. It is best to have someone available most anytime when they need answers to questions, when they need recommendations, or when they need help in doing a task.

5. Eventually the extension service could have people available to help provide other services associated with irrigated agriculture.

6. If extensions are to be made or if more people want to enter the group and water is available, then the engineering group can make the designs for the extensions and assist in the construction of those extensions.

7. After projects are built, officers frequently change, in fact we recommend that officers be changed so that everyone has a chance to be an officer and so they have more appreciation for the work that has to be done. We recommend that they do not change all officers at once because then they would have a new group that doesn't know much of what has gone on before. By changing one or two officers every year, everybody can have a chance to work and everybody will know the problems associated with the program.

8. The farmers should be given some instructions before the advisors leave as to how much land can be irrigated with the available water, and they should be advised not to try to extend the project to more land than their water will irrigate.

9. The farmers may refuse to irrigate at night. In this event, they should be made to realize that when their water is limited, by irrigating at night, they essentially can double the amount of land that can be irrigated. If they plan to extend the system, they may have to insist either that the new people or that everybody on the system start to irrigate at night. On a project operating on streamflow, or springflow, if the water is not used today, it is gone forever, and they can never recover it. Night irrigation may be hard to teach if people have not been used to working at night, but in those areas in the developed world where irrigation is necessary and where water supplies are limited, it has been learned that irrigation has to be done at night as well as in the daytime.

10. The farmers need help in knowing how to irrigate, where and when to irrigate, and how much water to apply for efficiency and for maximum plant growth.

Task 7: Train farmers in production and marketing of new crops

"The cropping patterns in most of Latin America are fairly well fixed, and the normal farmer raises very few crops. Irrigation in some cases was to improve their own crops. But because of the climatic conditions in the highlands of Guatemala it takes a long time to grow a crop of corn, so usually we wanted to introduce new crops.

"There was a natural reluctance on the part of the farmers to changing their traditional methods of agriculture. This reluctance is common all over the world and is not unique in Guatemala. The farmers live on such a low subsistence level that they cannot afford one crop failure. Such a failure would mean the difference between life or death for the families in

many cases. Nevertheless, they are learning that there is a better way; and given the right opportunity they are changing. I was told that it would be impossible to change the farmers out of their traditional methods; and if they did produce other crops, they would not eat them. However, I have seen a considerable change in the time I have worked in Guatemala.

"We recommended to the farmers that they shift from cultivating primarily corn and beans to some type of vegetables and eventually to small fruits such as strawberries, raspberries, or blackberries. A lot of people were interested in planting peaches, nuts, and also apples which are very popular in that part of the world.

"With these crops, it is possible to have from 3 to 4 harvests per year on the same land. The value of the crops are much more than the traditional corn and beans and much more food can be produced for the country as a whole. We have had reports from the farmers themselves that they have been able to increase the incomes on their small plots from 5 to 50 times over what they have been accustomed to. Of course not everyone has yet learned how to manage their farms to get these increases, but for those who have followed instructions and have learned, it is a fact."

1. It will probably be necessary for the farmers to change their cropping patterns and their crops grown in order to produce enough income to pay for the irrigation systems. So, after the project is turned over to the owners, the irrigation team members need to instruct the farmers on what to plant, how to plant and take care of the new crops, and how and when to irrigate.

2. Assist the farmers to develop a system to market the new crops.

PRINCIPLE 9: EXTEND THE PROGRAM TO OTHER AREAS AND REGIONS

"Following the first project, over 20 other projects were built in the surrounding area. The results of the first project and the advertising of these results were such that, after two years, neighboring communities were begging the government to help them do the same type of thing. Anyone engaged in this type of work must be patient, because it may take a considerable amount of time to convince both the farmers and the governmental agencies that these projects can be built at a minimum cost and be successful when done right.

"When we went into an area and people wanted to see a project, we invited at least the officers of their group plus anybody who had transportation, to see successful projects operating in other locations. In some cases, we took people 50 to 100 kilometers in order to see an operating project.

"In certain areas several projects were operating so it was quite simple to take farmers to see them. Many times people would go on their own and talk to the farmers on a project that was operating. This had quite a multiplication effect since people recognized the advantages very quickly and sometimes even demanded that we work with them.

"In Guatemala, farmers who had worked on their own irrigation systems for some time helped out in communities where new systems were being built. These farmers supported the leading farmers in the new community during one to three crop cycles. These farmers visited the new project one to three times every week. The farmer trainers taught the new irrigators when to irrigate, how to irrigate, when to fertilize, and when

to use herbicides or insecticides if necessary. By having local farmers train other farmers, the success rate was quite high. There are several reasons for this: 1) Farmers tend to trust farmers more than they do outsiders, and 2) the farmer trainers were used to doing the farm operations, and could teach by actually showing the new farmers what to do. A demonstration plot was planted on several farms in every project. Demonstration plots of a tenth of an acre or more were planted to potatoes or vegetables or whatever other crops were expected to be grown in that area. The farmers who owned the land cultivated these crops under the direction of the farmer trainer who was helping them to learn how to use the project.

"These farmer trainers were paid by the Extension Service. Their pay was at the lowest pay scale the government had for extension work. Some of the jobs were part time to begin with. Later on, the ones who were best were paid full-time to train other farmers to manage their own land. This was done by showing the people how to do their own work, not by doing it for them."

To Be Found

New areas where such projects are wanted and needed.

Elements to be Considered

1. Once the first project is operating successfully, bring farmers from other areas to talk with the farmers on the completed project.

2. Have farmers who understand the construction process and show leadership capability become foremen for the construction of new projects in other villages.

3. Have farmer foremen perform some engineering functions such as simple surveying, and so free the engineers to perform more technically demanding functions.

4. Farmers themselves carry out the construction including:

--digging the trench,

--installing and bedding the pipe,

--fixing valves and faucets,

--constructing forms, and

--mixing and placing concrete.

5. Have farmers trained as foremen supervise all phases of construction including:

--assigning workers to specific tasks,

--teaching individual farmers how to do their assigned jobs,

--following engineering designs,

--making recommendations if changes in design are necessary,

--ordering additional materials, as needed,

--inspecting the system as it is installed, and

--testing the system to make sure it works.

6. Have an engineer check on the project as little as once a week.

7. Do whatever is possible to keep personnel who work on the irrigation teams in the program. These people will have had more experience than anyone else in the country in their respective jobs. Have them train others.

8. Give the field teams substantial autonomy in the control of their funds. If they manage the operating funds, there is less chance of funds being siphoned off for other uses.

9. Train the people who will be managing the program over a long period of time. The logical people for this job in many countries are those who are designated as extension agents. Most extension agents need to be trained in how to irrigate, when to irrigate, and how much to irrigate. They need to know how the irrigation system fits with the crop production cycle.

10. Have the agents, along with advisors who really understand the system, train local farmers in how to use their own systems. It would be a good idea to have several farmers in each community trained to help their neighbors. If local farmers are not trained to train others, there will be a period of time when farmers on new projects will not know how to use their water, and they may in time even abandon the project unless there is someone to help them succeed in the production of crops.

11. After two to three crop cycles of a farmer trainer working with the project in what kinds of crops to raise and what cultural practices to follow under irrigation, people within the community will be able to do the work that is necessary on their own.

12. Private organizations that do marketing and processing may furnish some services to the farmers, especially when they write contracts for produce. They may provide some field work and recommendations for the use of their products.

13. After foreign advisors have left, there must be commitment on the part of the local government to continue the work. By keeping the operating teams intact, designs can be made and projects built. If funds are provided and they are given the opportunity, these teams will keep building more projects and may even train other people so that there will be a continuously expanding program by which projects can be built wherever they are to the advantage of the country.

Recommendations

1. Begin extensive programs at the start of the project to build a staff which is trained in design, construction, development, and on-farm extension activities. Besure to do this in time to ensure that they gain actual experience before the advisors leave.

2. Pay trained personnel enough so they can and will work full time on the job.

3. Emphasize helping the farmers after projects are built.

4. Extend the same methods of self-help throughout the country, to other programs, and to other developing countires of the world.

APPENDIX A

SAMPLE DESIGN PROCEDURE AND PRECAUTIONS FOR A GRAVITY-OPERATED SPRINKLER SYSTEM

Gravity-Operated Sprinkler System

Given: Sixteen families, each with approximately 1/2 hectare of land, have obtained the right to a spring located about 2050 meters from their land. The spring flow is about 10 liters per second in the dry season. Two farmers have land about 950 meters from the spring where the difference in elevation is about 50 meters, the rest of the group have land that is more than 233 meters below the spring in elevation. The water must cross a deep, narrow canyon very close to the spring.

Problem: Design a gravity-operated sprinkler system to serve the group.

Solution: Assume a maximum daily evapotranspiration of 5 mm per day. The water would serve to irrigate 15 hectares of land if used 24 hours a day. Since there is more land available, all the water will be used.

Professional surveyors gave an approximate line for the main pipeline. For the first kilometer they maintained an approximate slope of 5%. Horizontal and vertical control were maintained, and the results of the survey are plotted on plan and elevation maps.

A 5% slope is 5 meters per 100 meters, and the pipe must be large enough to carry the 10 liters per second and still have pressure to serve the two highest users.

The friction loss table shows that a 3" pipe would have a velocity of 2.10 m/sec and a head loss of 5.03 m per 100 m. Therefore, in one kilometer, the loss would be 5.03 x 10 = 50 m. The pipe would carry the water but would not leave any pressure to operate the sprinklers.

A 4" pipe would have a velocity of 1.27 m/sec and a head loss of 1.5 m/100m. The pressure would be approximately 50 m - loss = 50 m - 15 m = 35 m in the 950 meter of pipe from the spring to the first two users. This provides adequate pressure for the sprinklers.

Because of the steep terrain, a pressure reducing box will be installed at 1 kilometer. This is a concrete box about ½ m by ½ m by ½ m. When the water from the pipe enters the box, the energy of the flowing water will be dissipated. The water will then enter the second section of the line which will be 395 meters long with a difference in elevation of 448.9m - 336.6 m = 112.3 m, which is a slope of $\frac{112.3 \text{ m}}{395 \text{ m}} = 0.284$, or 28.4 m/100 m. The location was determined by geographic conditions and pressure requirements further down the line.

A 2" pipe has a loss of 32.88 m/100 m and a velocity of 4.58 m/sec which is too high. A 2½" pipe has a loss of 12.94 m/100 m and a velocity of 3.12 m/sec. Again the velocity is high. A 3" pipe has a loss of 5.03m/100m with a velocity of 2.1 m/sec. The 3" pipe would run partially full, but it is preferable to keep velocities low.

Install another box to break the pressure at station 1+379 (1379m). The line divides at this point. One half the water will be put in each pipeline. So the design of each line will be for 5 liters per second.

In order to have pressure to operate sprinklers in each of the areas, the pipes must be large enough to deliver the water without too much loss. Since many sprinklers are designed to operate around 45 psi (32 m), the design will be made to have a pressure at the sprinklers between 40 and 60 psi (28 m and 42 m).

Section I is much steeper than Section II. Nevertheless, the lines are to be sized so that approximately the same amount of water will flow in each, and control valves are to be installed at the box so the water can be controlled and divided as needed.

Section I has a total drop to the dividing point of 336.8 m - 236.4 m = 75.4 m in a distance of 222 meters. A 2" pipe has a friction loss of 9.39 m/ 100 m and a velocity of 2.29 m/sec. A 2½" pipe has a head loss of 3.71 m/ 100 m and a velocity of 1.56 m/sec.. This velocity is high, and the head loss is somewhat excessive. So use a 2½" pipe. The main line continues 196 meters to the end with a drop of 11.9 meters, so continue with a 2½" pipe.

At station 1+588 a side line takes off to serve two members. Use a 2" pipe 105 meters long.

Section II has a drop of 336.6 m - 317.3 m = 19.3 m drop in a distance of 314 meters to the connection for the first user. To conserve pressure loss, use a 3" line which for a 5 l/sec flow has a head loss of 1.45 m/100 m at a velocity of 1.05 m/sec. The water will arrive at the first turnout with a pressure of 19.3 m - 314 (1.45) m = 14.75 m which is low; but since the land to be irrigated is very steep, the water in the line to the field gains pressure as it goes down from the outlet. It will be enough. Continue with a 3" pipe for another 340 meters with a drop of 317.3 m - 268.4 m = 48.9 m.

Serve the two other users with a 2" pipe taking off from the 3".

The plan is to supply each user with a 2" valve so he can use 2" aluminum sprinkler pipe to irrigate his plot. Each user is to have at least one 1" outlet with a valve with hose threads, so a hose and portable sprinkler can be used.

Every user was furnished the two inch valve and a faucet with hose threads. As they learn to use the system, they may at their own expense add other valves.

Where valves are installed for control purposes, such as in Sections I and II of this design, an air inlet standpipe or ball valve must be installed in the line to protect the line from negative pressure in case the valve is completely closed.

Precautions:

1. Air release valves are needed when a line is being filled, an automatic ball type valve is best. It will allow air to be expelled or will allow air to enter when there is no pressure. One of these valves needs to be installed at any high point in the line, such as when the line goes over the top of a hill, an air block at such locations may put a complete or partial blockage in the line.

2. At every low place in the line, especially when passing through a deep canyon, a drainage valve should be provided so that the line can be drained to eliminate dirt or trash or when repairs have to be made.

3. In long lines, especially those that have high pressure and/or high velocities, caution must be exercised in opening and closing valves. Water hammer effects may produce pressures much higher than the normal static or operating pressures.

4. Entrance boxes to pipelines should be provided with screens to keep foreign matter out of the lines.

5. PVC pipe should be covered. The ultraviolet rays of the sun will, in time, make the pipe very brittle and subject to rupture.

6. Except for very simple irrigation systems, an Agricultural or Civil engineer who has had training in hydraulics will be needed. The engineer should be acquainted with the kinds of pipe that are available in a given area and should have friction loss tables and/or slide rules that give the same information. The tables are usually available in books on hydraulics or in booklets issued by pipe manufacturers. Various companies who sell irrigation equipment have designed slide rules which have the same information that can be found in tables. Engineers trained in other disciplines can be taught the use of the friction loss information for design purposes, although there is no substitute for experience when one is making designs. Every situation is different and engineering judgment must be used to obtain a workable solution to any given problem. Many different solutions can be made to any hydraulic problem, but one must stay within the constraints of the materials and the costs.

7. Sometimes the phenomenon known as water hammer is ignored in pipe line design. However, if a valve is shut off too fast especially in long pipe sections, the kinetic energy of the moving water is changed to static pressure and can raise the effective pressure in the line to much higher values. The amount of the pressure change depends on the velocity of the water before the valve is shut, the length of the line, and the time required to close the value.

The increase in pressure may be calculated by the following equation:

$$P = \frac{0.0505\ VL}{T}$$

where P = increase in pressure in kgs/cm2

V = velocity in m/sec

L = length of line in meters

T = time required to close the valve in seconds.-

Or $P = \frac{0.070\ VL}{T}$

where P = pressure increase in pounds/in^2

V = velocity in ft/sec

L = length in feet

T = time to close in seconds

The assumption is made that the valve is closed at a uniform speed--which may not be true. Calculations are sometimes made by assuming increments of time for closure.

In Spanish water hammer is called "Golpe de Areite".

Bill of Materials to Buy

42 meters of 4" galvanized steel pipe

958 M of 4" PVC pipe 125 psi rating

654 M of 3" PVC pipe 125 psi rating

418 M of 2½" PVC pipe 125 psi rating

405 M of 2¼ PVC pipe 125 psi rating

400 M of 1¼ PVC pipe 125 psi rating

2 - 4" gate valves

2 - 3" gate valves

2 - 2½" gate valves

16 - 2" gate valves

3 - 4" tees PVC

1 - 4" tee galvanized

2 - 4" ells

7 - 2½" tees, PVC

7 - 3" tees, PVC

1 - 2½" x 2" tee PVC

2 - 3" tees

2 - 3" x 2" tees PVC

8 - 2" tees PVC

16 - 1" faucets with hose connection

48 - 2" aluminum pipe with #30 Rainbird sprinkler

16 - 5/8" x 50' hoses

16 - hoses for sprinklers

16 - #25 sectorial Rainbird sprinker

2 - 2½" air valves

1 - 3" air valve

1 gallon paint thinner to clean pipe

2 gallons of PVC solvent well cement
Other materials that individual members may want such as extra equipment and Portland Cement to build boxes