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WATER MANAGEMENT RESEARCH IN ARID AND SUB-HUMID LANDS OF LESS DEVELOPED COUNTRIES

Annual Progress Report
Utah State University—USAID
Contract AID/csd-2167

Logan, Utah

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FOREWORD

This is the first substantive report submitted under contract AID/csd-2167, "Water Management Research in Arid and Sub-Humid Lands of the Less Developed Countries." The Contract between AID/Washington and Utah State University was signed on June 28, 1968, and funded for an initial period of 21 months. The research work under the Contract is being conducted mainly in Latin American countries.

Concern of AID/Washington over the problems of feeding burgeoning populations throughout the world over the next 20 years resulted in AID's cooperation with several universities to work in water management research for increased agricultural production. This cooperation led to the creation of a Consortium called "The Council of United States Universities for Soil and Water Development in Arid and Sub-Humid Areas" (CUSUSWASH). The Consortium was formed on May 12, 1967, with the University of California, Colorado State University and Utah State University as Charter members. The University of Arizona joined the Consortium in October 1969.

Each of the universities of CUSUSWASH, although united in the common cause of helping to solve water management problems for optimum production of food and fiber, carries out its activities under separate contracts with AID/Washington. CUSUSWASH acts in an advisory capacity to each contract. Periodic meetings are held to report progress, exchange information and discuss problems encountered in carrying out programs. It was through agreements reached in meetings of CUSUSWASH that the geographical areas of work were defined in broad terms. Colorado State University will work in Pakistan, the University of California in India, and Utah State University in Latin America.

At Utah State the research has been conducted under the general direction of the Department of Agricultural and Irrigation Engineering with strong support from the Utah Water Research Laboratory, and other departments including: Agricultural Economics, Civil Engineering, Electrical Engineering, and Soils and Meteorology.

This report covers in some detail the work done by Utah State University, focused on water management problems for increased agricultural production in Latin America.

SUMMARY OF ACTIVITIES

INTRODUCTION

The Utah State University Contract AID/csd-2167 "Water Management Research in Arid and Sub-Humid Lands of the Less Developed Countries," was signed June 28, 1968. Activities under the Contract from its inception through November 30, 1969 are summarized in the following paragraphs. Details of work accomplished are contained in the body of the report.

PLANNING AND PROJECT DEVELOPMENT

Operations under the Contract were initiated in July 1968. By autumn 1969, field work on five separate work plans dealing with physical aspects of water management problems had been initiated in four countries. In addition, three work plans dealing with economic and legal considerations have been formulated and are in the final stages of implementation. Initiated work plans relate to irrigation methods, crop varieties, population and fertilizer interactions, evapotranspiration and water requirements, drainage and salinity, off-season irrigation and research planning to support the Sao Francisco Valley development in Brazil. One scientist is now in residence in Chile and plans are well advanced to place at least six more within the next few months in selected countries. In most cases scientists have been identified and country and AID Mission agreements developed. Several personnel are already receiving intensive language training in preparation for their assignments.

Chronologically, the first task was to assemble as much information on the water resources, soils and climate of Latin America as practical. Climatological and hydrological records were obtained from many sources including the following: Atmospheric Science Library; Bureau of International Commerce, U. S. Department of Commerce; Food and Agriculture Organization of the United Nations; Library of Congress; Meteorological data collection agencies in Latin America; Pan American Union, Organization of American States; private international development companies; USAID library, Latin American Bureau; USAID Missions in Latin America and the North Carolina Soils Testing Program. Specific information has been assembled for Argentina, Brazil, Chile, Colombia, Equador, Honduras, Peru and Venezuela. Publications of a more general nature have been obtained for Latin America as a whole.

Materials were reviewed to determine their relevance to the project at this time. Those portions of publications which recorded basic physical data in the arid or sub-humid regions of interest were copied, as were portions of publications or reports which describe in detail the basic fields of interest. Information of a more general nature was summarized and its location noted for future reference. Other information considered too general in nature, redundant or outdated by the researcher was noted on bibliography cards with a brief statement as to contents for future reference if needed.

Publications and reports located at sources other than libraries were obtained in complete form wherever possible; otherwise they were recorded in the same manner as library information. Appendix A contains a complete listing of materials and data obtained thus far.

With this background information, a University team visited El Salvador, Honduras, Venezuela, Colombia, Peru, Chile, Argentina and Brazil between February 17 and March 25, 1969. Research needs were enumerated by officials of the respective countries having knowledge of water management problems and by the USAID Missions. Project plans were discussed, specific country and USAID country mission interests ascertained, areas of priority established, and agreements obtained regarding the nature and scope of the research. A detailed report of the USU research team visit to Latin America is contained in Appendix B.

Following the trip, a statement of the research objectives, along with prepared work plans, was submitted to the concerned USAID country missions by the project staff. Country approval and USAID country mission clearances as well as Washington approval were obtained before work within a country was initiated. A digest of

the work accomplished on specific objectives under approved work plans follows.

APPROVED WORK UNITS INITIATED AND PRESENT STATUS

WP–1. Irrigation Interactions with Crop Varieties, Plant Populations and Fertilizers for Optimum Production

Chile. While each new agricultural input usually increases production, the real pay off comes where several inputs are used in combinations. Research on interactions is therefore a key element in extending the "Green Revolution." Research plots have been established at two locations. Two varieties of corn with various fertilizer treatments are included in the irrigation experiment. The work is being done cooperatively with the irrigation department of the National Research Institute of Chile at La Platina. A USU researcher has been stationed in Chile on a short-term basis to aid in implementing the project.

Venezuela. Through the cooperation of the Ministry of Public Works and CIDIAT (The Inter-American Center for Land and Water Resource Development), field research is now under way at several locations. Technical advice concerning growth of bananas, rice and pasture with different water applications has been provided by USU staff members.

WP–2. Evapotranspiration and Water Requirements

Accurate knowledge of the amount of water needed by a crop under widely variable conditions is paramount if effective water management practices are to be instituted. Climatological data have been collected and are being analyzed for estimation of evapotranspiration and crop water requirements in Colombia and Venezuela. The work in Venezuela is in cooperation with CIDIAT and with the Venezuelan Ministry of Public Works. Reports will be prepared for other countries of Latin America as data are collected and processed. Evapotranspiration estimates based on climatological data and formulas developed will reduce the need for exhaustive studies to determine consumptive use; however, some field trials will be made in order to verify conclusions.

WP–3. Drainage and Salinity Problems in Irrigation Projects of Colombia

Drainage and associated salinity is a basic problem of large geographical importance. This is no less true of Latin America than elsewhere. In cooperation with INCORA (The Agrarian Land Reform Institute of Colombia) and ICA (The Institute of Agricultural Research), an investigation of drainage problems was made on the proposed irrigation district of Atlantico-3 on the north coast of Colombia. Some field measurements were taken and leaching experiments initiated under ICA's direction and USU's supervision. Research objectives developed as a result of the work done last summer have been discussed with INCORA and ICA. Future efforts will involve a combination of work units WP–3 and WP–1. ICA is prepared to provide technical support and facilities to carry out the proposed investigations in cooperation with USU.

WP–4. Off-Season Irrigation to Maximize Benefits for a Limited Water Supply During Drought Periods

Frequently runoff is highest during the non-growing season. Through careful management, much of this runoff could be stored in agricultural soils for later use by crops. In Chile two research trials were established through, and in cooperation with, the Irrigation Department of the National Research Institute at La Platina. Pre-season irrigations were made in a designed experiment; plots will be harvested, data analyzed and recommendations made at the end of the growing season in February and March 1970. USU provided technical support to help initiate this activity and will assist in the collection and analysis of data and the continuation of the program. A USU scientist is in residence on a short-term basis.

WP–5. Research Planning in Sao Francisco Valley, Brazil

Where new developments are being planned, it is important that research be initiated in the field during the planning stage in order to avoid mistakes and to capitalize in the most efficient way on the new resources made available. U. S. experience (Grand Coulee, for example) emphasizes the importance of this step. During September 1969, a USU team visited several areas in Brazil proposed by SUVALE (Agency for the Development of the Sao Francisco River Basin in Brazil) as sites for research and demonstration centers. USU will cooperate with SUVALE in establishing a water management research program at these locations based on proposals made by the team. SUVALE's manpower resource consists mainly of young, relatively inexperienced personnel who need training and advice. Interaction experiments (WP–1 type) will be modified to adapt them to the experience of the research workers assigned to the new stations. A training and planning seminar program-

med for February and March 1970 will be followed by implementation of field research.

WORK PLANS APPROVED IN PRINCIPLE

Unless consideration is given to water laws and customs regarding water use, even the most carefully drawn plans may fail because water is not legally available. Questions of water rights are invariably complicated and subtle. Likewise, farmers will not adopt new practices unless there are economic gains to be made; nor will they adopt conservation practices on the farm if they do not foresee direct benefits. Field discussions have indicated a willingness of country agencies and AID Missions to consider these problems, hence the project staff has given them high priority. General plans have been submitted and approved by AID for development of detailed programs under the following titles:

WP–6. Determination of Water Rights Customs, Laws, and Court Decisions in Latin American Countries

WP–7. Economics of Farm Production and Marketing with Improved Irrigation and Drainage in the Sub-Humid Areas of Latin America

WP–8. Primary Benefits Resulting from On-Farm Conservation Practices to Improve Irrigation Efficiency.

Specific plans are in the final stages of formulation and field implementation will begin in the near future.

DEVELOPMENT OF RESEARCH OBJECTIVES

Considerable effort has been expended in developing specific objectives for field investigations that will be beneficial to the people of the underdeveloped countries. This was the primary purpose of the USU research team visit to Latin America. The research team also gave serious thought to personnel assignments that would result in findings aimed more at utilization than publication and in a local corps of trained researchers at the termination of the project. The team gave consideration to "institution building" at the local level.

The specific objectives as set forth in Article I, Paragraph C, of the Contract were used as an outline for discussions in the conferences with AID Mission and local country authorities. These objectives are:

1. The development of knowledge and data on how best to conserve and use water falling on the land as rain and the most efficient means of supplementing needed soil moisture by limited amounts of irrigation water.

2. The development of knowledge and data that can be used for economic on-farm design and construction of conveyance and delivery systems including structures for control and measurement of irrigation water.

3. The development of surface and subsurface drainage systems to eliminate the hazards resulting from surface flooding and high water tables.

4. The identification of important factors affecting the degree of leveling of the various soils in the major climatic zones and the relationship of these factors to erosion, water infiltration, good land use and cropping practices.

5. The development of methods of water application including time and amounts which are suitable and efficient for different soils of varying physical properties (water-holding capacities, intake rates, etc.) with major crops.

6. The integration of these water use factors into a productive cropping system consistent with farm size and available farming practices.

7. Where soil salinity and exchangeable sodium are problems, studies will include soil amendments, soil and water management procedures and use of salt tolerant crops.

Research needs for each country were determined within the framework of the above listed objectives. Priorities were then established and the cooperative arrangements necessary to implement the research were discussed. In all cases the research team found that the USAID and country officials had a high interest in one or more phases of the proposed research and wanted to cooperate to the extent of their ability and resources. The specific research, showing initial priorities, is discussed in the following section.

PROJECT WORK PLANS AND PRESENT STATUS

Specific objectives and research work plans were developed for the areas of high priority where staff could be assigned and facilities made available. These work plans were then distributed to the Missions through AID/Washington for consideration and approval. Plans for five related areas of research have been approved for field study and research has been initiated in one or more cooperating countries (WP–1 to WP–5 inclusive). Additional objectives have received provisional approval by USAID/ Washington and work plans are in the development stage (WP–6, WP–7 and WP–8). A detailed discussion of each work plan, including present accomplishments and future plans, follows.

WP–1. IRRIGATION INTERACTIONS WITH CROP VARIETIES, PLANT POPULATIONS AND FERTILIZERS FOR OPTIMUM PRODUCTION

Objective

The general objective is to determine the combinations of crop varieties, spacing and fertility conditions conducive to optimum crop yields from irrigation in the wet-dry areas of Latin America.

General

This proposal has been well received in all Latin American countries visited since it obviously fills a void in the present on-going research programs of most of these countries. Research has been conducted in many countries to determine the consumptive use requirements of crops, their response to fertilizers and the effect of using different methods of irrigation. Unfortunately, however, there is no indication of studies to determine the interactions when all the variables are combined. The response due to the interactions is, of course, important to optimum production and realization of maximum benefits from irrigation. It must be recognized that the proposed research is complicated and requires constant supervision to assure reliable data from which valid conclusions can be drawn.

Plan of work

The general plan is to conduct plot studies where irrigation fertility, crop varieties and plant populations are studied as variables, with the specific crop or crops to be determined for each location. Each experiment now under way was designed to fit the local resources and conditions. The following criteria were used to formulate the detailed plans:

1. **Planting date:** Planting dates will be timed to best fit the seasonal variations. Where there is a hot-dry period, a crop such as corn will be planted at a time that will permit the growth to progress so that the period of pollination will not be during the most adverse hot-dry period. Dry season crops will be planted so as to be harvested before the wet season begins.

2. **Plot arrangements:** Major plots will be irrigation variables: the first sub-plot, fertilizer variables; second sub-plot, varieties; and the third sub-plot, spacings. The size of the smallest plots will be dictated by the equipment and overall size and shape of land available. The total area and size of major plots will be dictated by the size of sub-plots.

3. **Probable crops:** Corn, pastures, semi-dwarf wheat, upland rice or vegetables are recommended. Country situations will govern the choice of crops.

4. **Variety selection:** Usually three varieties will be used: local variety in common use; "most promising" new; and "best" as recommended by local agronomists and those working for AID, Rockefeller Foundation, etc.

5. **Fertilizers:** Blanket applications of phosphate, potash and minor elements will be made as needed for crops where nitrogen is most critical. (This will be determined in cooperation with the North Carolina staff working on the soil fertility testing program in Latin America.)

6. Irrigation amounts: Three levels of irrigation will usually be selected. For the maximum, the moisture will be maintained so that there is little or no stress on the crop. The criteria for the different amounts will be based on evidence of plant stress, evapotranspiration rates and tension measurements, or by sampling and determining the proportion of the available water consumed. It is anticipated that a measure of consumptive use will be made at each location. The criteria to be used at specific locations will depend primarily on available help and equipment.

7. Plant populations: Plant populations will be varied by using different row widths, plant spacings or seeding rates.

8. Location: Research tests are to be located where climatic and soil conditions most nearly represent the agricultural areas of the cooperating countries. These will also be situated as close as possible to other research projects inaugurated under the Water Management Research Contract so that manpower and equipment can be most effectively used.

This type of experiment has been implemented in Chile and Venezuela and is contemplated in at least four additional locations. Studies are proposed for Magdalena, Colombia; La Platina, Chile; and Guanare, Venezuela. During a recent visit to Latin America, suitable facilities were also found in El Salvador, Honduras and Brazil. As extensions of this project are established in cooperating countries, detailed arrangements will be made in advance of initiating the new trials.

Present status

Chile. The interaction experiment WP-1 has been implemented in Chile in cooperation with the Department of Irrigation of the National Research Institute of Chile located at La Platina. The Irrigation Department has assigned two graduate students to the project who will receive training as the work progresses. Since the soils of La Platina are shallow, research plots were chosen on private farms at two locations: Fundo El Castillo and Fundo Condoroma. The farms were located by Research Institute personnel who also made the necessary arrangements with the cooperator to carry out the research program on his land. Utah State University has assigned a researcher to work with the Institute personnel. It is anticipated that his present short-term assignment will be extended to a two-year period.

This experiment has three moisture variables with two replications of each. These are the major plots upon which all of the other interactions will be superimposed. Moisture No. 1 will receive irrigation when 45% of the available moisture has been depleted. Moisture No. 2 will receive irrigation when 60% of the available moisture has been depleted. Moisture No. 3 will receive irrigation when 75% of the available moisture has been depleted. A moisture meter with Bouyoucos blocks will be used to determine when to irrigate in conjunction with soil sampling for moisture percentage. Irrigation will be by furrow, using V-notch weirs to measure the water both on and off each major plot so as to determine the actual amount of water applied to the soil in each irrigation treatment.

A blanket application of phosphorus and potassium will be made over all of the experiment in ample quantities to insure against any deficit. The amounts needed will be determined by soil analysis. Nitrogen will be varied on each major plot using the following rates: 0, 100, 200 and 300 kilos per hectare for moisture plots No. 1, 2, 3 and 4, respectively.

Tracy hybrid No. 133 and Tracy hybrid No. 90 are the field corn varieties that will be used for the experiment. Two plant population variables will be used with each variety and superimposed upon each major plot. Plant population No. 1 will be 60,000 plants per hectare and plant population No. 2 will be 90,000 plants per hectare.

The experiment at Fundo El Castillo was planted October 1st, with a 4-row John Deere corn planter. The planting rate was about 140,000 seeds per hectare on 34" (86 cm) rows (see Figure 1 for plot layout). An excellent stand of corn of both varieties has emerged. Thinning to the desired plant population was completed in late October. The experiment at Fundo Condoroma was pre-irrigated and then planted in late October. Cooperation has been excellent on every hand and all is progressing very satisfactorily, primarily due to the assistance and guidance of Senior Juan Tosso, acting director of the irrigation department at La Platina.

Venezuela. Through the cooperation of the Ministry of Public Works (MOP) and the Inter-American Center for Land and Water Resource Development (CIDIAT), interaction experiment WP-1 has been implemented in Venezuela. Field plot studies have been initiated at three locations: the Guanare Research Station, Bocono Irrigation Project and the Majaguas Irrigation Project. Crops will include bananas at Bocono and Guanare, rice and sugarcane at Majaguas, and pasture and corn at Guanare. Personnel from MOP and CIDIAT will conduct the experiment aided by periodic consultations and assistance from USU staff.

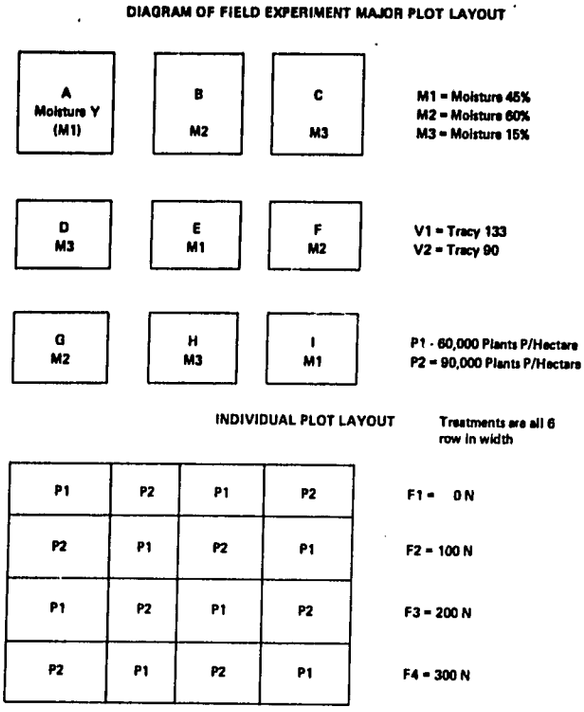

Figure 1. Field plot layout.

The irrigation variable will constitute major plots for bananas, rice, sugarcane and corn. Sub-plots will be used for fertility variables. Varietal differences will be in split plots and separate blocks. The pasture design will be less complex with the irrigation and crop variables stripped perpendicular to fertility plots.

Water will be measured both on and off the plots using orifices, siphons and Parshall flumes. Tensiometers will be used to determine moisture levels up to 0.8 Bar values and moisture blocks far greater than 1 Bar tension. These will be set at 3 depths—mid root depth and above and below this depth for each crop. Soil samples will also be taken prior to irrigation.

In the case of rice, moisture control will include:

W1 - Driest, no continuous ponding but soil at 10 cm not less than field capacity before irrigation.

W2 - As W1 but continuous ponding of water at flowering and until near harvest.

W3 - Wet, continuous ponding of water from seedling stage up to 10-15 cm depth as plants grow.

It is planned to use the following irrigation systems for crops other than rice:

W1 - Dry regime;irrigate only when the soil at the median depth of the root zone for the crop and that age is at 12 Bars tension near the lower root zone or shows wilt (whichever is first).

W2 - Medium moisture; irrigate when the soil at the median depth of the root zone in at 2 to 4 Bars tension.

W3 - High moisture; irrigate when the soil at the median depth of the root zone is at 0.7 Bars tension.

Waf - Alternate furrow irrigation for sugar cane and possibly for corn. Sensing devices are placed in seed row and irrigation is done only in alternate rows when need is indicated as in W2 level.

Water tables within depths of 3 meters will be followed by measurements of wells (pozos) installed at that depth. Piezometer batteries will be used also in some studies such as the pasture and banana plots.

Fertility variables will be limited and established to bracket those values recommended by the Ministry of Agriculture (MAC), where they have given values (rice, bananas, corn and sugarcane). The details are not yet firm, but present plans for fertilization are given in the following list.

1. Bananas
   - Fo - No fertilizer
   - F1 - 20 Kg. N, 10 Kg. P, 50 Kg. K/Ha. Add one-quarter of this per hectare every 3 months.
   - F2 - 40 Kg. N, 20 Kg. P, 100 Kg. K plus lime. Add one-quarter of this per hectare every 3 months.
   - F3 - 80 Kg. N, 40 Kg. P, 200 Kg. K. Split for additions each 3 months.

2. Sugarcane
   - F1 - 80 Kg. N, 30 Kg. P, 100 Kg. K/Ha. Put 1/3 N, 1/3 K, and total P below seed at planting or after cutting (between rows) and remainder 2 1/2 months later.
   - F2 - 160 Kg. N, 60 Kg. P, 200 Kg. K. Put on same proportion at first as in F1 and remainder 2 1/2 months later.
   - F3 - 240 Kg. N, 90 Kg. P, 300 Kg. K. Same initial amount as F2, same as F2 at 2 1/2 months, and remainder at 5 months.

3. Rice
   - Fo - No fertilizer
   - F1 - 40 Kg. N, 20 Kg. K. Put half of N and K plus all P drilled at seeding. Rest of N and K at boot stage.
   - F2 - 80 Kg. N, 40 Kg. P, 40 Kg. K. Apply as for F1.

4. Pastures
   - Fo - No fertilizer
   - F1 - 50 Kg. N, 20 Kg. P. Put 1/3 N and all P broadcast and disced into soil before seeding. Broadcast remaining N in 2 equal applications at 3-month intervals.

5. Corn
   - Fo - No fertilizer
   - F1 - These levels will be determined following the results of harvest of the past crop. Only N will vary.
   - F3 - The Comite de Fomento Regional del Maiz, Portuguesa, suggests 60 Kg. N, 25 Kg. P, and O K is profitable.

Planned measurements for control of water, determination of time for irrigation and evaluation of treatment effects are tabulated in the following list. Where water measurements are involved, only the type of reading planned will be listed since the measurement procedures are standard.

1. Bananas
   a. Moisture blocks, tensiometers, wells (in the wet season), piezometers, gravimetric moisture determinations, and measurement of irrigation water using Parshall flumes.
   b. Yield: Weight, number of hands, number of fingers per hand, lengths and diameters of fingers, general appearance (cracked, well filled, missing fingers, insect or disease problems), and number of leaves on plant.

2. Sugarcane
   a. Moisture blocks, tensiometers, wells, piezometers, gravimetric moisture determinations, neutron meter, measurement of irrigation water using siphon tubes and Parshall flumes.
   b. Growth measurements (height, appearance, density) at early through late growth
   c. Yield: Wet weight, sugar content, dry weight, and density at maturity.

3. Rice
   a. Measurement of irrigation water and drainage losses using Parshall flumes. Also temperature measurements of water or root zones.
   b. Yield: Length of growth at various maturity stages from seeding to hard dough stage, weight of grain (yield), density, losses from shattering and cracking (estimates), and miscellaneous data such as lodging, disease, weed measurement at harvest and weight of grain per 1000 kernels.

4. Pasture
   a. Measurement of irrigation water, drainage runoff, and irrigation frequency using Parshall flumes.
   b. Yield: Production of dry weight and N content (protein). Also growth characteristics such as vigor, competition with weeds and diseases.

5. Corn
   a. Measurement of water as with sugarcane.
   b. Yield: Weight of shelled corn corrected to 15% humidity, density of stand, weight of 1000 kernels, approximate height and diameter of plants at hard dough stage and general observations.

Crop seasons

Sugarcane – December 1969 to December 1970.
Rice – November 1969 to March 1970.
April 1970 to August 1970.
Bananas – October 1969 to December 1970.
Corn – November 1969 to March 1970.
April 1970 to August 1970.

Future work

Colombia. ICA (Instituto Colombiano Agropecuario) is anxious to participate in a cooperative research program. This agency has been charged by the Ministry of Agriculture of Colombia with responsibility for research in agriculture. The staff consists of young engineers and agronomists, many of whom need guidance, training and experience in research techniques and methodology in irrigated agriculture. ICA has assigned three of their staff to work in water management research and drainage and to cooperate with USU. Field work should get under way during the spring of 1970.

Brazil. The main contact in Brazil has been with the USAID Mission and SUVALE, an Agency of the Ministry of Interior responsible for the development of the Sao Francisco Valley. A team from the United States Bureau of Reclamation (USBR) is currently working with SUVALE on a feasibility study of the river basin. The work contemplated in Brazil will provide direct support to the USAID Mission program and the USBR team.

Since the manpower available to staff SUVALE's proposed research and demonstration stations is young and inexperienced, USU has proposed a training and planning session in February and March 1970 to develop the philosophy and methodology to carry out experiments such as WP-1. Designs will be formulated for implementation on the new stations during the training sessions.

El Salvador. There is considerable interest on the part of USAID/El Salvador to develop a program with the Ministry of Agriculture in Water Management. Approval of a program awaits the findings of an Agricultural Sector Study which will be used as a guide to future programs. It is expected that there will be considerable emphasis on intensifying irrigation agriculture in El Salvador. In this event, water management research and extension will be very important elements. USU will keep in close contact with USAID/El Salvador and will be ready to cooperate in programs applicable to the AID/csd-2167 Contract.

WP-2. Evapotranspiration and Water Requirements

Objectives

The overall objective of this work plan is to prepare and publish technical bulletins on evapotranspiration and water requirements of crops for individual Latin American countries or regions in Latin America. Within this general objective, immediate efforts are directed toward obtaining the following short-term objectives:

1. Estimate evapotranspiration and water requirements for crops in El Salvador, Venezuela and Colombia using, among others, the methods presented by J. E. Christiansen and G. H. Hargreaves at the International Commission on Irrigation and Drainage in April 1969.
2. Review present experimental installations and analyze available data for comparing formulas used to estimate evapotranspiration. Determine suitable monthly crop coefficients that can be applied to measure pan evaporation and/or computed potential evapotranspiration to attain actual consumptive use.
3. Develop additional data collection facilities or improve those now existing in these three countries in cooperation with a government agency now doing this type of work. Obtain additional equipment as needed for proper and systematic collection of data required to meet the objectives outlined above.
4. Publish tentative bulletins on evapotranspiration and crop water requirements for these three countries based on analysis of presently available data, recognizing that revisions may be needed as more and better data on crop coefficients become available.

Current status

Efforts to the present have been confined to Colombia and Venezuela. Data collecting has proceeded in both countries through the cooperation of many agencies involved in maintaining weather data. USU staff members visited Colombia and Venezuela in July and August of 1969 to collect new data and to verify those previously collected. These data are now being processed and analyzed. It is expected that the draft report from Venezuela will be completed in February 1970.

This project is cooperative with CIDIAT. The initial work in Venezuela was sponsored by CIDIAT and much of the computer analysis in the development of the formulas that will apply to humid area conditions has already been done. The final report will reflect this cooperative effort.

Formula development

An analysis has been made of all available Venezuelan data pertaining to evapotranspiration and in which Class A pan evaporation data were included. On the basis of a study of these and other data (two years of records from Davis, California, and records from a high elevation station in Argentina) the climatic coefficients for the formulas presented by Christiansen and Hargreaves at the ICID meeting in Mexico, April 1969, have been modified to better fit Venezuelan climatic conditions. New equations were also developed for relating wind velocities measured at different heights above the ground. These equations are based on Venezuelan data where wind velocities were measured at 0.6, 2.0, 5.0 and 10 meters above ground level.

From these studies the following six related formulas were developed. Computer symbols are used in these formulas.

```
RSC = XK1*RMD*CS*CE                          (1)
EVPC = XK2*RMD*CS*CE*CT2*CH2*CW2             (2)
EVSC = XK3*RSD*CT2*CH2*CW2                   (3)
ETR = XK4*RMD*CT2*CH4*CW4*CS*CE              (4)
ETS = XK5*RSD*CT2*CH4*CW4                    (5)
ETV = XK6*EVPD*CH6*CW6                       (6)
```

The symbols used are defined as follows:

RSC The computed incoming radiation expressed in equivalent evaporation in millimeters per day. For all data, the average of RSC is equal to the average value of the measured incoming radiation for the station; RSD values of XK1 were thus determined for each station for comparison.

RMD The theoretical extraterrestrial radiation reaching the outer atmosphere based on a solar constant of 2.0 and expressed in equivalent evaporation in millimeters per day. (RIM is used to indicate inches per month when depths are expressed in the English systems.)

CS The coefficient for sunshine. It can be expressed by the equation CS = .69 + .31 x (S/.5) in which S is the mean monthly sunshine percentage.

CE The coefficient for elevation above sea level. It can be expressed by the equation CE = .97 + .03 x (EL/305) in which EL is the elevation in meters.

EVPC The computed Class A pan evaporation, expressed in the same units as the radiation (mm/day or inches per month). The average value of EVPC is equal to the average value of EVPD, the measured pan evaporation.

CT2 The coefficient for temperature in Equation (2). It can be expressed by the equation CT2 = .65 + .15 x (TM/25.) + .20 $(TM/25.)^2$ in which TM is the mean monthly temperature in degrees centigrade.

CH2 The coefficient for humidity in equation 2. It can be expressed by the equation CH2 = 1.27 - .27 x $(HM/.70)^3$.

CW2 The wind coefficient in Equation (2). It can be expressed by the equation CW2 = .71 + .29 x (W10/8) in which W10 is the mean wind velocity in kmf per hour at a height of 10 meters.

EVSC The computed Class A pan evaporation using measured incoming radiation.

ETR The computed potential evapotranspiration using the theoretical radiation, RMD or RIM. All other symbols used in Equation (4) are defined in the same manner as those for Equation (2).

ETS The computed potential evapotranspiration using measured incoming radiation, RSD, expressed in equivalent evaporation.

ETV The computed potential evapotranspiration using the measured mean monthly pan evaporation, EVPD.

For these six formulas to be compatible, the following relations must exist:

CW4 = CW2 x CW6 XK4 = XK5 x XK3
CH4 = CH2 x CH6 XK4 = XK2 x XK6
XK2 = XK1 x XK3

Tentative values for these constants are:

XK1 = .500 XK4 = .267
XK2 = .350 XK5 = .535
XK3 = .700 XK6 = .765

These values represent Class A pan evaporation and potential evapotranspiration for a well vegetated environment.

These relationships will be used to compute potential evapotranspiration for different climatic zones in Venezuela. It is assumed that the water requirements of crops should equal the potential evapotranspiration plus estimated losses in conveyance and application, allowing for sufficient leaching to maintain a salt balance. The monthly irrigation requirement should equal the total water requirement less the probable precipitation that occurs at least 80% of the time for each month.

Future work

When the bulletins for Venezuela and Colombia are completed, data collection will begin in other countries. Plans are to develop bulletins covering the needs of all Latin American countries, either individually or regionally.

WP-3. Drainage and Salinity Problems in Irrigation Projects of Colombia

Objectives

1. To determine more specifically the extent and nature of the drainage and salinity problems in Latin America.

2. To find a solution to the problems of increasing soil salinity and high water tables of Colombia and other Latin American countries.

General

A specific request was received from USAID/Colombia to consider cooperating with INCORA and ICA in determining the extent and nature of a drainage and salinity problem in the Atlantico-3 project of Colombia. The team presently conducting the feasibility study on the project is encountering many problems which require information which can only be obtained through investigation and field study. It is quite apparent that water management on the project may be the key to its success or failure.

To initiate the research, USU dispatched a drainage engineer to Colombia during the summer of 1969. Studies were undertaken as discussed below to provide immediate information. Both agencies of the Ministry of Agriculture, INCORA and ICA cooperated in the study and made staff available. Two other staff members from USU visited the area and provided assistance in determining the nature of the problem. ICA has assigned two professional staff and two technicians to continue the cooperative research program with USU. INCORA is also providing substantial logistic support for the studies.

Present status

The drainage problems of Atlantico-3 can be categorized as those of both light and heavy soils. Several studies initiated on the light soils during the summer of 1969 (July to September) are described below.

Leaching studies. These studies were implemented to determine if the saline areas of orchards growing in light soils could be reclaimed by leaching through permeable sand lenses that characterize the area as "feeder veins."

To test the feasibility of this approach, four adjacent leaching plots 20 x 30 meters were established in a saline area. The plots were separated by dikes. Rows of observation wells and piezometers were installed to facilitate measurement of the build up and subsequent dissipation of the groundwater mound under the plots and to allow sampling for groundwater quality determinations. Samples were taken before leaching to determine soil salinity.

The plan called for leaching of two plots by flooding and two by sprinkling, applying a total of 1000 millimeters of water in two increments of 500 millimeters each. The soil is sampled after each application to determine salinity. Water application began in late August.

Preliminary data indicate an extremely low infiltration rate (1 millimeter per hour or less). Sprinkling was temporarily discontinued until the soil surface could be treated to improve intake rates and until some low application rate sprinklers could be obtained. Application of water and field measurements will continue until January or February of 1970 under the direction of ICA personnel. A check on the progress of the tests was made by USU in late November 1969.

Infiltration studies. Reclamation of saline soils cannot be accomplished without leaching and/or drainage, which is extremely difficult under conditions of very low infiltration rates. When sprinklers are used to apply leaching water, as with Atlantico-3, most of the water tends to run off instead of penetrating the soil when the application rate exceeds the infiltration rate. Since low infiltration rates appeared to be associated with the saline areas within light textured soils, work has been initiated to determine what factors were causing the infiltration problem and what could be done to improve intake rates to make leaching more reasonable.

Studies are now in progress to determine the rate of infiltration, rate of wetting front movement and bulk density of the upper horizon under various levels of salinity and conditions of vegetative growth, both with soil amendments and surface treatments being used. Indications are that a high bulk density at the surface and poor soil structure are associated with the more saline areas. Analysis of this preliminary work will guide the design of further field studies. The latter may include the installation of tile lines and a surface treatment, such as deep chiseling and/or the addition of soil amendments.

Future work

A plan for research on the heavy soils of Atlantico 3 was discussed in late November 1969 with the Director of Research of ICA and the Regional Director of INCORA. A cooperative program was developed to carry out the required research beginning in 1970.

Measurements will be continued on light soil areas to complete work in progress. Additional studies will be carried out as necessary to solve the problems of reclamation and water management.

WP-4. Off-Season Irrigation to Maximize Benefits from a Limited Water Supply During Drought Periods

Objectives

1. To determine the effects of water management practice on crop yields by using water available during the fall, winter and early spring seasons to fill the root zone soil moisture reservoir.

2. To develop criteria for making optimum use of available irrigation water by matching cropping patterns to the available supply.

General

This research activity was prompted by serious drought conditions existing in Chile and received high priority by USAID/Chile. There is a general lack of understanding and appreciation of off-season irrigation in Chile, although there are a few areas where certain perennial crops are irrigated during the non-irrigation period to store moisture. It is the concensus that better water management will result if this practice is used to take advantage of the unused runoff and if wells are pumped during the non-irrigation season tc provide a full soil moisture reservoir prior to the period of maximum use. The Department of Irrigation of the National Research Institute of Chile at La Platina is the active collaborator in getting this work initiated.

Present status

A USU expert collaborated with the Irrigation Department of the National Research Institute at La Platina during the period 1 July through 6 September 1969. Field plots were selected which had relatively deep soils with good water holding capacity and good drainage characteristics. Since the soils at La Platina were ruled too shallow for this study, cooperating farmers were sought in areas having adequate irrigation distribution systems and measurements will continue until January or February of 1970 under the direction of ICA personnel. A check on the progress of the tests was made by USU in the following crops: grapes, alfalfa, corn and hemp.

Experimental procedure

A minimum plot size of one hectare was selected

for each crop, with soil conditions and previous farm management practices as uniform as possible for each of the plots. One-half of the plot was to be irrigated during the non-cropping season to bring the soil to field capacity through the root zone (2 meters). For comparison, no pre-season irrigation was applied on the other half (see Figure 2).

Prior to irrigation, soil studies were conducted from which the following data were obtained:

1. Moisture percentage prior to irrigation
2. Field capacity
3. Permanent wilting point
4. Apparent specific gravity.

The soils were sampled according to the pattern shown in Figure 3, except where an apparent variability of the soils required more samples and/or the configuration of the test area changed the shape or size of the study plot.

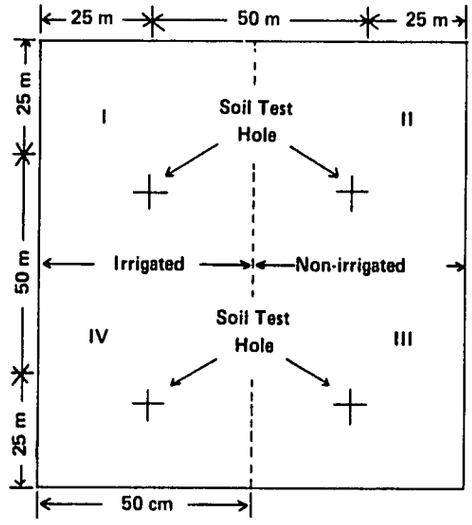

Figure 2. Layout of experimental plot showing the irrigated portion and the location of the soil sampling holes.

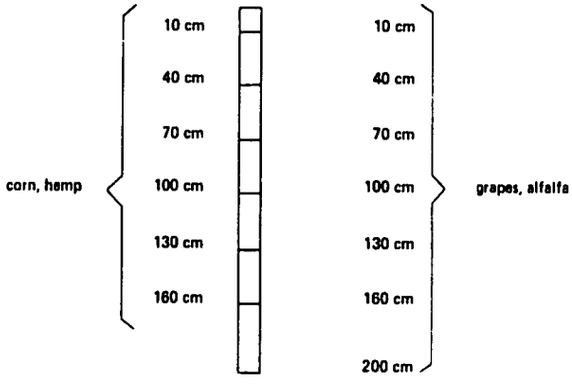

Figure 3. Soil sampling depth in soil test hole.

Each hole was sampled for moisture characteristics at the depths indicated in Figure 3, with all samples taken large enough to perform at least two replications of each test. Moisture samples were placed in double-thickness plastic bags and transported to the Irrigation Laboratory at La Platina for analysis. The apparent specific gravity sample was placed in a standard metal soil sample container enclosed within a plastic bag and transported to the La Platina laboratory for analysis. Because of the lack of equipment available and the time involved, the apparent specific gravity was only sampled at a depth of 10 cm. Ring infiltrometers were used to evaluate the infiltration rate in each plot to be irrigated. An average of the results from three rings in each plot was used.

Upon collection of the foregoing information, arrangements were made to irrigate each test area on separate days under supervision of the USU research personnel. This procedure insured that the test plots were irrigated to field capacity throughout the entire depth from which the moisture samples were obtained. Over-irrigation of some portions was of no concern in these experiments.

Each farmer was instructed to follow his normal irrigation procedure during the coming season on both pre-irrigated and non-irrigated portions of the test plots. In this manner, the amount of soil water available in the pre-irrigated half will remain at a maximum and will be available for plant use later in the growing season when irrigation water is in short supply. Each farmer will be periodically visited by Senior Juan Tosso of the La Platina to observe progress throughout the growing season.

Harvesting in this region will begin in about April and should be completed for all crops by the end of May. (Alfalfa will be an exception and will require special attention to evaluate each cutting.) The yields from both halves of the test plots will be carefully analyzed and compared in order to evaluate the effects of the pre-season irrigation on crop production.

Remarks

As soon as the results of this research are available to confirm the anticipated benefits of pre-season irrigation, this practice will be recommended for implementation soon after the fall harvest is complete. It should commence in early June, provided there is water in the irrigation canals. Most of the canals are closed later for cleaning and repair. This earlier start will also allow a small amount of available surface water to be effectively used over a larger portion of the irrigated area. Addition-

al test plots will be established in June 1970, but the major effort will be to encourage the practice of pre-season irrigation in general where water is available.

WP-5. Research Planning in Sao Francisco Valley, Brazil

Objectives

1. To assist SUVALE and AID in planning for the development of agricultural experimental stations in selected areas so that a program of water management research can be implemented.

2. To provide recommendations on procedures and techniques for implementation of a research program.

3. To assist in determining the professional staff needed and to develop administrative guidelines to aid in the operation of the stations.

4. To determine equipment needs, facilities and plot layouts for the stations.

General

This proposal is a result of the USU research team visit to Brazil in March 1969. Joint meetings were held with USAID officials, the USBR feasibility study team and officials of SUVALE to determine the areas of priority for the cooperative research program.

Background

The Rio Sao Francisco Basin (or Valley) in Northeast Brazil contains 640,000 square kilometers, about 7½% of Brazil's land mass (slightly smaller than the State of Texas). The river rises 300 kilometers northwest of Rio de Janeiro in mountainous areas of high rainfall, accumulating 60% of its water supply before flowing northward 1,800 kilometers through one of the driest areas in Brazil. The river is navigable in the upper 1,200 kilometers of this region, between Pirapora and Petrolina. At its mouth 300 kilometers south of Recife, the river discharges an average of 3,150 cubic meters per second, about 100,000 million cubic meters annually, into the Atlantic Ocean. This is about 18% larger than the Nile at the Aswan Dam.

The basin has a population of about 6,000 people and some 2,500,000 hectares of crop land. It is sparsely settled and underdeveloped except in the south. Crop production is by dryland practices; cultural operations are rudimentary, yields are generally low and plant varieties are sub-standard. Cattle production is dominate in the higher elevations. Livestock throughout the valley are of generally poor quality, but some attempts are presently being made to improve strains. Although good farmland is low priced, the large private ownerships and the abject poverty of potential farmers have limited the development of family sized farms.

The educational level in the basin is low; illiteracy varies from 40% in the cities to about 75% in the remote rural areas. School buildings for the primary grades are generally available, but it is difficult to retain teaching staff in the rural areas. Above the primary level schools are private and too expensive for the majority of the population.

Adequate transportation and communication facilities serve only the larger cities and minor portions of the rural areas. The rainy season interferes with transportation where there are only gravel and dirt roads.

The Brazilian Government has long been aware of the vast potential for land and water resource development in the Rio Sao Francisco Basin, and is actively working on plans to develop areas of the valley. USAID/Brazil is assisting in reconnaissance and feasibility studies in selected areas. Irrigation agriculture is not extensively practiced in Brazil, hence, little or no reliable information and experience is available to aid in the development.

Present status

A visit was made by a USU research team to the proposed station sites in the Sao Francisco Basin. The team was accompanied by officials of SUVALE and a member of the USBR feasibility study team. As a result of the visit, a special report was prepared providing observations and recommendations for the three major stations visited (see Appendix C).

The personnel who are now involved in the research and demonstration activities of SUVALE are young men with very little experience in irrigated agriculture and its problems. They are eager and interested in improving their programs and receptive to new ideas.

Future work

It is proposed that a two-week training course be conducted for Brazilian staff to prepare detailed work plans for each of the stations and experiments which will be carried on. A suggested time for this training program is during late February or early March 1970. In addition, it is proposed that at least two full-time men be assigned to cooperate with SUVALE in implementing the research program at these stations. This will provide supervision and technical assistance for the program .

WP-6. Determination of Water Rights Customs, Laws and Court Decisions in Latin American Countries

Objectives

1. To assemble pertinent information of water rights in Latin America, their acquisition, evaluation and administration. This will include present use, practices and customs in addition to written laws.

2. To compare methods and procedures for acquiring, evaluating and administering water rights and uses in the different Latin American countries. Such comparisons would involve the rights to surface and groundwaters and to both intra-country and international streams.

3. To present the results of the studies for the consideration of cooperating countries for such purposes as they may deem useful.

4. To assemble information related to land and water development as a companion study to objectives one through three above. (This would include a resume of projects now under way or to be considered in the near future. It would also emphasize the importance of updating the water codes in the cooperating countries and of training personnel to administer water rights in connection with existing or proposed projects.)

General

This activity is still in the planning stage, but sufficient work has been done to indicate some of the problems facing Latin America. The orderly administration and adjudication of water rights has not received the attention it needs. Many countries have laws on their statute books, but few, if any, have developed the administrative competency and personnel to administer these laws. Also there is a wide gap between practice in the distribution and management of water and the law itself. Efforts are needed to reconcile the differences so that the legal and administrative procedures do not jeopardize the beneficial, rational and efficient use of water.

Present status

During the past two years CIDIAT initiated a program to collect information on the question of water rights and to provide microfiche copies of this information. The results of this study are on hand and will be supplemented as additional information becomes available. The United Nations group CEPAL (Economic Commission for Latin America) stationed at Santiago, Chile, have made an advisor available to Latin American countries wishing to revise their water codes. Many codes have been changed over the past few years, and changes are continuing.

USU has involved a staff member who will continue to collect data and information and to define the problems that exist. Some work has been done at Utah State and additional work at Santiago, Chile.

Summary of work completed on water rights project to date

With reference to water rights investigations in Latin America, the USU project research team has:

A. Accumulated the following information

1. Twenty-seven thousand (27,000) pages of material on water law codes, treatises, commentaries, decrees and international agreements. These materials are recorded on 16 mm microfiche, indexed and easily accessible and transportable.

2. Twelve thousand (12,000) pages on the general subjects of water resource development, economic development, river basin studies, hydrological forecasting and European water legislation recorded in the same form as Item 1.

3. Approximately 100,000 pages of materials in the same form as Item 1 in the general subject areas of development of underdeveloped countries.

4. Fourteen hundred (1,400) pages of non-published working papers of UN studies completed in 1969 on water laws of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama, and older studies in Venezuela, Uruguay and Argentina. These studies are being microfilmed for insertion into the microfiche system.

5. Numerous other information sources within the U. S. have been located and identified through correspondence.

B. Determined the scope of present and probable future efforts of international organizations promoting the improvements of water laws in Latin America.

C. Determined the present status of water law and its administration practice and enforcement in Chile (see below).

D. Identified some areas where there are opportunities for useful projects on an inter Latin American level including

1. The writing and publication of a summary or digest of Western Hemisphere or Latin American water law.

2. The establishment of a system for the collection and dissemination of information on water law and administration.

3. The maintaining of 1 in current form by semi-annual or annual packet parts or supplements.

4. The search for an institution to continue these programs after they are once established.

E. Developed a work program for identification of specific in-country field studies.

Summary of report on water law in Chile

The present water code was established in 1952 and amended in 1966 to integrate land reform provisions. The agency established in the 1966 amendment to administer water rights for Chile has not yet been staffed and brought into existance. In the irrigated zones, local institutions exist to supervise and control water distribution.

Limited investigations have been made by the Land Tenure Center of Wisconsin into the water law provisions of the Agrarian Reform Law in one geographical area. The study has not yet been published. The international center has studied the water code in general, but there are no plans to publish the study.

Conflicting and priority use problems are critical in the Central Valley because of drought conditions. There is a critical need for retirement of the code regulations and education of the administrators and users in the concepts of distribution and reasonable use in order for their water resource to meet present demands.

Needed expansion of agricultural production in the northern regions is dependent primarily on the development and use of subterranean water sources. This development could be greatly enhanced by implementation of a national system of law and administration of this resource.

There is very little information available on water rights and administration in Chile, and a central administering agency does not exist. Thus when problems arise and water is in short supply, as it has been lately due to severe drought, there is no agency prepared to consider what measures can be taken. The usual procedure is to settle disputes on an emergency ad hoc basis. This may work for a time, but it is an inadequate solution for a permanent program.

Latin America in general The UN, through CEPAL in Santiago, appears to be the only organization previously engaged in promoting the development of water resources in Latin America through studying and recommending improvement in the legal and administrative systems for controlling distribution. The activities of CEPAL have been limited to providing consultants upon request to aid in limited field studies, reports and preparation of draft codes. Dr. Guillerino Cano provided most of the early studies and reports; more recently they have been made by Dr. Mario Valls who is now preparing final drafts of studies on some Central American countries. There have also been some short-term experts provided by the UN.

Dr. Valls felt that the improvement of the institutions and laws for distributing water were vital to development of Latin America and that there were many areas where information and understanding could contribute substantially to progress. He focused on the need for books containing a digest of the laws and institutions as they now exist and the critical need for information flow on water rights, administration and related areas to people and agencies concerned with these problems. The UN is not working in either of these areas that he deems critical (see Appendices D and E).

Mr. Seckinger, the Land Tenure Center, and The International Legal Center were all very favorably impressed with the need for, and utility of, a digest and information collection and distribution system.

WP-7. Economics of Water Management Research in the Arid and Sub-Humid Areas of Latin America– Rural and National Impacts

General

The major problems of water management must include the impact of change and innovations upon the local and national economy. What happens at the farm level determines the effect of irrigated agricultural production upon the economy as a whole. Thus, this facet of water management is receiving consideration under the USU program of water management research.

Objectives

Up to this point the work has been in the planning stage and contains the following objectives:

1. Establish benchmarks. In order to estimate economic changes associated with alternative land and water management practices, it is necessary to identify current production methods, yields, hectarages and costs.

2. Evaluate price elasticity for main food crops. The net worth of alternative land and water practices cannot be evaluated in the absence of estimated price effects related to production increases, sources and prices of production.

3. Relate domestic absorptive capacity to hectarage potentials. Predicted domestic demands for food and animal products are invaluable in project design and for forward planning purposes.

4. Determine feasible water conservation, cropping and small machinery practices. Results of demand price studies will be combined with primary and secondary data concerning effects of improved water management, varieties, crop combinations and fertilizers to help farmers in selected areas choose the best net income probabilities.

5. Forecast main crop production levels. As more and more alternative production input "interactions" data become available, technologically achievable national outputs can be predicted for food and eventually animal and industrial products.

6. Generalize direct and indirect economic impacts of viable land and water practices. Given judgments on farmer acceptance rate of improved management methods and the net expected farm benefits, rural income limits can be predicted; potential needs for infrastructure and other physical marketing and credit facilities can also be estimated.

It is anticipated that some field work will be done by March 31, 1969, but the major effort in this phase of the project will not begin until fiscal year 1970. Work plans are ready and will be submitted for consideration.

WP-8. Irrigation and drainage by Modified Mole Systems

General

The drainage of heavy soils with low infiltration rates and already high water tables to allow rapid drying of the soil is a serious problem, especially in areas of high rainfall. Preliminary work is presently under way at USU to develop a modified mole system to help alleviate the problems associated with poor drainage. Some laboratory work under controlled conditions is under way and will result in the design of a modified mole system which will be field tested in Latin America. The modifications to the mole system will tend to alleviate many of the failures that have been commonly associated with conventional mole drains. A new technique will be employed which, if successful, will have a great impact upon land preparation, time of planting and water management in general.

Objectives

1. To design and fabricate an implement to be used in the construction of modified mole systems.

2. To test the implement by constructing mole systems on the University Drainage Farm where soil types are similar in many respects to those of Latin American countries. Laboratory tests will be conducted to find the moisture content of the soil which produces stable and well formed moles with least resistance to the moling implements.

3. To construct mole systems in the Latin American countries using an implement developed, and to measure the efficiency of the implement and the systems.

4. To improve the device as indicated by the studies and prepare detailed drawings of it. It is expected that a handbook describing the mole system and method of construction will be prepared.

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SUMMARY OF INTERNATIONAL TRAVELS

Anderson, Bruce H.	– October 31 to November 9, 1968 Venezuela to Utah
	– February 22 to March 22, 1969 Brazil, Venezuela, Colombia, Peru, Chile, Argentina
	– August 26 to October 5, 1969 Venezuela, Colombia, Brazil
Bishop, A. Alvin	– February 17 to March 25, 1969 San Salvador, Brazil, Panama, Venezuela, Peru, Chile, Colombia
Christiansen, Jerald E.	– June 16 to July 30, 1969 Guatemala, San Salvador, Panama, Venezuela, Peru, Chile
Kidman, Don Carlos	– August 30 to present Chile
Nielson, Rex F.	– August 26 to October 5, 1969 Colombia, Venezuela, Brazil
Olsen, Edwin C., III	– June 16 to September 15, 1969 Chile
Peterson, Howard B.	– February 17 to March 25, 1969 San Salvador, Brazil, Panama, Venezuela, Peru, Chile, Colombia
	– August 26 to October 5, 1969 Colombia, Venezuela, Brazil
Stutler, Kern	– June 16 to July 23, 1969 Venezuela
Watts, Darrell G.	– June 18 to September 22, 1969 Colombia
	– November 23 to November 29, 1969 Colombia

APPENDIX A

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BIBLIOGRAPHY OF BASIC DATA

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APPENDIX B

REPORT OF THE USU-CUSUSWASH WATER MANAGEMENT TEAM ACTIVITIES IN LATIN AMERICA

REPORT OF THE USU-CUSUSWASH WATER MANAGEMENT TEAM ACTIVITIES IN LATIN AMERICA

During the period February 17 to March 26, 1969, scientists from Utah State University traveled to Central and South America to initiate field work under USU-USAID Contract No. 3-67 for "Water Management Research in Arid and Sub-Humid Lands of the Less Developed Countries." The team consisted of Dr. Bruce Anderson, Dr. A. Alvin Bishop, and Dr. Howard B. Peterson. Field visits were made in several countries to observe water management problems and to discuss the problems with USAID Missions and local country officials. The countries in the order visited included El Salvador, Honduras, Venezuela, Colombia, Peru, Chile, Argentina, and Brazil.

The primary purpose of the trip was to discuss the proposed research with USAID Mission officials and country nationals charged with the management control and development of the water resource. The discussions followed the general plan of outlining the major water use and management problems of each country followed by a listing of the research being done. Priorities were then given to research needs and to a discussion of available sites and facilities. The following is a brief report of the activities carried out in each country.

El Salvador

The USU team arrived in El Salvador on the evening of February 17, where we were met by Mr. Virgil Peterson, our USAID contact. On February 18 we met with USAID Mission officials, along with members of the Ministry of Irrigation and Agriculture of El Salvador. The need for consumptive use data was strongly indicated in the ensuing discussion. Some experiments are now being carried out, but the Salvadorans feel that they need help in evaluating the experiments and interpreting the results. A more apparent need has to do with the efficiency of systems and methods for applying irrigation water. It was pointed out that very few farmers in the country are now using irrigation water. Some irrigation projects are in the formative stage, but most of the farming is fully dependent upon natural rainfall.

There has been some groundwater development in El Salvador and some quality problems have been encountered. For this reason, research in quality criteria for the conditions of El Salvador seems to be in order. There is a United Nations project for generating power using thermal energy from the hot volcanic groundwaters. These waters seem to be high in boron and sodium and their disposal may be a problem.

El Salvador specializes in raising cotton, with large areas devoted to this crop. Other major cash crops include sugarcane, coffee and shrimp. Crops grown mainly for local consumption are rice, fruits, vegetables, beef and dairy products. One practice that seems to have caught on is the irrigation of pastures for the production of feed for dairy and beef animals, but irrigation of other crops is rather limited. In future development, it appears that much of the water for irrigation will come from groundwater sources and research in the problems of recharge and management of groundwater basins is of paramount importance.

Land grading may be questionable since the soils are extremely shallow, stratified and contain hard pans. Practically no sprinkler irrigation is being carried out in the country at the present time. Irrigation now extant consists primarily of individual systems serving or a farmer. There are only two group irrigation projects, one of which has been developed under the Ministry of Agriculture.

On the afternoon of February 18, the USU team inspected a potential irrigation project in the Zapotecan Valley. We also visited the Agriculture Research Station in the valley where we observed experiments with vegetable crops under irrigation. One project in the valley is being served from underground water sources. The development consists of three wells and pumps, one with a capacity of 1,500 gallons per minute and two with capacities of 900 gallons per minute. These wells supply nearly 400 acres of land. At the time of our visit, much of this land was idle, with the remainder in sugarcane, tomatoes and cucumbers.

The inspection party proceeded to the headwaters of the river where groundwater is very close to the surface and drainage is a considerable problem. Some shallow drains have been constructed and the water table was observed to be 18 to 24 inches below the ground surface. The major crop in the area was corn, but nothing much was growing in the area of high water table.

In the discussions with the Ministry of Agriculture personnel, the name of Kern Stutler was mentioned several times and he seems to have established a very high rapport with the Salvadorans. At the Experiment Station, Kern had initiated lysimeter investigations to determine the consumptive use of corn. Evaporation pan data were also being taken with the idea of testing the Hargreaves method for computing consumptive use.

There appears to be a good opportunity to initiate water management research and to show what might be done with irrigation in El Salvador. The potential irrigated area, we were told, may be as high as 300,000 hectares with only about 5,000 hectares being irrigated at the present time. A research team consisting of J. E. Christiansen and Kern Stutler could launch such a program very effectively since Kern knows the country, the personnel in the Ministry of Irrigation, and commands the respect of the local people. During two to three month visits, this team could help analyze and interpret data from the two-year lysimeter study and help formulate plans for future work. There would be no problem in getting cooperation from the local people if an arrangement involving Stutler could be developed.

On Wednesday, February 19, we visited with the Mission Director who assured us that the Mission was extremely interested in developing the water resources of El Salvador and further, that any water management research done under our contract would be coordinated with the plans of the El Salvador USAID Mission.

Honduras

We arrived in Honduras at 12:30 p.m. on February 19 where we were met by Dick Hughes who outlined the schedule of our meetings for the afternoon of February 19. First, in the company of Mr. Hughes, we met with members of the Ministry of Natural Resources to discuss the problems of irrigation in Honduras. At the present time very little irrigation is being practiced in Honduras, even though there are some good examples of excellent irrigation systems by the United Fruit Company and Standard Fruit Company. Strange as it may seem, the irrigation has not gone much beyond the boundaries of the fruit companies. In addition to the fact that farmers rely almost totally upon the rainfall, land tenure is a problem and the farmers are very reluctant to attempt to grow any crops except those that provide a year-long food supply. There is a general feeling that the major problem is credit, which the small farmer has difficulty obtaining. Because of this, there is now a priority program to provide credit for the small farmers in Honduras. Although vegetables have a ready market, it appears that most farmers do not like to produce them because of their perishable nature. We were told that there is an extension program in water management at the present time, although the program is just getting under way.

Later in the day we met personally with the Minister of Natural Resources and he pledged his support to any research program that we might initiate in Honduras. He indicated that part of the Experiment Station land in the Comayagua irrigated area would be available for experimental purposes. There are two small irrigation projects in the Comayagua area; one of 1,700 hectares and the other of 3,500 hectares. The Experiment Station is located on one of the projects which was developed in about 1960 and serves the area with a canal having a capacity of 50 cubic feet per second.

On February 20, in company with Mr. Hughes, we took an airborne tour of proposed irrigation projects in Honduras. Flying from Tegucigalpa, we went first to the Choluteca project, then to the Nacaome Project, back to the Comayagua Project and returned to Tegucigalpa. We landed at Comayagua and visited the Experiment Station for a couple of hours, looking at the irrigated pastures and farming operations being carried out in connection with the breeding of the Brahma beef stock and Brown Swiss dairy animals.

Rounding out our visit to Honduras was a meeting with the new Mission director in which we discussed in some detail the problems that might be encountered in launching a research program in that country.

It appears that housing will not be a problem in Honduras, but schools would be a problem in all areas except near Tegucigalpa. If the research is located at Comayagua, it was suggested by the Mission people that the families be located in Tegucigalpa and that the professional people assigned to the project commute to Comayagua to carry out the research work. Staff quarters could be provided at the project area at Comayagua, but the professional staff would have their main office in Tegucigalpa, going to the fields when required. A new road will be completed in April of this year which will cut the driving time between Tegucigalpa and Comayagua to about 1½ hours.

In general, irrigation is not very popular with the local people at the present time. The major irrigation projects are those which have been developed by the United Fruit Company and Standard Fruit Company and, even though these large companies have carried out a very extensive irrigation operation over the past two or three decades, it appears that very little of their modern practices have been adopted even by the nearby farmers. This suggests that the farmers are either not interested or that they are afraid of trying irrigation and do not care to go to the extra work that irrigation would involve. One or two small pilot irrigation projects, such as the one at Comayagua, suggest that the farmers will be reluctant to use irrigation water. Even in Comayagua where irrigation water is available, we observed that much of the land is idle in the middle of the dry season.

Only a small part of the land that could be irrigated is being irrigated at the present time.

Some irrigation trials are being initiated at the station in Comayagua on pasture lands. Research involving kinds of fertilizer and rates of application, time and amounts of irrigation water and possibly some variety trials could be combined with these.

Panama

Although Panama was not on the itinerary, a stopover here was necessitated because of airline scheduling difficulties. We were met at the airport at 1:45 p.m., February 21, by Mr. George Hargreaves and Mr. Peter C. Duisberg of the American Geodetic Survey who had heard of our proposed work and wanted to discuss it with us. Mr. Hargreaves has done considerable work on water requirements of tropical crops and interesting discussion followed.

Venezuela

We arrived in Venezuela about midnight, February 23, and were met at the airport by Ray Miller and Bruce Anderson. Our meetings with the Ministry of Public Works and USAID officials began at 8:30 a.m. on February 24 and continued for a day and a half. It was pointed out that Venezuela has a heavy investment in irrigation and drainage facilities, but that the efficiency of these projects is very low. Mr. Miller reported that nothing had been done on the irrigation trials set up by Sterling Taylor in 1962 at the recommendation of Dr. Wynne Thorne. Much more information is needed about the heavy soils of this region to determine the appropriate course of action. He further noted that the research area at Guanare has experimental plots and irrigation systems close to the station so that water can be obtained and managed according to the experimental requirements. A chemistry laboratory and other laboratory facilities are also available.

Some discussion followed concerning the climate of Venezuela, which has very distinct dry and wet seasons. The rainy season begins in April and continues through November. During this period, due to the very heavy nature of the soils and the possibility of puddling, very little tillage work or land forming can be accomplished. Any particular work for land grading and smoothing should be confined to the months of December through March.

With reference to existing projects, it was noted that many developments have been made on fairly poor land and very little emphasis had been placed on getting proper water management on good soils. The first emphasis should be placed on water management practices on good soils, leaving the problem soils for later developments. It was pointed out that the physical condition and fertility of the soils of Venezuela are a major problem and that the initial water management practices should be linked with fertilizer trials in order to obtain the best fertilizer and water combinations.

Four specific areas of water research were outlined. First, pasture drainage problems in the Majaguas area should be considered, since pasture is one of the most important uses of land in Venezuela. The drainage of pasture lands during the wet season is very important. Ken Matheson pointed out that a combination border for drainage and irrigation should be designed and tested in order to obtain a duel purpose facility for both applications. The pasture drainage problem will require the following kinds of research: (a) determine the combination of border dike and ditch system that can be used for simultaneous drainage and irrigation; (b) develop design criteria for furrow drainage and border drainage; and (c) determine the relationship for the movement of water into and through the soils being studied.

A second area of research concerns the frequency of irrigation. Very little work has been done in Venezuela concerning the irrigation requirements of the soils, the soil moisture storage capacity, or the best methods of application. Apparently some work has been done on bananas, but the data have not been analyzed or published. It was indicated that the frequency of application studies should be made to determine: (a) the time between irrigation of the various crops on different soils; and (b) the soil moisture levels for maximum production. Discussion of the crops to be used in the frequency trials indicated that some experiments should be made on pasture and corn, with beans having high priority. Other crops mentioned were cane, bananas, plantanos, cocoa, cotton and vegetables. It was pointed out that aeration may be a problem on many of the heavy soils of rather recent origin.

A third major area of research has to do with cultivation methods to improve soil moisture management. Apparently nothing is known about the effect of cultivation practices on soil moisture or crop response, and some research in this particular area seems to be needed.

A fourth area of study concerns solar energy availability for tropical agricultural conditions. Ken Matheson opinioned that the total energy available for growing crops during various months of the year was much less than in some of the temperate zones farther

north, consequently crops would not mature as quickly in Venezuela as elsewhere. The energy-climatological relationships have a high priority for study in all of the tropical areas.

During the discussions it was decided that the initial research at Guanare under Dr. Miller's leadership should be concentrated on two general areas. The first area will include a study of border and furrow irrigation methods to determine design criteria for combination drainage and irrigation borders to be used on pasture, and studies of combination irrigation and drainage furrows for use on row crops. The exact experimental design is to be worked out by Dr. Miller, but in general it will involve determining the length and width of borders for different soils and different crops, and measurements of the drainage efficiency of these borders. Essentially the same information will be required to determine the length and size of furrows for combination drainage and irrigation. In effect, the combination irrigation and drainage systems for both furrow and border irrigation would involve length of run, width of borders, slope, shape and spacing of furrows, etc. Trials for borders having widths of 5, 10 and 15 meters were suggested with lengths of 50, 100, 200 and 400 meters. It was suggested that the furrow size be varied from shallow to deep furrows (approximately 30 centimeters from ridge to bottom of furrow) with spacings as required for the crops to be grown.

The second major research area to be initiated concerns frequency of irrigation. The frequency of irrigation and the relationship of water to fertilizer and crop yield should be given very high priority. Dr. Howard Peterson suggested that at least one experiment should be set up with the water fertilizer interaction as a demonstration of the differences that might be expected in corn with different water and fertilizer levels. Nitrogen should be the variable in the fertilizer, with water being varied from the limits of fairly high moisture levels to high stress levels. Considerable discussion was made of the types of crops to be tested. Dr. Peterson suggested that since corn is most sensitive to nitrogen, it should be used in the experiment. There was considerable reluctance on the part of the Venezuelans to use corn, since they felt that this crop could not be grown with success during the dry season. Dr. Peterson suggested that corn does very well under irrigation in other locations and if it does not do well in Venezuela during the dry season, research should be directed toward determining why it does not respond. One very likely answer is that the variety normally grown during the wet season would not be expected to do well in the dry season, and that a different variety might respond better.

It was decided that initially the water management trials (frequency of irrigation) should be made on pasture lands, corn and black beans. This seems to be a rather ambitious undertaking and Dr. Miller will need considerable assistance to make much progress with such an extensive study.

Dr. Anderson pointed out that the design of irrigation systems would be given considerable backstopping from CIDIAT, with additional assistance from Professor Milligan, Carlos Grassi and Byron Palmer. Carlos is very well versed in modern irrigation problems and would be of considerable help in outlining an experiment to test the combination irrigation and drainage systems. The water fertilizer cross will be largely Dr. Miller's problem, with assistance from Dr. Peterson at Utah State University and others.

Colombia

We arrived in Santa Marta at 3:00 p.m. February 26 and proceeded immediately to the Magdalena area to see the pilot farms and experimental areas there. A large area is being converted from banana cultivation to general agricultural crops. The land was formerly owned by United Fruit Company and only recently was it returned to the Colombian Government for distribution to prospective farmers.

The major problems of this area will be concerned with clearing the land of banana trees land grading, construction of farm distribution systems and adaptive methods of irrigation to the crops and local conditions. It is apparent that the present irrigation and drainage system serving the bananas will need considerable modification to accommodate the smaller areas involving many farmers. As yet the land has not been subdivided and turned over to the new owners; therefore, all of the problems involved in launching a new project are in evidence.

Utah State University has a contract with Colombia to establish a sub-center of CIDIAT at Magdalena to provide education and training in the development of water and soil resources. This sub-center, along with the land, water and facilities available, should prove an excellent location for water management research. Several scientists from Utah State are presently on the job and could maintain the continuity of research work until permanent staff could be assigned under the contract.

On February 28 we met with Mr. Ken McDermott of the USAID office in Bogota to discuss our research plans with Mission personnel. The Mission seemed enthu-

siastic about our proposed project and were anxious to give us what support they could. However, they were somewhat hesitant about combining the training program at Santa Marta with a research program. It was indicated that there is a severe salt problem in the lands near the Santa Marta area where they hoped we might help with the solution. Other water management needs were discussed and some detailed plans were made.

Later in the afternoon, in company with USAID/Colombia staff, Dr. Anderson and Dr. Peterson met with Colombian Government officials concerned with water development. Dr. Peterson also had a visit with Dr. Waugh of Rockefeller Foundation.

Peru

We arrived in Lima at 6:00 p.m. March 2. The following morning we met with Mr. McLendon of the USAID office to discuss the Peru program. The political problems in Peru at the present time will make it difficult to initiate any program in the immediate future. However, it was indicated that we might work out some cooperative program with LaMolina to assist with the research work being done there.

From the USAID office we went to LaMolina where we were met by Dr. Aurturo Cornejo, Dean of Agricultural Engineering. We discussed in some detail the various research projects now being carried out at LaMolina. Dean Cornejo is extremely anxious that a cooperative program be worked out with USAID. It was suggested that our professional staff might go to Lima on short assignments to work with either students or staff doing research at LaMolina concerning the irrigation problems of Peru. The possibility of any detailed work in Peru, however, is rather remote at this time.

Chile

We arrived at Santiago, Chile, at 2:00 p.m March 4, and went immediately to the USAID offices where a meeting was held with a number of government officials involved in land and water development. The following Chilean people were present:

Sr. Juan Fernandez	Ing. Agr. Servicio Agricola, Ministerio de Agr. Division de Conservacion de Recursos Agricolas
Colonel Orlando Jorquera	Pdte. Com. Coordinadora Sequia. Comision Nac. Sequia.
Sr. Guido Meller	Creditos Externos, Oficina Planificacion Agricola
Sr. Sergio Lazcano	Jefe. Projectos Puesta en Riego, Of. Planificacion Agricola del Ministerio de Agricultura.
Sr. Juan del Canto	Jefe Depto Recursos Financieros ODEPA
Sr. Juan Tosso T.	Ing. Agr. Projecto Riego. Instituto Investigaciones Agropecuarieas. La Platina.
Sr. Hiram Grove	Director, Ext. Exp. "La Platina"
Sr. Patricio Carmona B.	Seccion Riego y Drenaje, CORFO
Sr. C. B. Seckinger	Agr. Development Officer USAID/Chile
C. A. Cramer	Chief Engineer USAID/Chile
Sr. Ignacio Dominguez	En Representacion de Don Ricardo Isla., Facultad de Agronomia, Universidad Catolica
Sr. Alfonso Monardes	Economista Agricola Mision Economica

The scope of the Utah State University water management contract was outlined by Mr. Seckinger for the officials of Chile as follows. The objectives of this research will include but not be limited to:

a. The development of knowledge and data on how best to conserve and utilize water falling on the land as rain and the most efficient means of supplementing needed soil mois-

ture with limited amounts of irrigation water.

b. The development of knowledge and data that can be used for economic on-farm design and construction of conveyance and delivery systems including structures for control and measurement of irrigation water.

c. The development of surface and sub-surface drainage systems to eliminate the hazards resulting from surface flooding and high water tables.

d. The identification of important factors affecting the degree of leveling of the various soils in the major climatic zones and the relationship of these factors to erosion, water infiltration and good land use and cropping practices.

e. The development of methods of water application, including time and amounts which are suitable and efficient for different soils of varying physical properties (water-holding capacities, intake rates, etc.) with major crops.

f. The integration of these water-use factors into a productive cropping system consistent with farm size and available farming practices.

g. Where soil salinity and exchangeable sodium are problems, studies will include soil amendments, soil and water management procedures and use of salt-tolerant crops.

Considerable discussion followed concerning the various research possibilities in Chile. Plans were made for a day-long field trip the following day with members of the Department of Agriculture engaged in irrigation work in Chile.

On Wednesday, March 5, we proceeded to field sites north and west of Santiago. We went as far north as Los Andes and viewed the problems encountered in irrigation and the damage due to the extreme drought. It was pointed out that, due to the drought, only about 50% of the irrigated land received water this year (1968-69) and yields were also reduced from 15 to 30%.

From statements made by the Chilean officials, it appears that very little irrigation research or irrigation science is being applied at the present time. Farmers are irrigating pretty much without any technical help or supervision, using the water according to their water rights. The field inspections included the Calina and Aconcagua areas. We returned to Santiago late in the afternoon.

On Thursday, March 6, a field trip was made to the Experiment Station at La Platina where some irrigation trials and consumptive use studies are underway by the Chilean Government. Various methods of water application were being tested to determine the effect on controlling diseases in orchards. Consumptive use studies were being made of corn and potatoes.

Three troublesome problems at the La Platina station are the control of weeds, the sediment problem in the irrigation canals and the low permeability of the soils. The station has built a small storage pond for silt control, but apparently nothing is being done to control the weeds in the area or to solve the problem of low permeability.

After observing the experimental work at La Platina, we traveled south to Chillan, where on Friday, March 7, we visited the technical institute and observed the irrigation and consumptive use experiments being done there. Some work on methods of application and intake studies were under way with furrow intake trials and rings being used. After visiting the field experimental plots and the weather station at the institute, we held a meeting with officials in the Chillan area to discuss irrigation problems in that vicinity. Dr. Bruce Anderson suggested that CIDIAT might sponsor a brief course in research methods and techniques so that standard methods could be used in their irrigation trials.

The problem of consumptive use in relation to climatological data was discussed at some length. One of the most important problems raised by the Chilean people concerned the methods of application in relation to irrigation efficiency. It was suggested that irrigation efficiency in relation to the water supply might also be an appropriate study. Methods for design of irrigation systems were also discussed in some detail. Possible farm structures for irrigation, including underground concrete pipe, sprinkler irrigation and appropriate structures for surface methods were considered. Surface drainage in the Chillan area during the rainy season seems to be a problem since the annual rainfall in that area averages about 48 inches. Sediment transport in Chillan does not seem to be the problem that it is at Santiago.

Research work might include the following:

1. Establish consumptive use studies and correlate with weather data.

2. Set up controlled experiment on rates of frequency of application of water using different crop varieties, fertilizers, etc.

3. Study the use of Na NO_3 as a cause of low permeability of soils.

4. Initiate trials on off-season irrigation from streams and groundwater as a drought modifier.

5. Hold a short course on research methods.

Argentina

We arrived in San Carlos at 12:00 p.m. on March 8. March 10 and 11 were spent in team discussions concerning the progress in achieving the objectives of the trip. Notes of country meetings were compared and a brief outline for a trip report was prepared. Research possibilities under the contract for the countries visited were reviewed and project proposals outlined. On March 12 we flew from San Carlos to Neuquen where we were met by members of the Water and Power Administration for Argentina. Thursday morning (March 13) was spent in the field with members of Aqua and Energia (Ministry of Water and Power). The afternoon was spent in the Experiment Station of INTA located south of General Roca.

INTA is an organization concerned with the research and extension of agriculture in Argentina. It is supported by a tax on the land amounting to 1½%. It is not dependent upon the Government of Argentina for any direct appropriation and has a budget to do the work that is required. On the other hand, Aqua and Energia is an arm of the Government of Argentina and depends primarily upon appropriations from the Government to finance its operations.

The personnel at the Experiment Station are involved primarily in the work related to the principal crops in the Rio Negro Valley including apples, pears, grapes and tomatoes. Although the entire valley is irrigated, there is practically no work being done on the irrigation phase of agriculture at the present time. The irrigation and drainage problems observed in the field were discussed. There was some discussion of the drainage work being initiated at the Experiment Station.

During the 1968-69 growing season there has been a drought in the Rio Negro Valley, reducing the supply to about fifty percent of the normal. However, it was stated that yields during the year were normal and that the crops had not suffered from the drought. This suggests that in normal years water applications are far in excess of the plant requirements. Water is delivered to the farmers on a rotation basis and the charges are made at the rate of about $8.00 per hectare per year. No charge is made for excess water and natural drainage appears to be fairly good. This accounts for the fact that the valley has been able to continue in production for nearly 70 years with few major drainage systems.

The total system includes the main canal of about 120 kilometers, nearly 1,000 kilometers of distributory canals and 1,000 kilometers of major collector and secondary drains. Thus, the total maintenance of the system involves the servicing of over 2,000 kilometers of channels annually. Water is in the canals for about nine months of the year, leaving only three months available for major maintenance. For this reason, much of the maintenance is being done with water in the canals. The district has fourteen or fifteen draglines in continuous operation in the maintenance of the canals and drains. Drainage is one of the major problems in the area and the evidence of high water table and salinity were visible in many sections visited. Part of the drainage problem is created by use of the drains for discharging waste waters. We concluded our visit to the Rio Negro Valley and continued on to Buenos Aires the evening of March 13.

March 14 was spent in discussions with Mr. Jack Helpin of USAID outlining the problems encountered in water management in the area and discussing the major points of our contract. Mr. Helpin outlined the general administrative organizations dealing with water in Argentina and indicated the role that USAID might play in participant training and other activities connected with water management problems. Apparently there has been no real pressure on USAID or, for that matter, on any agency to get involved in any part of the water management problem. The Rio Negro Valley has been given very little detailed study because, as pointed out by Mr. Helpin, the total agricultural production from irrigated land in Argentina amounts to only 15 percent of the total agricultural product; thus, the pressure is on for other areas outside the water field. Mr. Helpin pointed out that only recently has the Government of Argentina been involved in a basic study of the soils resource of the country, and the water resources have been given very little attention in developing legislation and controls. Mr. Helpin indicated that USAID budgets had been curtailed somewhat and that any participant

training in the water management and irrigation field could not be considered for fiscal year 1968-1969. In fact, he told us that of the more than 100 participants trained from Argentina up to now by USAID, none have been taken from the irrigation and drainage area. If a participant is to be selected for training abroad in the field of irrigation and drainage, it would be necessary for pressures to be exerted by the Government of Argentina in this direction.

After meeting with Mr. Helpin we met with members of the Water and Power Administration of Argentina and again outlined our particular interest in doing water research in Central and South America. Some of our discussions with Mr. Helpin were mentioned and the Ministry of Water and Power indicated that, according to their most recent figures, 30 percent of the agricultural production of Argentina is derived from irrigated lands which amount to only 4 percent of the total cultivated land of the country. If these latter figures are true, irrigation takes on a much more important role than indicated by Mr. Helpin. Generally speaking, the water resources have not been given any careful appraisal and the problems of water use and management (irrigation and drainage) are not being considered by any government agency in Argentina at the present time.

Some discussions were held with the Ministry of Water and Power concerning the role of CIDIAT in continued training of selected personnel from Argentina to increase the competence of professional people managing the water resource. Members of the administration indicated that an annual course sponsored by the Ministry of Water and Power and CIDIAT would be desirable, and plans were initiated to develop such an in-country course in irrigation and drainage for late 1969 or early 1970. It was also indicated that the government should select a trainee for work in the department under the general direction of CIDIAT with the hope that a scholarship could be obtained from OAS for this individual for graduate study in the United States leading to a Master's degree. Considerable discussion about the qualifications of the particular individual followed, but no decision was reached. The Ministry of Water and Power are hopeful that a man can be selected to begin training under this contract, either by first attending the six-month comprehensive course sponsored by CIDIAT and then coming to the United States, or to begin working in the Experiment Station at General Roca and increasing his competence in English so that he would lose little time when he comes to the United States for graduate study. If the work in General Roca was done under the direction of one of the professionals provided by CIDIAT, it is possible that the data collected might be used for a Master's thesis by the individual.

Brazil

We arrived in Rio de Janeiro March 16 at 3:25 p.m.

Early the next morning we went to the offices of USAID where we were met by Mr. Guzman, area development advisor, and various other people in USAID/Brazil. A meeting was held in the office of Michael Galli to discuss the involvement of USAID in the development of the Sao Francisco River Valley. The technical assistance team being assembled to prepare detailed project development plans of the Sao Francisco Valley will work in cooperation with the counter-part Brazilian team (SUVALE). This team will include agricultural engineers, soil specialists and agronomists. One of the assignments of the team is to develop several pilot farms (demonstration farms) in the various zones of the Sao Francisco River Valley. It is expected that one of these pilot farms might be used as a base for our experimental work in Brazil.

We also met with Mr. Wyman R. Stone of the Engineering Division who briefly outlined some of the activities that are to be carried out by the Bureau. He indicated that research was not given a high priority in the preliminary planning and development phase of the operations.

In a conference later that day with EPI, it was indicated that FAO has been doing experimental work at the station at Petrolina, the site suggested as a base for our research activities also. Under IRI, the national headquarters for research in Brazil, regional research institutions are set up in the various regions of Brazil. Each of the eight regional research centers has a number of satellite stations to do specific research in the various problems of agricultural development. In addition to this national emphasis on research, some of the Brazilian states have additional research departments. Only recently some of the rural universities have initiated research in connection with university activities. A new division of agricultural engineering has just been created in IRI, recognizing the importance of water use.

On Tuesday, March 18, additional meetings were held with USAID/Rio personnel concerning activities in Rio. A rather long, detailed meeting concerning research possibilities was held with members of SUVALE. We departed for Recife about noon, arriving there late in the afternoon, where we made contact with Mr. White and discussed our schedule of meetings and contacts in Recife.

On Wednesday morning (March 19), we met with Mr. Freeman Smith and Mr. White of USAID/Recife for

a briefing on the $13,000,000 loan being negotiated between USAID and Brazil to support research in the country. The National Research Council (CNPq) will get some 20 percent of the funds with EPE, the equivalent of our Agricultural Research Service, receiving the other 80 percent.

Later in the morning, a meeting was held with all the agricultural staff at Recife where we discussed the Utah State University Water Management Research Contract. Although the large loan is being made to the Brazilians for research, it was apparent that high priority is not given to research by all concerned. Some of the staff indicated that training should receive the greatest priority.

During the afternoon, we visited the new Training Center at the university complex near Recife. We were quite impressed with the new Training Center developed under USAID support. Dr. Bruce Anderson was especially pleased that such a fine facility was available for CIDIAT activities.

After discussing our commitments in Recife and Rio, it was decided that Dr. Peterson should return to Rio to work with SUVALE people concerning the research that might be initiated there while Drs. Anderson and Bishop would remain in Recife to discuss the research contract with Brazilian counterparts of SUVALE, SUDENE and other divisions in Recife.

On March 20, the research contract was explained in some detail, but there seemed to be considerable confusion on the part of the Brazilians concerning just what research involved. They were anxious to construe research to include project development feasibility studies, and the problems of training were always cropping up rather than research. We explained the difference between the two Utah State University contracts, one involving the CIDIAT Training Program and the other the Water Management Research Program. It was evident that the Brazilians wanted to think in terms of training. It was pointed out to the group that research generally provided the information for training activities. We departed for Rio at 4:00 p.m. arriving at 11:00 p.m.

On Friday, March 21, summary discussions were held with USAID and SUVALE people concerning the possibility of research. Some plans were made for developing a more detailed work plan if considered advisable by USAID/Rio. It seems that considerable adaptive research should be done, especially in the large Sao Francisco Valley development. Information is lacking concerning most of the questions that are usually asked in connection with irrigation developments. The combinations of crops and fertilizers best adapted to irrigated conditions is not known. Consumptive use data for most crops planned for the area is needed. Methods of water application best suited to the soils and agricultural conditions of Brazil must be determined. In general, additional knowledge regarding the conditions for maximizing the water resource is required. Brazil has had very little experience in irrigation and the adaptive research might also be used as a demonstration of the practices necessary to yield maximum returns.

General Conclusions

In all countries visited, the need for adaptive research was evident. Education and training in water use and administration is also a critical need. It is believed that many opportunities exist to do significant studies, under the present limitations of the contract, at a number of locations in Latin America. The needs, possibilities and scope of the research varied from country to country. The areas of major interest which show promise of yielding significant progress are outlined in the following table.

Country	Research Area	Suggested Manpower in Professional Man Months
El Salvador:		
	Analyses of lysimeter data	3
	Irrigation application and efficiency studies	3
	Establish research needs	2-3
	Water Quality investigation	3
	Water requirements	2-3
Honduras:		
	Establish irrigation research on irrigation/fertilizer/variety interaction at Camayauga	3
	Water requirements of crops	2
Venezuela:		
	Combined irrigation and surface drainage facilities	3
	Irrigation/fertilizer/variety interactions	3

Country	Research Area	Suggested Manpower in Professional Man Months
	Water use-climatological relationships	3
	Frequency of irrigation and method of application	2-3
Colombia:		
	Water/fertilizer/variety experiments	2-3
	Methods of application and irrigation efficiency including land preparation	3
	Reclamation of saline and alkali soils	
Chile:		
	Studies of off season irrigation for drought proofing	6
	Underground water development for drought proofing	3
	Irrigation efficiency in relation to method of discharge and application	2
	Comsumptive use and climatological relationships	2
Brazil:		
	Provide technical help in establishing an experimental station at Pirapora, in the Sao Francisco Valley. An irrigation engineer and agronomist experiences in research and management of research stations.	4

APPENDIX C

REPORT OF THE UTAH STATE UNIVERSITY WATER MANAGEMENT TEAM IN BRAZIL

REPORT OF THE UTAH STATE UNIVERSITY WATER MANAGEMENT TEAM IN BRAZIL

Introduction

The role of the Utah State Team is to assist in developing an irrigation research program at three previously selected irrigation pilot project areas in the Sao Francisco Valley. Prior to arriving in Brazil and during the first week in the country, the Team reviewed all the available publications and reports related to this assignment. In addition, personal conversations were held with individuals from private and governmental agencies to obtain additional information. Visits were made to the following locations:

"Instituto de Pesquisas e Experimentacao do Centro Oeste" at Sete Lagoas (IPEACO)

The experiment station sites and pilot projects at Pirapora and Formoso

The experiment station site at Sao Desiderio

The experiment station at Bebedouro

The experiment station at Mandacaru

One member of the Team also visited the stations at Petrolandia and Propria

Discussions were held with the local superintendent and research personnel at each site. It is recognized that the visits to each of these sites cannot provide all of the background information necessary as a base for recommendations. This fact was taken into consideration when formulating the suggestions.

The important sociological and economic problems related to the development of the Sao Francisco Valley were recognized, but are not directly considered in this report.

Background Information

The irrigation experimental stations proposed for Pirapora, Formoso and Sao Desiderio can furnish valuable information on the nature and magnitude of the problems involved in the development of irrigation in the Sao Francisco Valley.

There are several direct benefits that result from irrigation. The first is the assurance that adequate water can be available to a crop in drought periods of the wet season. With this assurance, a farmer can fertilize and otherwise manage the land for maximum production with minimum risk of crop failure. The second is that irrigation facilitates growing a crop during the dry season. In addition, it may make feasible the development of an entirely new industry for the area. One example might be a dairy industry which would be impossible without irrigation. The total benefits of irrigation to supplement rainfall in the wet season and as a source of water in the dry season remain to be determined.

In making our suggestions we are assuming that the initial experimentation is to be directed toward accumulating information which can be used for demonstration and training in the early stages of farm development. Later, it is expected that experiments will be concerned with fundamental studies on consumptive use, long-term effects of irrigation, cultivation, fertilization, etc., on the quantity and quality of the crops produced.

We have been impressed with the objectives and plans for the various stations; however, we are suggesting a greater use of small plot techniques. This type of testing offers several distinct advantages over large field plantings. It allows the experimenter to test several kinds of crops with many variables in the shortest period of time and at considerably less expense than with large fields.

It is suggested that the initial research work involve a series of small plots to study several factors of production such as irrigation, fertility and crop varieties. The variables to be considered will depend on the crop to be grown and the nature of the problem anticipated. In tree fruit production, variety trails may be of minor importance and greatest emphasis should be placed on irrigation and fertility. In contrast, varieties are of major importance when studying cereal crops.

When the production factors necessary to grow the crop have been determined, the most favorable combinations can be used in demonstrational plantings. Large demonstration plantings should be avoided in the initial phases of the project until sufficient information is available to insure a reasonable degree of success.

The nature and magnitude of the problems in the development of the valley are impressive. The remoteness of the area and living conditions will make it difficult to secure and retain a competent technical staff.

The lack of well trained, experienced research personnel in irrigation agriculture is a reality. There appears to be a continuing supply of technicians recently graduated from school who are willing to work in the area for a few years until a better position becomes available. If SUVALE is to develop and maintain a strong research program in irrigation agriculture, it will be necessary to make the salary and living conditions in the valley attractive enough to retain competent staff.

In the initial phases of the program, it will be desirable to obtain the services of experienced personnel within the country. It is possible the services can be obtained on contract or consulting basis from other areas such as the Institute at Sete Lagoas. This would be particularly necessary in the area of plant diseases, insect control and plant nutrition. It would not be advisable to try to maintain such competence at each of the stations.

The agronomists presently stationed at the three experimental farms have limited research experience. This situation must be recognized in any planning and action taken to improve their capabilities. Research cannot be prescribed and specifications written as in the construction of a building. The benefits from considerable judgment and experience must go into planning and conducting the experiments.

It would be advisable to develop a training session for ten days to two weeks at a central location, such as Belo Horizonte, where the field personnel could be brought in as a group and schooled in the more practical areas of research. It would be possible to assist them in the design of specific experiments and to explain the reasons behind decisions to use certain techniques in irrigation research. The training program could also be used to stimulate within the individual a personal interest in the program and to provide him with an opportunity to use his own ingenuity and imagination.

This report is intended to contain suggestions, examples and recommendations to be used as a guide but not as a blueprint for water management investigations.

Personnel

An executive scientist should be assigned overall supervision of the irrigation research. He should implement administrative and policy decision functions into the research program including any special assistance necessary to train the field staff. He should cooperate with the staff economist, project engineers, agronomists, etc., in developing and planning the research needed for decisions in farm development, and should also cooperate in the development of training and demonstration programs. We recommend that, if possible, the Director of Irrigation be given special training in irrigation research and demonstration techniques.

One professional person should be in charge of the research at each station. He should be responsible for the coordination, cooperation and overall administration of the program. At least three or four agronomists and one irrigation engineer should be in residence at each location. The agronomists should be assigned a group of related crops which would enable them to have some degree of specialization. As an example, one agronomist could be responsible for forages, another cereals and a third fruits and vegetables. The irrigation engineer should cooperate with each specialist in planning and conducting all experiments involving irrigation.

In addition, the technicians and coordinators should have available for planning and consultation experienced specialists in irrigation, plant nutrition, insect control and plant diseases. These specialists should be available when experiments are being planned and whenever a major problem arises during the conduct of the experiment. The specialists should be supplied by contract with other agencies if SUVALE is not able to employ such persons on its staff. The individual should know what his responsibilities are as well as the authority he has in making decisions regarding details in the research program.

The Team has little capability in making recommendations as to the size of the non-technical labor force necessary to develop the experimental farms. No mention is made of the personnel required to level land, install and maintain water systems and to operate and maintain the machinery. It is assumed that such capability is, or will be made, available. Experience has shown that it is necessary to maintain continuity and competence in the non-technical field staff on experimental stations. We suggest that when competence and experience is developed in tractor drivers, irrigators, etc., every effort be made to retain these persons on the projects.

Farm Equipment

The major items of equipment required can be classed into two categories; temporary and permanent. The heavy equipment needed to clear the land, level, construct ditches, etc., must be available for the initial preparation but need not be permanent at the experimental stations. It can be moved from some other pro-

ject for temporary use. At Pirapora, adequate heavy equipment is available at the SUVALE shop. We assume that some similar arrangement is being made to get the necessary equipment at Formoso and Sao Desiderio.

Permanent equipment must be provided for each farm. We feel a minimum inventory must include the following items:

Medium-sized wheel tractor (40 hp) with three point attachments

Disk plow

Disk harrow

Rotary mower

Land plane or mechanical leveler

Wooden float to be constructed on the site (plans provided)

Tool bar for tractor equipped with shovels for furrowing in addition to a set of cultivating tools

Seeding equipment, preferrably several single units to be attached to the tool bar - a series of planter plates should be available to plant different sized seeds

Fertilizer spreader

Duster or sprayer for insect control

Blade Terracer for minor leveling and scraping

Irrigation siphons - 300 (1" x 5'), 20 (3" x 5'), 20 (4" x 5')

Water meter on main line

Three single-row hand seeders

At Pirapora, a new Massey-Ferguson tractor with disk plow, disk harrow and rotary mower are on the site. We are not aware of the other equipment that has been ordered or otherwise will become available for these three stations.

In addition, small items such as scales and hand tools for harvesting, weed control and irrigation must be provided. Mechanical equipment for harvesting small plots has not been recommended because of difficulties in maintenance and repair.

Facilities

Adequate facilities must be available for the technical staff at the research station or in the immediate area. A continuing research capability is vital to the success of the program and good facilities are inducements for technicians to remain on the project. Funds spent for providing adequate and attractive living quarters will result in many benefits to the research program. Office area is needed for the station professional staff to provide working and storage space for records and information. Storage for seeds, fertilizer, insecticides, and herbicides must be provided. A storage area and repair shop equipped with tools is necessary to service machinery and vehicles in order to avoid costly delays.

Weather Stations

A modest meteorological station should be established at each of the three sites. These should be located where there is easy access for recording of data and maintenance of equipment. The minimum equipment should provide for measuring maximum and minimum daily temperatures, class A weather bureau evaporation pan, recording rain gauge and wind gauge. If possible, the station should be established and maintained in cooperation with the Weather Bureau. The costs of acquiring, installing and operating the more sophisticated equipment are great and should not be included at the expense of the experimental activities.

Crops

The Team recognizes a limited capability in selecting crops to be studied at the various stations. We feel it is essential that some priority be given to certain crops to be tested before work plans can be developed. The suggestions in Table 1 are from reports and publications in addition to conversations with local researchers.

There is little information available on the time, rate of planting and spacing of various crops to be tested. Some indications can be gained from the data collected at Petrolina (see Table 2). These are presented to serve as guides for the trial plantings, but will need to be adjusted to the wet and dry seasons at the three stations.

Soil Fertility and Plant Nutrition

The general knowledge of soils of the types at the various stations indicates that all are, or will become, deficient in nitrogen, most are deficient in phosphorus and some are deficient in potash. For maximum produc-

Table 1. Crops to be Tested at Three Stations.

Crops	Pirapora	Formoso	Sao Desiderio
Corn	3	3	3
Barley	2	2	2
Sorghum	3	2	2
Beans	3	3	3
Soy Beans	2	2	2
Potatoes	3	3	3
Alfalfa	2	3	3
Grasses	3	3	3
Cotton	1	2	2
Peanuts	1	2	2
Peas	1	2	2
Vegetables	2	2	2
Tropical Legumes	2	2	2
Tree Fruits	2	2	2

1/ Not to be tested
2/ Tested on a limited basis
3/ Tested in considerable detail

Table 2. Guide for Planting Times and Spacings for Several Crops.

Crops	Planting Date	Spacing
Barley	April or May	15 to 20 cm between rows
Sorghum	Dec or Jan	80 cm between rows, 12 plants/M
Potatoes	May or June	70 cm between rows, 30 cm in row
Elephant Grass	Dec or Jan	60 x 60 cm
Peanuts	July, Aug or Sept	no data
Tomatoes	April or Sept	80 x 50 cm
Cotton	Mid July or early Aug	1 M beds - 2 rows/bed

tion of many crops, it will be necessary to apply lime as finely ground dolomite. The sandy soils at Pirapora will likely need small but frequent applications of minor elements. Soil tests for available phosphorus, potash and lime should be used to determine the requirements at each station. Provisions should be made to have plant samples analyzed in order to determine if nutrient deficiencies exist in crops or if there are major nutrient imbalances.

Fields that are to be used for screening several different crops to determine their adaptability should receive uniform applications of fertilizer at rates suggested by the soils laboratory making the fertility tests.

Irrigation Experiments

In the initial stages of the station development, it is suggested that the irrigation variable be limited to time and frequency of application studies with the various crops being grown. However, data should be obtained regarding total water applications and soil moisture conditions before and after irrigation. Comparisons should also be made on the effect of supplemental irrigation during the wet season. The frequency studies may make use of oil moisture data collected gravimetrically, preselected time intervals or physical symptoms of the crop. In some instances all three procedures may be used simultaneously. Such details should be discussed in the planning sessions as previously proposed. As the research program develops, more sophisticated studies can be implemented where different rates of fertilizer, spacing and irrigation can be combined to study interactions.

Care should be exercised in interpreting the economic benefits from irrigation. Direct comparisons of irrigated versus non-irrigated yields can be misleading. There is little or no value in comparisons between yields of crops grown in the dry season with and without irrigation as there would ordinarily be no crop unless irrigated. There often is little gained by comparing the yield of a crop such as grass produced in the wet season with that in the dry season because the value of the grass is much greater in the dry season. This would be especially true for a new industry or for improving beef production. An evaluation that must be made is between non-irrigated production in the wet season with the production from irrigation as a supplement in drought periods of the wet season. Another advantage of irrigation is the production on the same land of two crops per season. The total value of irrigation then must be at least the benefits from wet season supplements plus the entire production in the dry season.

Experimental Stations

Pirapora

The site selected for the experimental station at Pirapora is excellent in that it is typical of the pilot area with a topography well suited for irrigation. The soils are relatively coarse textured with a low water holding capacity, low fertility and high acidity. Problems of water application and plant nutrition are anticipated.

At the time the site was visited, the majority of the large trees and brush had been removed. A portion of the land had been disked twice; however, no leveling

had been initiated. The water conveyance system and storage reservoir are yet to be completed. We were advised that the pumps and pipeline have been ordered and are to be delivered within several months.

We have indicated in the diagram of the experimental station (Figure 1) that only about 20 hectares of land be placed under irrigation during the initial stages of development. The remainder can be used for experiments with non-irrigated crops and later developed for demonstrations and training. Fields, blocks and sub-blocks within the area developed for irrigation can also be used to conduct experiments with non-irrigated crops if comparisons are to be made. It is our opinion that an attempt to develop the entire area at one time would result in further delays in getting the station in operation.

A schedule of activities is suggested so that the station can be placed in operation at the earliest possible date. The details in these suggestions are made to fulfill a request by the Director of Irrigation Research of SUVALE.

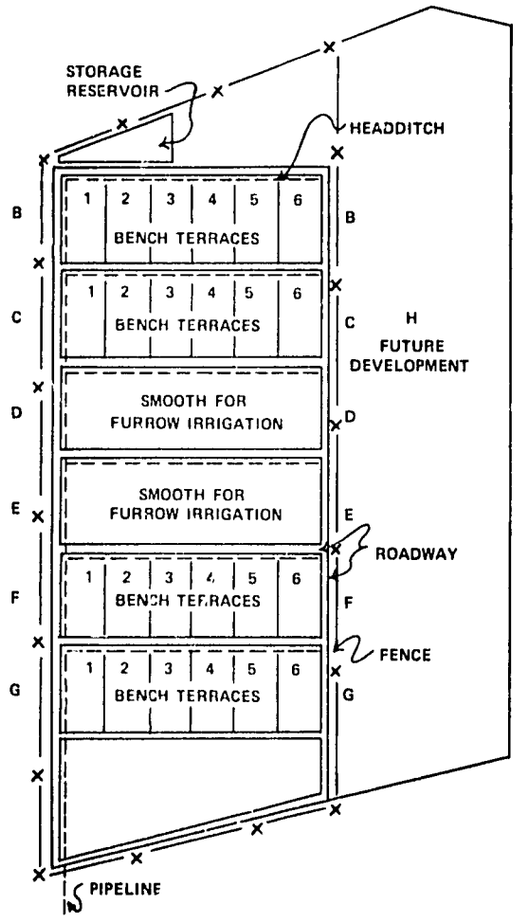

Figure C-1. Pirapora Experiment Station field layout.

1. Remove tree stumps and large roots in fields A through G - drag material to other areas for burning.

2. Smooth old windrows, hummocks and roughest areas with a dozer

3. Develop bench terraces at 50-meter intervals with cross slope eliminated on fields B and C; smooth to uniform slope

4. Install lined ditch level through each terrace with drops between terraces on fields B and C

5. Install pump and pipelines as soon as possible along with items 1 through 4

6. Construct and line the reservoir

7. At the earliest date water is available in the pipeline, make length of run trials

8. Following the first irrigation, recheck land for subsidence areas; resmooth if necessary

9. Initiate planting schedule according to season in fields B and C

10. After length of runs has been determined on B and C, make a decision on length of runs to be used on D, E, F, and G; it is suggested that runs should not exceed 100 meters on experimental blocks

11. Smooth fields D and E for furrow irrigation with no terraces

12. Install lined ditches on fields D and E after length of run has been determined

13. Repeat as in item 8

14. Initiate planting schedule according to season on fields D and E

15. Depending on experiences and success on areas B and C, develop F and G similar to B and C; it is anticipated that F and G will be used for pasture studies

16. Smooth area A to irrigate on contour; this area should be reserved for tree fruits

17. Field H should be smoothed and planted to non-irrigated pasture (trees need not be removed as

they can serve as shade for animals) this area should be held in reserve to be developed for irrigation research or demonstration as the need arises

18. The old fence must be removed from the center of the farm to allow for realignment of fields; a new fence should be constructed around the entire farm to prevent animals from destroying any experimental planting

Figure 2 is a sketch of plot layout showing how a trial can be fitted to the dimensions of a block, with the sub-plots being shown. Such a design could be used for a trial during the wet season with water treatment W_1 receiving no irrigation and W_2 irrigated when the crop shows need for water. If additional variables were desired, the design would be expanded to use additional blocks. This is not intended as a plan but as an example of how an experiment can integrate irrigation and other production variables.

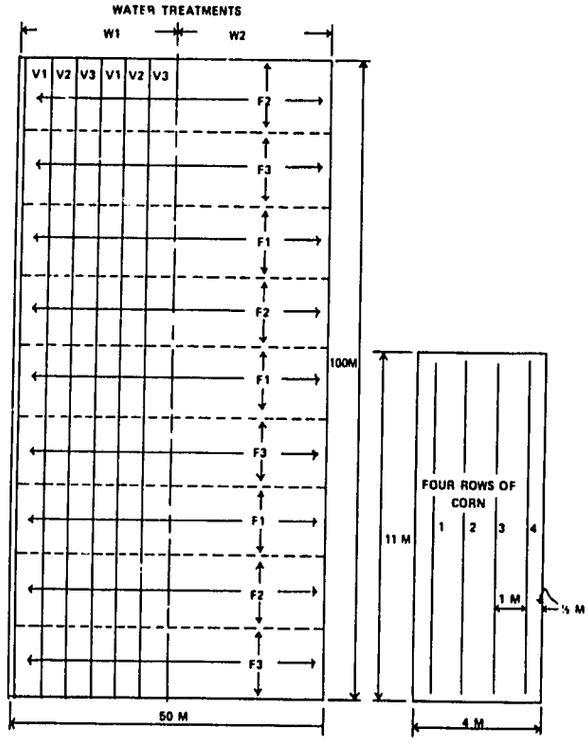

Figure C-2. Block diagram with plot and subplot layout using corn as an example.

Formoso

The soils of the area have many characteristics that are favorable for good crop production. The most disappointing feature for irrigation agriculture is the undulating topography with slopes varying from 3 to 5 percent. Water will be most difficult to control with furrow or border methods of application. The steep and irregular land is likely to erode with high-intensity storms after the native vegetation has been removed. Localized areas may become waterlogged as a result of water being applied to the higher lands.

If such land is to be irrigated, provisions should be made for careful control of the water. This can be done by use of contour furrows, small paddies or by sprinkler application. With sprinklers, the rates and quantity of water applied can be most easily controlled and erosion and waterlogging problems reduced to a minimum With contour furrows, erosion can be effectively controlled by using alternate furrows at each irrigation (that is, every other furrow dry).

At the present time, trees and stumps have been removed from the pilot area and the removal of large roots is in progress. Land leveling has not been done and should not be undertaken on a large scale because it will expose the heavy subsoil. The pumping station and canals are only partially completed. SUVALE estimates two months of work will be necessary before water can be supplied to the project area.

The experiment station should be initiated on the class one land where the slope is a minimum (not over 3 percent). A small portion of the experimental area proposed will be on second-class land. An area of approximately 28 hectares of mostly class one lands (Figure 3) has been selected from the pilot area where the experimental work with irrigation can be conducted. Water application by sprinkler irrigation can be achieved on these better lands without land grading or special preparation. When detailed soil and contour maps of the proposed experimental area are available, other water application methods, including surface irrigation, can be considered.

The choice of sprinkler irrigation will entail some additional installation at the project. A pipeline with a small booster pump from the main irrigation canal to the area can be used. The canal can serve as storage to avoid operating the large pumps. Another alternative is to

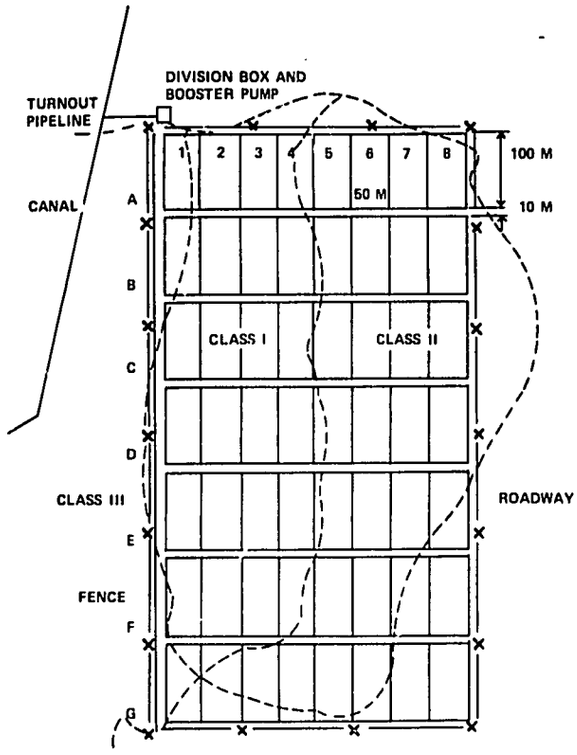

Figure C-3. Formoso Experimental Station.

A - G = Experimental Fields.
1 - 8 = Blocks which can be subdivided into plots and subplots
A - 1 = Field A Block 1.
Proposed for Irrigation by Sprinkler.
Scale 1 CM = 50 M

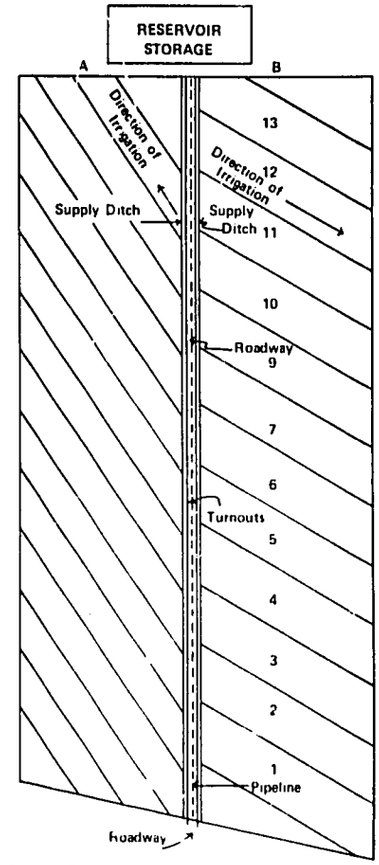

Figure C-4. Experimental Station Sao Desiderio.
Field layout, with pipeline in center of field. Scale 1cm = 30 meters.

build a reservoir above the high-level canal to provide pressure for operating a sprinkler system.

We feel that the experiment station and pilot project will serve a useful purpose because of the many problems associated with the development of an irrigation project in the area.

Sao Desiderio

The land that has been rented at the Sao Desiderio project appears to be a good site for the experiment station. It has been suggested by some that the area of approximately 16 hectares is not large enough for a research station (Figure 4), but in our opinion the area is of sufficient size to conduct all the irrigation research necessary for the project in the immediate future. Additional land for demonstration and training can be obtained when the need arises. The site is cleared and is reasonably smooth. A new fence is currently being constructed. It is anticipated that a water conveyance system will be installed within the next year.

The slope of the land makes it necessary that a pipeline be installed in the center of the field as the primary source of water. Outlets must be placed in the line at appropriate intervals to serve the secondary supply ditches. These lateral ditches may need to be lined for water control and to prevent erosion. The land must be smoothed to slope between the ditches. No major cuts and fills are anticipated.

An alternate field design is shown in Figure 5. This provides for three major blocks divided into fields of 50 meters wide and approximately 100-120 meters long. This design would be better suited to small plot research.

The water supply to the fields in either design can be supplied through level ditches, gated pipe or plastic tubes. A storage reservoir should be considered for each of the designs shown.

It appears that this station can be placed in operation within a minimum period of time and at a lower cost than either of the other stations. It is recommended that the land be smoothed immediately and prepared for

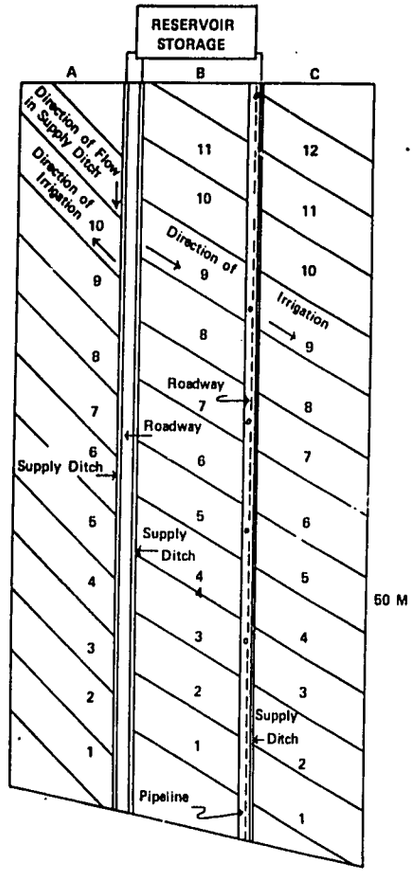

Figure C-5. Experimental Station Sao Desiderio.
Field layout alternate design.
Scale 1 cm = 30 meters.

seeding a legume green manure crop to be grown during the next wet season.

Acknowledgment

The Team wishes to acknowledge the assistance and cooperation of the many individuals in the various agencies dedicated to improving agriculture in Brazil. We register a special vote of thanks to Dr. Avelino Costa-longa, who accompanied us throughout the two trips taken in the valley. He served as a guide, interpreter, and gracious host.

APPENDIX D

UNITED NATIONS
ECONOMIC COMMISSION FOR LATIN AMERICA

NATIONS UNIES
COMMISSION ECONOMIQUE POUR L'AMERIQUE LATINE

NACIONES UNIDAS
COMISION ECONOMICA PARA AMERICA LATINA
EDIFICIO NACIONES UNIDAS
AVENIDA DAG HAMMARSKJÖLD
CASILLA 179 D
SANTIAGO, CHILE

REFERENCIA:

CABLE: UNATIONS

9 December 1969

Dear Mr. Anderson:

Following our conversation, I am glad to state below the fields of Water Law that need prompt action in Latin America.

As you know, ECLA's secretariat set up a working group in 1957 to carry out preliminary studies on water resources in the region.

The legal and institutional approach of those studies show a proliferation and a rapid change in water legislation designed to promote economic development. Most of the countries are studying ammendments to their existing legislation and others have recently passed new laws on the subject.

Our preliminary work is coming to an end in all the area and we are now frequently required to collaborate in drafting a new legislation. FAO, the UN Natural Resources and Transport Division and the UNDP, have also been requested assistance on this field.

Training of personnel is expected to be undertaken on a continued basis by a Center sponsored by some Latin American cuuntries with the technical assistance from UNDP.

Notwithstanding the importance of the work performed on the subject, there is no available source of information on the existing Water Legislation in Latin America and isolated individual efforts to compile it lacks the necessary time and space projection.

Mr. Bruce Anderson
Utah State University
Logan, Utah, U. S. A.

Though action may be required in many fields, I understand that the collection, compilation and dissemination of information on existing water legislation in Latin America, is a neglected task that deserves special attention because of the influence it may have on the progress of Water Law in the region.

Sincerely yours,

Mario F. Valls
Natural Resources and Energy Programme

APPENDIX E

CENTRO DE ESTUDIOS SOBRE TENENCIA DE LA TIERRA

UN PROGRAMA COOPERATIVO DE LAS NACIONES AMERICANAS Y LA UNIVERSIDAD DE WISCONSIN

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UNIVERSITY OF WISCONSIN
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DIRECCION EN CHILE
RICARDO MATTE PEREZ 0342
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SANTIAGO-CHILE

December 10, 1969

Mr. David R. Daines
Utah State University
Logan, Utah
U. S. A.

Dear Mr. Daines:

This letter is in response to our conversation of December 4 in which we discussed my experience in Chilean water law research and your proposed water law project in South America. First, by way of background, I am an International Legal Center Overseas Fellow doing water law research under the auspices of the Wisconsin Land Tenure Center. I arrived in Chile in September 1968, and after some inquiry and preliminary study, I began a field study of the application of various key water law articles in the 1967 Chilean Agrarian Reform Law. My work fit into the over-all Land Tenure Center program that has as its objective the study and analysis of the different types of ownership and use of means of agricultural production, i.e. land and water.

Though my experience in South American water law is limited, I would like to express my favorable reaction to your proposal. I agree with you that improvement in water management from a legal point of view depends now on the government officials who administer water rights and water use. In my own work I have found that coordination of water use plans between government agencies is essential, but often lacking. On a national level a water information center could help achieve the necessary coordination. Motivating the officials to use the center would be a possible hurdle, but lack of a central information facility would no longer be a plausible excuse for not making full use of much information that is now widely separated and only narrowly circulated. The same need for additional information exists on an international level. I believe that there is already a willingness among water administrators, at least among the Chilean officials with whom I have spoken, to form a central library of water resources materials. Your project could help them realize that goal.

The treatise or summary of water law in South and North America is a logical extension of the water resources information center. Such a summary could provide a comparative study of water law systems in the Western Hemisphere. Water administrators, legislators, and students would find a water law summary particularly valuable in explaining the systems used in various countries, in disseminating new ideas in water administration, and in providing legal research guides for more profound and detailed

studies. The treatise could, as you suggested, be supplemented when new developments warrant.

In sum, a water resources information center and a summary of American water law would fill existing needs, enlist the support of South American water administrators, and make a future contribution to the study of water law in general. Your project would be attractive to Latin American government officials since they would be contributing their expertise, rather than undergoing criticism. I would expect, therefore, that you could obtain their cooperation in completing the project and thereby motivate them to use it thereafter.

I wish you the best of luck in obtaining approval of your proposal and in carrying out the project.

With best regards,

Douglas B. Jensen
Acting Director

DBJ/sc

APPENDIX F

REPORT BY DAVID R. DAINES ON FINDINGS IN CHILE ON WATER RIGHTS PROJECT

REPORT BY DAVID R. DAINES ON FINDINGS IN CHILE ON WATER RIGHTS PROJECT

Made from September 1, 1969 through December 12, 1969

I discussed the status of water law studies in Chile with personnel at the Ford Foundation Offices in Santiago. They reported that the Foundation was providing some funds for the International Legal Center connected with the University of Chile. At the time, the Center was staffed by Daniel Stewart who was working on water law. The Land Tenure Center also had someone in Chile working in water law. I purchased a new water code which had just been made available. They thought the code contained drastic revisions.

I met with Dr. Bruce Anderson and other Utah State personnel at the Hotel Conquistador and accompanied them to the USAID office for a prearranged conference with Mr. Charles Seckinger. Mr. Seckinger expressed a lack of knowledge about the area of water rights and made an appointment for me to meet with hydrologists and engineers attached to the mission. I met with Marshall E. Moss and William W. Doyle, hydrologists with USAID in Chile and Carl A. Krammer, Chief Engineer. They expressed some knowledge of the present status of water codes and water distribution practices in Chile. They also spoke of a new water code and of the general structure provided in the code for agencies and institutions with regard to the administration of water rights. It was noted that even though the code established an agency for the administration of water rights, no funds had been allocated for this agency. In addition, the agency had no director and was non-functional.

They felt that at present there was no one with authority through which field studies could be effectively carried out and that it would be a long time before such an agency did exist, consequently such studies of water use practices at this time would not find political acceptance in Chile. Chile has serious problems in the administration of the present laws and policies on water use and they would not have the knowledge or information to cope with increased problems of the rational administration of their water resources. There is critical shortage of information and knowledgeable people in this field in Chile.

At the UN headquarters in Vitacura, which houses ECLA or CEPAL, I met with Dr. Mario F. Valls, a lawyer by training, who is in charge of the legal aspect of the Chilean natural resources and energy program. When a Latin American country requests assistance from the United Nations in the field of reviewing and drafting water codes, the services of Dr. Valls are made available to those countries. He has prepared many draft codes and studies of water laws. The United Nations has also hired other experts in the field of water law on short-term assignments for the same purpose. Dr. Valls is now completing a draft, presently unpublished, of the study of water laws of five or six Central American countries. He furnished me with copies of all of these studies in their present draft form together with other materials. Although Dr. Valls' library on water law consists of books and materials covering an area of three shelves four feet long, he claimed that he desperately needed more material for his work and that background materials are not obtainable in any form. Even though he is currently the authority in Latin American water law (according to the best of my information,) and even though his library is probably the most complete water law library in any institution in this field, it is critically limited. He examined my microfiche library and requested certain materials in the same form.

At a later date I conferred further with Dr. Valls and he outlined some of the areas where effectiveness of water law could be materially advanced by a project. During this discussion he made the following points:

Consultants on water codes: Short-term experts supplied by the UN to some South American countries have recommended for adoption their own state codes almost verbatim with little or no adaptation. He claims that few of these draft codes have been adopted and that those that have are ineffective.

Field studies: Field studies made in the past show that codes are not effectively implemented and that custom rather than law is generally the ruling force in water distribution in Latin America.

Changing codes: The majority of Latin American countries have either recently changed their water codes or are now in the process of revising them.

Inaccessibility of information: Those persons responsible for making and administering laws and regulations pertaining to water use frequently do not have access to information about their own existing laws and regulations, nor to information pertaining to how

problems that they encounter may have been solved in other countries.

Scope of UN work: The United Nations is not going to expand its activities into the field of collecting and disseminating information even though Dr. Valls feels that this is an area of critical need.

Problems with formal ties: Creating formal ties with the United Nations on any project would be very difficult. Cooperation of a more informal type, such as the free exchange of information that the UN has acquired in areas of mutual interest, is easily accomplished.

Personal interest: Dr. Valls is definitely interested in working in some of these areas but would like to work out a program that would change his living quarters from Santiago, Chile, to his home town of Mendosa, Argentina.

Digest: There is a need for a digest of water laws as they now exist in Latin America. Dr. Valls feels that this would be very useful even if no provisions for supplementing and updating the work were provided. Such a digest would be more useful, however, if it were supplemented biannually or annually. He refers to the publication, *Survey of Mining and Petroleum Laws of the World,* Bureau of Mines circular No. 8017 by Ely Northcutt, obtainable through the superintendent of documents for the price of $1.00, as the type of work that was needed in the field of water law. He also cited the following reference: *1956, Law Leys De Aguas En Sudamerica; Coleccion FAO Cuaderno De Fomento Agropecuario No. 56,* Rome by Dr. Guillermo J. Cano and F. F. Vargas Galindez, 741 pages. According to Dr. Valls, most of the laws have changed drastically since this work was published. He said that Dr. Cano prepared a 135-page study in 1959 under the auspices of FAO. I was also informed that Dr. Cano had left the UN and was in the process of moving back to Argentina.

Institution at Mendosa: Dr. Valls felt that a project involving development of a water law digest could benefit by affiliation with some permanent institution after the initial collection of material and institution of the systems by publication of a book. He stated that a group associated with the University of Mendosa, Argentina, was trying to establish such an institute and would be the best possibility.

Dr. Valls also recommended that I join the International Association for Water Law, stating that if I would send in my application listing him as a reference, he would recommend my admission to full membership.

International Legal Center: It was suggested that I talk with Dan Stewart at the International Legal Center.

Availability of experts: There are no practicing lawyers in South America who could be considered as specialists in water law, according to Dr. Valls. Courses in water law have been taught from time to time at the University of Chile and at the University of Mendosa; however, even the most dedicated students have not continued in the field of water law after graduation.

We concluded our conference with an agreement to give more thought to the specific areas of interest and specific means of implementing a program.

The following day I conferred with Mr. Charles Seckinger at USAID and outlined some of the possible areas that we might pursue in a program. He was very receptive to the general idea of collecting and disbursing information on water law and preparing a water law digest. He agreed that both programs could benefit by ultimately becoming attached to a permanent institution once they were on the road, but thought that the projects would be of lasting value even if not continued indefinitely.

After receipt of Dr. Bruce Anderson's letter of November 4, 1969, I made arrangements to permanently terminate my private consulting work and return to Santiago to conclude my preliminary investigation in Chile on the water law project. I drafted a letter to Bruce and rough drafted some notes on my findings to that date and studied the Chilian water code.

Tuesday afternoon, November 8, I arrived in Santiago and went to Dr. Vall's office where I obtained a rough draft of some ideas on programs in the field of water law. I reviewed the draft and returned to the USAID office. Mr. Seckinger was out of town so I talked with his administrative assistant. We discussed the project in general terms including the part of Bruce Anderson's letter indicating Washington approval for a two-year overseas assignment without affecting mission ceilings on personnel. He said that they had received no official confirmation from USAID Washington that University contract people would be exempt from personnel ceilings of the missions. Therefore, they were not prepared to take any action in that office. He did give me some general information about their guidelines on allowances for living in Chile on a two-year assignment as University contract personnel. He also provided me with telephone numbers of Mr. Douglas Jensen of the Land Tenure Center and Mr. Daniel Stewart of the Inter-

national Legal Center. I made an appointment to meet with Mr. Charles Seckinger when he returned.

I returned to UN headquarters on Wednesday for further conferences with Dr. Valls. We reviewed his draft and I requested from him two letters, one outlining the general needs in the field of water law as he saw them, and the other outlining his ideas as to how a program might be established to fulfill these needs. He said that there were many areas of need but that the need for a digest and for a better flow of information were the two that he focused on. Dr. Valls requested copies of certain microfiche that I had and said that he would prepare the letters for me. He also gave me permission to take with me to Utah typewritten copies of all of his drafts on the Central American Water Law studies and other works that he had. I promised to return them to him after copying.

The following morning I phoned Mr. Dan Stewart and he was unable to meet on that day, so we made arrangements to meet on Saturday. I arranged a meeting with Douglas Jensen of the Land Tenure Center on this day for lunch.

Report on conference with Mr. Douglas Jensen

Douglas Jensen is a 1967 graduate of Stanford University and has been employed by the Land Tenure Center, Casilla 6122, Correro 22, Santiago, Chile. He stated that he would be replaced in January by Mr. Reubin Nevina of the Wisconsin Land Tenure Center. Mr. Nevina is writing a Ph.D. Thesis on *Law & Society on Irrigation and Canal Associations.* Mr. Jensen has completed field studies and is preparing an article published by the Land Tenure Center in the Land and Water Law Review, which was essentially an exposition on Agrarian Reform and the New Water Code connected with the Agrarian Reform. His study resulted from 50 interviews with water users, drafters of the Code and the government agencies responsible for administering the land reform program. He had completed a rough draft describing his work and is now in the process of translating and preparing a final draft. His work consisted of, and was limited to, an investigation of how five or six areas of the Agrarian Reform laws related to water rights and a study of how those provisions were being implemented in the field We discussed the history of the water code and what kind of institutions and customs existed for the administration of water rights.

On Friday, November 11, I reviewed and compiled notes and also reviewed some of the materials on the microfiche. The following day, I met with Mr. Daniel Stewart of the International Legal Center, who provided me with the following information.

Mr. Stewart is presently the Director of the International Legal Center, which is funded by Ford Foundation for the purpose of improving the methods used in teaching in law schools and universities in general. The program as it was designed to apply to law schools had its main thrust in the introduction case method of teaching law. Mr. Stewart had not been able to work in the law schools because his father-in-law was the Dean of the University of Chile's law school, and this resulted in nepotism problems. Because of these problems he was attached to the school of Economics where he taught a course on water law. Mr. Stewart said that he was abandoning the field of water law and leaving Chile because the University had not supported his program and because there was no other work in Chile in the field of water law. He was in the process of returning to California to practice law in the Los Angeles area. In his opinion, for reasons of national pride and politics, Chile probably would not be receptive to a suggestion of assistance in making infield studies. Even possible activities least offensive to sensitive Chilian pride, if performed in Chile at this time by North Americans, would be very poorly received and, in fact, generally resented because of the forthcoming presidential election. After the election a year from now, the entire climate of Chile might well shift to a position more favorable to this kind of technical assistance.

Mr. Stewart was very interested in the microfiche information system and felt that this system held great promise not only in the field of water law but in other areas where information was so badly needed and lacking in Latin America. He suggested that I present the microfiche information system and my collection of water law in connection with the system to his father-in-law, the Dean of the law school of the University of Chile, the following Monday. Mr. Stewart had also conducted a study into the historical background of the water code of Chile and had conducted limited field studies. He attempted to gain support from the International Legal Center for preparation of a paper containing his findings but because of the lack of support from the University and for various other reasons, the funds were not provided for him to complete his study. Therefore, he is terminating his work without the completion of a publishable descriptive document.

He indicated to me that he was acquainted to some extent with Dr. Valls' work at the UN and that Dr. Valls was actively looking for other employment and was interested in changing his place of residence from Santiago to Argentina.

Mr. Stewart was impressed with the need for more information in the field of water law in South America and felt that the preparation of a Digest containing present status of water law in Latin America would be extremely useful to all the people working in the field. He expressed the probability of a favorable reaction to a program for the collection and dispersion of water law information.

There was some doubt on the part of Mr. Stewart about the quality of writing that was being done in Dr. Valls' office at the UN. Even though there were no funds available to publish his findings he stated his intention to search for a way to make publication possible. Stewart indicated that his wife was a very good English-to-Spanish translator and that she might be available in California for a project of this type. In discussing the background of the water code, Mr. Stewart stated that there had not been any basic changes since the Water Code of 1952 was inacted. He said that when the Agrarian Reform Law was passed in 1965, it contained certain provisions which integrated the Agrarian Reform Law with the 1952 Water Code. He further claimed that the recent publication which I had acquired was simply an extract of the Water Law Provision of the 1965 Agrarian Reform Law and the 1962 Water Code.

This was somewhat contradictory with the information previously given by the engineers and hydrologists with USAID but was consistent with my own studies of the Water Code in Chile. Arrangements were made to meet with Dr. Eugenio Velasco, Dean of the law school of the University of Chile, at his home the following Monday afternoon, which happened to be a Chilean holiday.

We discussed generally the different legal systems under which we operated and the importance of water law. He confirmed that there were no lawyers in Santiago with any substantial background in the field of water law. He was particularly interested in the possible application of the microfiche system to economically expanding the library holdings of his University. He requested that I come to the library at the University of Chile to demonstrate to the librarians and the professors the microfiche water information system which I did the next morning. The reaction was one of intense interest in the possible utilization of this system in expanding the law school library holdings.

I conferred with Charles Seckinger at the USAID office in Santiago and made arrangements for the use of the pouch system to deliver the materials that I had collected on the project. Mr. Seckinger reported that he still had not received any confirmation of the statement contained in Bruce Anderson's letter of November 4, 1969, concerning the fact that assignments on our contract in Chile would not go against the personnel ceilings of the missions. He told me that the new mission head had just arrived and that he did not feel it wise to approach him about approval for our new program at this time. He felt that there were other pressing problems concerning on-going programs with which the new mission head would want to become thoroughly familiar before giving any consideration to the approval of a new program. He further stated that he didn't think there would be any opportunity to discuss the project with the new mission head before my tentative date of departure. He said that the appearance of Americans on the streets of Santiago was a very explosive political issue and that they were quite generally resented by the Chilians. In an election year he felt that, regardless of the type of program, there would be considerable resistance on the mission level to expanding the number of personnel attached to the mission.

Mr. Seckinger spoke favorably of the information system and of the preparation of a digest for that type of work but also expressed his doubts about the ultimate prospects for approval of a two-year assignment in Chile in view of the probable desire of the mission head to cut down the American presence in Chile. He invited me, however, to leave with him a project proposal which he agreed to discuss informally with the mission head as time permitted. I decided to wait until my return to discuss the situation with Dr. Bishop and Dr. Anderson before submitting a preliminary proposal. Mr. Seckinger was very interested in the microfiche information system and its application to his office records and files. He seemed favorably inclined to the possibility that we could gain acceptance in one or more phases of our water law program in Chile on short-term assignments without locating someone for an extended stay.

On the following day, I returned to the UN headquarters for a final discussion with Dr. Valls where I received the letters and some additional water law materials. We reviewed generally the matters contained in his letters and I received from him a list of the microfiche materials that he requested that I procure for him. I returned to the offices of the International Legal Center and had a final conference with Messrs. Stewart and Jensen. I received Mr. Jensen's letter outlining some of the areas of need in water law in Latin America as he envisioned them. Mr. Stewart was unable to prepare a letter since he was in the process of making arrange-

ments for leaving the country. In these discussions, we reveiwed some of the basic matters contained in the previous notes.

The 11th and 12th of December were spent in transit by air from Santiago, Chile, to Logan, Utah. During this period of time I studied my notes and reviewed some of the program possibilities. During the stay, I accumulated additional bibliographic material on Latin American Water Law which is included on a separate sheet titled "Additional Bibliography" and a list of contacts and their addresses that are contained on a supplemental sheet.

List of Contacts

CHILE

Jacques Chonchol, Vice President of the Institute of Agrarian Development INDAP c/o CEREN, University Catolica de Chile.

Rodrigo Santa Cruz, Secretary of Drafting Committee, Cora, Santiago, Chile.

Professor Jose Luis Cea, University Catolica de Chile.

Professor Francisco Cumplido, University of Chile, Escuela, de Deretechos.

Garretson Heighton, New York University Law Center.

Mr. Douglas B. Jensen, Land Tenure Center, University of Wisconsin, Casilla 3861, Santiago, Chile. Acting Director of the Chilian Office of Land Tenure Center to be replaced by: Reubin Nevina, January of 1970. Predecessor to Douglas Jensen was Mike Lyon, (the Chilian office has as his address) Casilla 3861, Santiago, Chile.

Additional Water Law Bibliography acquired in Santiago, Chile

1. Legislation de Las Aguas Subteraneas Europa, published by FAO.

2. The Law of International Drainage Basins, edited by Garrison, Etan, and Olmstead, published by Ocena.

3. Summary of Mining and Petroleum Laws of the World, Bureau of Mines Information Circular. 8017, 215 pages by Ely Northcutt.

4. Dictionary of Legal Terms, published by Robb, Spanish-English, English-Spanish.