BIBLIOGRAPHIC DATA SHEET

1. CONTROL NUMBER
PN-AAH-332

2. SUBJECT CLASSIFICATION (695)
AP12-0000-G512

3. TITLE AND SUBTITLE (240)
Assessment of irrigation activities in Bolivia

4. PERSONAL AUTHORS (100)
Harvatin, J. F.

5. CORPORATE AUTHORS (101)
Devres, Inc.

6. DOCUMENT DATE (110)
1980

7. NUMBER OF PAGES (120)
53p.

8. ARC NUMBER (170)
BL631.7.H339

9. REFERENCE ORGANIZATION (130)
Devres

10. SUPPLEMENTARY NOTES (500)
(In English and Spanish. Spanish, 44p.: PN-AAH-333)

11. ABSTRACT (950)

12. DESCRIPTORS (920)
Agricultural production
Bolivia
Irrigation
Water management
Water supply
Water resources
Sprinkler irrigation
Assessments

13. PROJECT NUMBER (150)

14. CONTRACT NO.(140)
AID/SOD/PDC-C-0223

15. CONTRACT TYPE (140)

16. TYPE OF DOCUMENT (160)

AID 590-7 (10-79)

ASSESSMENT OF IRRIGATION ACTIVITIES

IN BOLIVIA

Devres, Inc.

2426 Ontario Road, N. W.
Washington, D. C. 20009
(202) 797-9610
Cable: DEVRES
Telex: 440184

ASSESSMENT OF IRRIGATION ACTIVITIES

IN BOLIVIA

Prepared for: U.S. Agency for International Development
Bolivia Mission
La Paz, Bolivia

Prepared by: DEVRES
Joseph F. Harvatin
2426 Ontario Road, N.W.
Washington, D.C. 20009

Contract No. AID/SOD/PDC-C-0223 - Work Order No. 3

13 February 1980

WEIGHTS AND MEASURES; EXCHANGE RATES; ABBREVIATIONS

1 kilogram (kg)	=	2.204 pounds (lb)
1 kilometer (km)	=	0.621 miles
1 hectare (h)	=	2.471 acres
1 centimeter (cm)	=	0.3937 inches (in)
1 millimeter	=	0.3937 inches (in)
1 liter (1)	=	0.0353 cubic foot (ft^3)
1 liter per second (1/sec)	=	.0353 cubic foot per second (ft^3/sec)
1 cubic meter per second (m^3/sec)	=	35.32 cubic foot per second (ft^3/sec)
1 square inch (in^2)	=	6.452 square centimeters (cm^2)
1 pound per square inch (lb/in^2)	=	0.07031 kilograms per square centimeter (kg/cm^2)

EXCHANGE RATES

October 1979 1 peso $b. = Dollars US$ 0.05

ABBREVIATIONS

GOB	-	Government of Bolivia
MACA	-	Ministry of Agriculture and Farm Affairs
ANDC	-	National Community Development Service
DDC	-	Departmental Development Corporation
USAID	-	United States Agency for International Development
GOBOL	-	Geological Services of Bolivia
ENDE	-	National Electric Company of Bolivia
CODETAR	-	Development Corporation of Tarija
SETAR	-	Electric Services of Tarija
BID	-	Bank for International Development
FAO	-	Food and Agriculture Organization of the United Nations

TABLE OF CONTENTS

LIST OF ANNEXES

I. EXECUTIVE SUMMARY

A. Purpose

Although Bolivia has pronounced wet and dry seasons with abundant land and water resources, little concerted effort has been made to promote irrigation in the country. This study was made to provide an overview assessment of the state of irrigation in Bolivia, and to recommend measures which would alleviate current problems and improve the quality of irrigation in the country.

B. Procedures

The field staff reviewed available studies and reports on Bolivian irrigation. Interviews were held with personnel of MACA, SNDC, DDC and other personnel working with agricultural development and irrigation. Irrigation projects and other rural areas were visited in each of three physiographic regions. On-site project investigations were made in each region and interviews were conducted with farmers and project personnel.

C. Conclusions and Recommendations

1. Present irrigation practices

Irrigation in Bolivia is very inefficient and prospects for immediate improvement are not good. The large majority of farmers are using the primitive production methods of their ancestors. Their technology is still traditional in the use of fertilizers, herbicides, insecticides, plant varieties and seeds. Irrigation and soil conservation are poorly understood

and practiced. These poor production techniques, along with the marginal lands upon which they are applied, produce low yields and limited returns. The irrigation of crops on lands having severe capability limitations provide limited short-term benefits and often have disasterous long-term effects on crop yields and soil erosion.

Primarily, small irrigation systems are established. There is little to be gained by modifying present structural and hydraulic characteristics of delivery systems. Here, the immediate needs are those of education and extension service. A concerted effort must be made to intensify educational and extension services on these established projects. The concentration of effort should be directed to basic farm management, production techniques, irrigative water management and soil conservation practices.

2. Use of marginal lands

Many small irrigation projects are located on lands which are too marginal for the cultivation of irrigated crops. Among the more limiting factors of land capability for irrigated activity are steep slopes, soils susceptable to erosion, shallow soils, limited moisture holding capacity of soils, large concentrations of stones, salinity, threat of waterlogging, frequent flooding and adverse climate. As long as marginal lands are being developed for irrigation, the problems of poor crop yields, low returns, soil erosion and poverty will continue.

Future selection of proposed projects should be influenced by the

Engineers generally have less than three years experience in irrigation and higher echelon technical support is unavailable. The turnover rate in technical personnel is high, creating disruption and uncertainties in work schedules.

There is a critical lack of tools and equipment needed to do a professional job. Basic soil and water testing and measuring equipment are unavailable on a Departmental level. They are also handicapped by a lack of technical aids such as criteria, standards, guides and methodology for running irrigation projects. In addition to their irrigation activities, many engineers and technicians are involved with other institutional activities creating gaps in their irrigation training and experience.

Since irrigation activities are being carried out by several institutions, they are competing with one another for the available funds, personnel and equipment. Consequently, none of them has the essentials for being a strong and effective irrigation organization.

The GOB should be encouraged and assisted in consolidating all irrigation activities, and establish a strong effective irrigation authority to provide overview, and leadership for irrigation in Bolivia. The thrust of this authority would be to provide national policy, administrative and technical direction for all irrigation activities in the country.

capability of the land to sustain relatively high yields under irrigation without adverse effects on the land. Some lands currently having severe capability limitation can be safely irrigated with the application of modern soil conservation technology. Steep slopes can be benched, terraced, corrugated for close growing crops or other special treatment may be applied to effect production and safe irrigation. Other limitations may also be removed by certain land improvement processes. The U.S. Soil Conservation Service provides excellent guidance on the subject.

3. Institutional performance

The quality of irrigation work on small projects which have received institutional (SNDC, DDC) financial and technical aid are an improvement over the older more primitive irrigation systems. However, the quality standards for planning, design and especially construction are still below acceptable standards for modern irrigation systems.

The underlying reasons for the low quality performance of irrigation installations are lack of funds by both the institutions and farmers. In most instances, returns from lands are insufficient to support large expenditures for updated systems. Thus, to a large extent, farmers are provided with a product which is within their financial budgets.

Along with a lack of sufficient funds, the institutions are handicapped by insufficient numbers of qualified technical personnel.

4. Costs and returns

Cost and return relationships are not normally an important factor in selecting small irrigation projects for institutional assistance. Costs for irrigation systems are computed, but returns are broadly estimated and project selection is often based upon a social need rather than on a cost and return basis. Complexity of the project is sometimes used as a criterion for selection. The more complex project is rejected in favor of a more simple project requiring less technical assistance time. The ability of farmers to pay their share of project costs can also be a factor in selecting projects. If the farmers are willing to assume their share of the costs, the project is apparently worthy of institutional assistance irrespective of land capability or meaningful cost and return relationships. The social rather than the economic value of the project is very often the real basis for selecting projects for institutional assistance.

Institutions involved with larger projects (500 or more hectares) appear to be doing a more realistic job in determining costs and return relationships in project development.

Realistic and meaningful cost and return relationships should be prepared for all projects being considered for financial assistance. The cost of needed land improvements and conservation measures necessary to develop marginal land to acceptable levels of topographic and surficial characteristics should be included in project costs.

5. Irrigation priorities

There are insufficient streamflow, surficial storage or underground water data presently available to make reasonable determinations of regional potentials for irrigated agriculture. Most of the reliable data available were developed for large river basins or for specific project studies. If potential irrigation activities are to be realized, more accurate determinations of both surface and ground water quantities that can be feasibly developed for irrigation must be made.

For the near and intermediate time frames, it is believed that the valley area offers the greatest opportunities for the development of irrigation projects. There are apparently sufficient quantities of surface water available to sustain large areas of irrigation. Inter-watershed diversions may be necessary to provide water for specific areas having high quality land resources for irrigation. The valley areas also offer superior topography, climate and soil characteristics.

Over the long-term period, the lowlands of the Santa Cruz region offer the greatest opportunities for irrigated agriculture. Ground water and surface water resources appear to be adequate in quantity and quality for considerable irrigated development.

The topography and soil resources of this area offer possibilities for sustained agricultural development over a long period of time. The climate is sub-tropical and as such can produce crops during the dry months with the aid of irrigation.

The larger projects irrigating 500 or more hectares of land should be given high priority in any time frame. These larger projects are oriented toward training of farmers, application of modern farming and irrigation methods, and the setting of high production goals. These types of operations will be the foundations for Bolivian irrigated agriculture of the future.

6. Water laws

There are no valid laws regulating the diversion, allocation and use of the public waters in Bolivia. Once a water facility is developed, the governing and distribution of water is made on a community basis, wherein the farmers themselves determine water use within the community. There are disputes between various urban populations, farmer groups and individual farmers within a group: as the demand for agricultural, municipal and industrial use increases, the problems of water regulation will become increasingly serious.

The use of irrigation water containing raw sewage from urban, rural and local sources provide a significant hazard for contaminating vegetables grown for human consumption. The spread of serious communicable diseases could easily result from the practice.

The GOB should be encouraged and assisted in implementing meaningful water laws for establishing water use priorities, regulations and pollution control.

7. The San Jacinto Project

The San Jacinto Project is well conceived and has considerable merit. In addition to the production of electricity, it is projected to irrigate approximately 4,450 hectares of land. The proposed project presents many advantages and opportunities for irrigated agriculture in Bolivia. The project will be planned, designed, constructed and managed by a team of professionals. The program provides for an agricultural experiment station, a farm demonstration project and extension services for training and assisting farmers in the art and science of agricultural production and water management.

This project has the potential for serving as a model and source of inspiration for better irrigation methodology to Bolivian farmers and should be supported to the fullest extent possible.

8. Lack of social and technical studies

The present mechanism for aiding the development of irrigation has been generally ineffective in producing high quality irrigation systems in Bolivia. While the effort does, to some degree, expand the irrigated area, increase agricultural production and improve the well being of the individual farmer, it does not develop irrigated agriculture to its full productive potential. Too often it has had adverse effects on the lands being developed. This can be partly attributed to the absence of social analysis and technical feasibility studies conducted prior to the commencement of the project. Too many systems have been installed without adequately considering

cultural and soil conservation practices that maintain the land in permanent agriculture. Land and irrigation water have not generally been used in a way that insure high crop production without wasting either water or soil.

It will be helpful if all national and international bodies supporting irrigation projects in Bolivia would insist on prior social analysis, and technical feasibility studies to make certain the operators are likely to make a prudent use of the land and water resources to be developed for them. Furthermore, if maximum benefits are to be derived from future irrigation development, adequate provisions must be made to insure the quality and effectiveness of the irrigation works to be installed, or the improvements to be made. This may require the services of irrigation specialists to supervise the work.

D. Acknowledgements

Devres' field staff member would like to express his sincere appreciation to the Government of Bolivia officials, USAID officials, officials of other organizations, and individuals for their cooperation, assistance and hospitality extended to him in the course of his field work in Bolivia.

A list of those officials with whom the team member had discussions is included in Annex 2. The list does not include the many farmers and irrigation project workers with whom the field staff member had conversations, but whose personal identity has not been recorded. Devres' field staff member is indebted to all of them.

II. INTRODUCTION

A. Purpose

Although Bolivia has a pronounced wet and dry season along with abundant land and water resources, little concerted effort has been made to advance irrigation in the country. This study was made to provide an overview assessment of the state of irrigation in Bolivia and to recommend measures which would alleviate current problems and improve the quality of irrigation in Bolivia.

Bolivia is predominantly an agricultural country with about two-thirds of her population engaged in agricultural activities. However, the performance of the Bolivian agricultural sector has been less than satisfactory since the Agrarian Reform in 1952. The supply of most agricultural products has not kept pace with population growth. Traditional agricultural production methods, poor management and a lack of capital have been the primary factors contributing to the stagnation of agricultural production. However, indications are that Bolivia has the potential, and will benefit from an increased level of irrigation activity over what it now has.

B. Procedures

The field staff reviewed available studies and reports on Bolivian irrigation. Interviews were held with personnel of MACA, SNDC, DDC and

other personnel working with irrigation and agricultural development. Irrigation projects and other rural areas were visited in each of the three physiographic regions. On-site project investigations were made in each region and interviews were conducted with local farmers and project personnel.

C. Background

1. Economy

Bolivia is one of the least developed of the Latin American countries. A land-locked country, considerable portions of which are at extremely high altitudes, it presents formidable geographic barriers which limit transportation and communication facilities and impedes economic development. The government, including its autonomous and semi-autonomous corporations, is the largest single employer. About two-thirds of the population live in rural areas and agriculture provides about one-third of the gross domestic product. The country is rich in minerals and the mining sector is the source of nearly all the country's export earnings. Bolivia has access to the sea via the Chilean port of Arica. A railroad financed by Argentina and one financed by Brazil facilitate commerce with these two countries.

Mining is the backbone of Bolivia's money economy. Tin is the major product, accounting for the major portion of exports. Antimony, lead, zinc, tungsten, silver and copper are other mineral exports. Hydrocarbons, petroleum and natural gas are becoming more important to the Bolivian economy.

Manufacturing is largely limited to textiles, food stuffs, glass, ceramics, cement and leather goods. High transportation costs which restrict access to markets and scarcity of skilled entrepreneurs and technicians have all served to retard the development of industry.

Bolivia faces chronic foreign exchange problems. Its concentration on production of non-ferrous metals, particularly tin, has made it dependent for foreign exchange earnings on highly unstable and widely fluctuating world prices. Since the country depends on outside sources for an important portion of its food supply, its demand for foreign exchange is less flexible than is the case for most other Latin American countries.

2. Agricultural sector

Bolivia is predominantly an agricultural country with about two-thirds of her population engaged in agricultural activities. However, most of the agriculture is at a subsistance level with farm families barely producing enough for themselves and a little to sell or trade for necessities.

Prior to the Agrarian Reform in 1952, most of the land was owned by a few families. The Indians living on these lands were essentially attached to the land. They worked for the landlord and were allowed to cultivate a small parcel of land for their own use. They had no capital, they were not decision makers, had no extension services to help them and consequently, continued to operate their lands on a traditional and primitive

basis. Agricultural production, generated by the landlord's capital and managerial ability, declined or remained stagnant.

While the performance of the agricultural sector has improved somewhat in recent years, over the longer run agriculture has made only a minimal contribution to the economic development of Bolivia. Growth in agricultural production has consistently lagged behind other sectors of the economy. Agricultural growth rates have failed to keep pace with increase in the population, with a resultant decline in per capita food production. Consequently, agricultural prices have experienced strong upward pressures.

Imports of agricultural products contribute significantly to Bolivia's balance of payments problems. Exports of agricultural products currently represent a relatively small part of total exports, but there is reason to believe that agricultural exports will grow over the long term. This belief is predicated by continuing bilateral and multilateral financial and technical assistance to Bolivia's agricultural development. In this regard, several large-scale irrigation projects have been in varying stages of planning and implementation with foreign assistance. It is anticipated that the eventual implementation of all these new projects will make a significant impact on Bolivian agricultural production.

III. ALTIPLANO REGION

A. Introduction

Altitude in the Altiplano region varies from 12,000 feet (3,659 m) to 14,000 feet (4,268 m) above sea level. The southern section has an average temperature of 47°F (8°C) with annual precipitation of about 26 inches (635 m). The central section has an average annual precipitation of about 14 inches (355 mm) and average temperature of about 50°F (10°C). The northern section has an average annual temperature of about 53°F (12°C) with average annual precipitation of about 26 inches (660 mm). However, because of the altitude, frost can occur during any time of the year. Crop productions are limited by frost, water shortages and salts. The more common crops include potatoes, barley, quinua (a native cereal), legumes and other vegetables. Most crops are grown for home use, although some vegetables reach the markets in villages of the Altiplano.

B. Field Investigation

1. Status of projects

During the past several years, the Oruro office of the SNDC has completed four small irrigation projects, eighteen are currently under construction and five are in the planning stage.

Three small and one large sized irrigation projects were visited in the Oruro area of the Altiplano region. Two of these projects are supplied with irrigation water by means of filtration galleries in river beds. The other one is supplied by a small pump powered by a gasoline engine. Approximately ten hectares are being irrigated by each of the filtration gallerysystems while the pump system irrigates approximately one hectare.

One of the filtration gallery systems, which was designed by a predecessor of SNDC, has been in operation for eight years. The other one was in the process of construction and was approximately 80 percent complete. The pump system has been in operation for about two years.

A commune of about twelve families operate one of the filtration galleries while another group of ten independent families operate the other. The pump system is operated by a group of two families. In each case, they are a closely knit group who share in the costs, operation and maintenance of the project.

With institutional involvement, the group shares costs in funding the project. The group and institution each contribute approximately fifty percent of the costs. The farmers generally assume all labor activities themselves and, if necessary, pay their proportionate cost of materials.

With some technical help from the institutions, the farmers do all of the construction work. They dig canals, place rock and concrete lining, install flumes and other related works. Nearly all work

is done by hand; very little, if any, machinery is used.

Maintenance requirements of these primitive systems are awesome. They experience damage from flooding, bank sloughing, sedimentation, clogging of the canals and pipes with debris and severe damage and erosion by local thunder storms. Yet, these farmers do everything possible to keep the systems in operation because they know their well being depends upon delivering water to their crops.

In comparison with modern operations, the performance of these systems would be considered inadequate. However, considering the primitive characteristics of the system and the adverse operating conditions, the systems are functioning adequately and providing reasonable quantities of water to the farmers' fields.

Besides the problems of operation and maintenance of the projects, the farmers have to contend with a shortage of capital, lack of extension services and a poor marketing system.

2. Irrigation

In developing project plans, the institutions go through a process of preparing water budgets. The consumptive use of crops, probable precipitation and available stream flow are determined. However, the meteorological and hydrological stations are so few and scattered that transposition of climatological statistics to project sites could be risky, especially in the absence of a skilled hydrologist. In effect, the use of data of an unknown quality coupled with the farmers' poor water handling skills often render water budgets meaningless.

Because of poor marketing conditions for vegetables and the large amounts of livestock in the Altiplano region, alfalfa appears to be the most cost effective irrigated crop. It is also the most effective in preventing erosion from irrigation and rainfall.

Irrigation methods are extremely primitive. The farmers' understanding of irrigation is very limited. He is merely interested in flooding his land with water and has no concept of water management practices. In the process of flooding his land, he over-irrigates some portions of the field and under-irrigates others. He has little control of runoff from the field; water is directed down steep slopes, severely eroding the soil in the process. Conservation irrigation has no meaning to him. He is bound by his traditional methods of wild flooding.

Because of the scattering and general isolation of irrigated lands, they do not present serious water use problems in the area. The most serious problems concern erosion. While the farmer damages his own land through erosion, he does no serious damage to his neighbor's as most adjacent lands are unimproved waste lands. Waterlogging as a result of irrigation was not in evidence. Although there are large parcels of waterlogged lands in the area, they are the results of poor drainage characteristics of the region.

Most major water use problems of the future can be avoided by the adoption of sound water application and land use programs.

The method of applying irrigation water varies with topography, soil conditions, crops to be grown, value of crops, cultural practices,

available water supply, and the extent of land preparation practices. Most methods can be adopted over a wide range of conditions. On some sites, several methods of application are practiced.

Valley lands having relatively flat slopes permit the use of level basins (or borders) which are one of the most efficient methods of applying irrigation water. In these areas, the use of graded borders and furrows will also have practical application. The upland slopes are limited to furrow and corrugation types of application.

On slopes in excess of five percent gradient, furrows should not be installed to run directly down the slope. They should be set to run across the slope and should be deep enough to contain storm and irrigation water without overrunning from one furrow to another. These cross-slope furrows should be set on a gradient sufficient to carry the amount of water needed to satisfactorily irrigate the furrow in the required time period without causing unnecessary erosion.

The sprinkler method of application is especially well suited on lands having steep slopes or irregular topography where the intake rate of the soil is greater than the application rate of the sprinkler. In many instances, the sprinkler rate of the application can be adjusted to meet the intake characteristic of the soil.

In spite of the benefits provided by sprinklers, they are considered impractical for use in the projects under consideration due to non-technical reasons. The sprinkler system of application requires a very

high investment of capital. Much special equipment subject to relatively rapid depreciation is needed. Power requirements are usually high since sprinklers operate with pressures from about 15 to more than 100 lbs. per square inch. Where low rates of water application are needed, much water is lost to evaporation.

The overwhelming capital requirements coupled with an apparently inadequate technical background by the farmers in the operation and use of this equipment effectively rules out this system of application in the project area even though the sprinkler offers substantially superior qualities for water application.

All methods of water application should have appropriate soil conservation practices installed to prevent erosion created by the system.

3. Crops and cost returns

The principal irrigated crops in the area are alfalfa, lima beans, barley, onions and potatoes. There are practically no reliable data on yields for farmer production. When institutions undertake project assistance programs, they generally estimate crop returns. In many instances, if a project has an unfavorable benefit-cost ratio, it is approved on a social rather than an economic basis.

Since there are very little reliable data available to support yields with and without irrigation, only estimates can be used in making comparisons Some farmers claim their yields are doubled with irrigation. This may be tr during an exceptionally dry season when rain-fed crops would have low yields.

However, in a normal season, a fifty to sixty percent increase in yields appears to be more realistic.

4. Irrigation institutions

Several institutions are involved with irrigation activities in the Altiplano region, including MACA, SNDC and DDC. In the Oruro area, MACA and SNDC have been more active than DDC. As yet, the Oruro office of DDC has not become involved with irrigation activity. As previously discussed, SNDC is involved in several projects.

MACA operates the Tacagua project which includes a large storage reservoir near the town of Challapata. The dam is an earth fill structure, having a height of 28 meters and a length of 185 meters. Both the front and back slopes are rock-faced. It has a total reservoir storage of 34,000,000 cubic meters with 31,300,000 cubic meters available for irrigation. It is currently releasing about 4 cubic meters per second (4 m^3/sec.) into two primary delivery canals, each having a capacity of about 2 cubic meters per second (2 m^3sec.). The system currently provides water for 4171 hectares of land and has the capacity to significantly increase the irrigated area in the future.

The project has sufficient land and water available. However, there are salt problems in the area which may inhibit crop production. Also, there was evidence of land and water mismanagement. The project was viewed during the dormant season and quality and quantity of crop yields could not be adequately assessed at this time.

One of the principal problems confronting the irrigation institution appears to be one of funding. Farmers consistently complain of long waiting periods for assistance from the institutions and of projects which have been started and then abandoned because of a shortage of institution funds. In addition to insufficient project funds, the institutions are hampered by a shortage of adequately trained personnel. Technicians, having various degrees of skills and training, provide most of the technical assistance for farmer projects. There is also an apparently large turnover in trained personnel and the number of people available for service varies from time to time.

5. Underdeveloped irrigation potential

In addition to the major irrigation projects currently undergoing various stages of the planning process, there appears to be a limited potential for significant irrigation developments in the Altiplano region. Discussions with various sources indicate a planned potential of about 50,000 hectares.

6. Irrigation priorities

Irrigation priorities should be based on a land capability system. Lands which are more suitable for irrigation should be considered ahead of those which have severe limitations for irrigation, such as very steep slopes, poor soils conditions, inadequate drainage or salt conditions. The quality of the water which is to be used for irrigation should also be considered. Irrigation activities which would utilize contaminated water to produce crops for human consumption or water having a high salt content, especially those having a high sodium hazard, should also be considered a negative in irrigation priorities.

IV. VALLEY REGION

A. Introduction

The agriculture of the Valley Region differs greatly from that of the Altiplano. Steep hills and relatively fertile valleys offer irrigation opportunities but serious erosion of soils is common. Rainfall averages about 32 inches (813 mm) while temperatures average about 65°F (18°C). The rainy season is from November to March and occurs during the growing season. Elevations range from about 4,500 ft. (1,372 m) to about 9,000 ft. (2,744 m). Principal crops include potatoes, corn, wheat, barley, grapes, fruits, alfalfa, and vegetables.

B. Field Investigations

1. Status of projects

All institution offices were closed, due to a national strike, at the time of our visit to Sucre. However, irrigated areas in this region are limited. It is assumed that irrigation activities by the institutions are also limited. Most of the irrigation is being done in the low-lands of long narrow valleys.

Three irrigated sections along the Rio Totakoa, Rio Quirpinchaca and Rio Chico were visited. These lands were along the river flood

plains and were subject to frequent threats of flooding. A series of stone walls were constructed along the irrigated sections to prevent flood water from entering the fields. While the walls kept flood water off the fields, they also contained excess irrigation water within the irrigated areas, thus preventing significant erosion along some river banks. Most of the irrigation water delivery systems were constructed prior to the Agrarian Reform. The systems are still being used by the present landowners.

The principal crops in the area are fruits and vegetables. The Rio Quirpinchaca carries raw sewage effluent from the city of Sucre as well as from villages and rural areas along its course. The irrigation of vegetables with contaminated water offers the opportunity for the spread of contagious diseases.

At Tarija, SNDC has been in operation for about 14 years. During this time, they have completed approximately 20 projects with a total of about 2,000 hectares of irrigation. The oldest project was completed about 14 years ago. Six projects are currently under study, incorporating about 1,500 has. of irrigated land. One engineer and two technicians are involved in irrigation planning and design.

A project on the Rio Camacho, having 430 hectares of irrigation and owned by 60 families was reviewed. This project was a rehabilitation of an older system. One of the more significant changes was the replacement of a swinging plastic pipeline with a concrete siphon. Other changes included the replacement of the road crossings and flumes. While the

work is a great improvement over the older system, it is still substandard in design and workmanship.

The DDC at Tarija has been in operation for three years, and has completed five projects, having a total of about 1,000 hectares of irrigation. The average ownership of these projects is about 1.5 hectares per family.

Three engineers and six technicians are working in the office. However, only a portion of their time is directed to irrigation as they are also involved in other DDC activities. One project is currently in the design stage. It will provide irrigation to approximately 200 hectares owned by 130 families. Nine more projects are being studied for future development.

A field review was made of the project being designed. Along with the installation of the delivery system a reservoir having a storage volume of 650,000 cubic meters is planned. The concept of having reserve storage water for use during the dry season has considerable merit. However, the areas to be irrigated have serious land capability limitations in the form of large concentrations of stones. Most of the land lies in an old river bed and removal of stones presents a serious challenge to the landowners. Fruits are presently being grown and will continue to be the principal crop. The cultivation of fruits will, to some degree, compensate for the land capability limitations.

At Cochabamba, MACA has the Angostura Project, which began operations in 1945 and irrigates about 6,700 hectares. The reservoir has a capacity of 85 million cubic meters. However, the project experiences shortages of water about 80 percent of the time. There are significant operational

problems, including a poor delivery system, waterlogging in the lower areas, salinity and generally poor water management.

SNDC at Cochabamba has been highly involved with irrigation for about two years and has completed about 10 projects, varying in size from about 15 to over 400 hectares. Total developed area is about 1,800 hectares with about 1,100 families benefiting. They are now planning several larger projects, some with financial and technical assistance provided by the German Government. They also expect the Swiss Government to provide some aid to irrigation projects in the area.

The office is staffed with about fifteen professional engineers and fifteen technicians, although all are not regularly assigned to irrigation projects. Two projects, totalling 6,000 hectares with 4,000 families benefiting, are in the design stage. The SNDC is generally moving to larger projects where there is a more pronounced compliance with technical standards and land capability criteria.

A field review was made of two SNDC projects. Both projects had similar characteristics in that they were irrigating generally flat lands with minimum capability limitation. Some of the farms had a form of leveled benches and basins installed. While improvements were needed in these installations, it was encouraging to see them in existence.

DDC at Cochabamba has been involved with irrigation for only one year and are only now becoming active in planning irrigation projects. They currently have four projects, totalling about 5,400 hectares with about 3,500 families benefiting, in the planning stages. The Misicuni

Project which will encompass a gross area of 45,000 hectares in Cochabamba will also be a part of DDC planning program. The project includes the production of electrical power, rehabilitation of the Angostura Project and the development of additional areas for irrigation. The office is staffed by one engineer and one technician and has the part time services of a soil scientist.

A cooperative effort by the Geological Services of Bolivia (GEOBOL) and FAO produced a well drilling and irrigation program in the Valle Alto. Twenty three wells are now in operation providing water for the irrigation of crops in the vicinity of Cliza. There is currently a 35 hectare demonstration area operated by FAO. Local farmers are cooperating with FAO in a program of modern farm management, including landleveling, fertilization, crop varieties, herbicides, insecticides and irrigation water management.

Each of the 23 wells will irrigate approximately 40 hectares for a total of about 900 hectares of irrigation. While there may be a future increase in the number of wells, it is expected that the maximum area that can be irrigated by wells will be approximately 1,500 hectares. The FAO is doing an excellent job in providing irrigation water and training farmers in the project area.

2. Project operation

As in the Altiplano region, most of the small projects in the area are organized under traditional farmer codes, wherein the farmers

regulate their water, provide hand labor for the construction of their projects and maintain the irrigation system. All projects are satisfactorily functioning within their design objectives which, to a large degree, are still primitive. Maintenance is a perpetual effort and most maintenance operations consist of the near-minimum necessary to permit a continual supply of water to the field. Major problems consist of frequent shortages of water, breakdown in delivery systems and the mismanagement of water. When water is available, farmers use it whether it is needed or not. Consequently, they frequently over-irrigate, waterlogging sections of land, and create problems of salinity.

The Angostura Project is managed and operated by MACA. The project was designed and constructed by Mexican consultants with financing by both Bolivian and Mexican goverments. The project has been in operation since 1945. The dam itself appears to be in reasonably good condition, however, the delivery system was poorly designed and maintenance has been lacking. The institution is hampered by a lack of sufficient qualified personnel, equipment and good management. Water shortages are frequent, a rote system of water distribution is used and farmers have little understanding of water use and management. The project made no provisions for drainage, consequently areas of the project are waterlogged and salinity is a serious problem throughout the irrigated section.

3. Irrigation

All irrigation is carried out by surface application methods.

The most common method employed is by furrows in row crops and wild flooding of alfalfa and other close growing crops. There is some evidence of graded borders and level basins being used in the Valle Alto sector and some farmers have constructed level benches. Irrigation in the Cochabamba area, while still below acceptable standards, is of a generally higher quality than that encountered in other parts of the country.

Water budgets are not a part of the irrigation process in the valleys. As elsewhere, farmers use their share of water whenever it is available whether they need it or not. On the Angostura project a quantity of water based upon the volume of reservoir storage and size of the farm, is allocated to each farmer at the beginning of the irrigation season. The individual farmer determines the times and rates for using his allocated water. Accurate measurements of water are not made. Instead, rote system of a given depth of water flowing for a certain period of time determines the amount of water the farmer receives. In addition to the inaccuracies of measurement, the project does not have enough personnel to properly overview the distribution of water; as a result, farmers often use more than their share of water. This excess is generally not needed, and contributes to the waterlogging and salinity problems. This matter of unequal and poor water distribution is prevalent in all projects whether they be large or small.

Surface irrigation systems are the most cost effective methods for irrigation in the valleys. The use of level borders should be greatly

encouraged as they are highly efficient, and since no machinery is used in cultivating and harvesting crops, they offer no deterrents to cultural practices. The apparent slow intake rates of the soil is another item in considering level borders or basins. Sprinkler irrigation systems are adaptable for all soils having an intake rate higher than the rate of application and are especially suitable for steep slopes and irregular topography. However, the high costs of initial investment, maintenance and operation preclude the use of sprinkler systems in the valley regions under present land ownership conditions.

Benefits from irrigating selected crops are a matter of several variables including precipitation amounts and timing, crop prices, available markets and farm management ability. In the Tarija area there is little doubt that vineyards will benefit most from irrigation. Without irrigation they cannot be cultivated, but a well managed vineyard under irrigation will return four to five times as much as other crops grown in the valley. Vegetables probably have the highest rate of return in the Cochabamba area. Alfalfa is grown on about 50 percent of the irrigated land in the valley. Nearly all of it is used in livestock and dairy operations, providing a high rate of return to the farmers, most of whom have larger than average operations.

Most problems associated with water use involve water rights and right of way. Traditional water distribution codes are highly ineffective as they cause severe land and water losses. In some

instances there are three or four farm delivery canals running parallel to each other within a distance of ten to fifteen meters. This practice increases seepage losses and uses valuable land that could be used for the cultivation of crops. A single canal with properly installed division boxes could avoid this waste of water and land. The use of pipes or conduits instead of canals could effect additional savings of land and water and increase production and returns to farmers.

Mismanagement of water on farms creates problems of erosion, waterlogging and salinity. An intensive training program in irrigation water management could extend existing water supplies by as much as 50 percent in some areas.

4. Crops and cost returns

Vineyards are the most effective crop on a cost and return basis in the Tarija sector. Indications are that a field in vineyards will return four to five times as much as other crops such as corn, potatoes and vegetables, which are grown in the area. Near Cochabamba, vegetables appear to have the better cost and return relationship. Alfalfa closely competes with vegetable production since it is used in dairy and other livestock operations. Alfalfa is being produced on about 50 percent of the irrigated land in the Cochabamba area. Corn, potatoes and fruits are other principal crops in the valleys.

The amount of rainfall and its seasonal distribution is only sufficient to produce one crop a year. Rainfall amounts and distribution also causes

rain-fed agriculture to vary on a yearly basis. Production will also depend upon the crops grown and the rainfall characteristics for the particular year. However, a generalization applying to average rainfall conditions and a good farm and water management program under irrigated conditions indicates production can be increased from 50 to 100 percent. Under present management, cost benefits from existing projects varies from marginal on the poorly operated farms to very good on the better managed operations.

5. Irrigation institutions

There are several institutions, principally MACA, SNDC and DDC, involved with irrigated agriculture in the valley. ENDE, through its association with the San Jacinto Project is also a part of the irrigation scene.

Since irrigation activities are carried out by several institutions, all of them are competing with each other for funds, qualified personnel and equipment. As a result, none of them have the essentials for a strong and effective irrigation organization. None of them have the necessary equipment for testing and measuring soil and water in the field. In addition to their irrigation activities, many engineers and technicians are assigned to other institutional activities, creating gaps in their irrigation training and experience. Under existing conditions, the irrigation engineer has very little, if any, technical tools and aids such as guides, criteria, standards and specifications available to him

and he often has no higher echelon of technical back-up available to him.

6. Underdeveloped irrigation potential

There is far more arable land available in the Cochabamba Valley than there are readily available water supplies. The ground water supply in the Valle Alto area appears to be capable of supporting only about 2,000 hectares of irrigation. The remaining ground water supply is unknown but is believed to be limited in its ability to support large areas for irrigation.

In the valley, sources of water can probably accommodate another 50,000 hectares of irrigation. However, the large portion of water for the Cochabamba Valley irrigation will probably have to be developed by trans-watershed diversions. There appears to be significant sources of water in the adjacent watersheds which may be transferred to the Cochabamba Valley. If these transfers can be effected, there appear to be a potential in excess of 200,000 hectares for irrigated agriculture in the Cochabamba Valley.

At Tarija, in addition to the San Jacinto project, there appears to be a potential for an additional 50,000 hectares for irrigation.

Steep mountain slopes and narrow valleys restrict potential irrigation developments in the Sucre area.

7. Irrigation priorities

Priorities for irrigation should be generally directed toward

the larger projects which include training and extension services for farmers. The Cochabamba Office is moving toward larger projects, greater than 500 hectares. These larger projects are also generally given more consideration in applying a higher order of technical standards and a better adherence to land capability limitations.

8. The San Jacinto Project

The San Jacinto Project at Tarija is a multiple purpose project being undertaken by the San Jacinto Association, an organization sponsored by the National Electrical Company (ENDE), the Development Corporation of Tarija (CODETAR) and Electric Services of Tarija (SETAR). A consortium of French and Bolivian consultants are engineering the project. Objectives of the association are the production of hydroelectric power, irrigation development, soil conservation and aforestation along with incidental flood prevention.

A detailed analysis of all project components could not be made within the alloted time. Since the work is being conducted by professionals, we assume a project of high standards and quality will result. Our consideration was, therefore, directed to general concepts of the irrigation program.

A sufficient quantity of water of good quality is apparently available for the irrigation of all crops within the project area. A combination of pump and gravity systems from the reservoir will provide water for approximately 4,450 hectares of arable land. Farm ownership is limited to three and one half hectares of land per family. This

area is considered to be an economic unit for irrigated farms in the area. The principal crop will be grapes. Other crops include potatoes, fruits, corn and vegetables.

Soils in and around the project area are extremely erosive. Lands to be irrigated are situated on soils which have undergone severe erosion resulting in deep scars and gullies. However, with the use of modern technology in land forming processes (leveling, benches, flat terraces, etc.), these lands can be reclaimed to a high level of topographic and surficial acceptability.

Forestation of approximately 6,800 hectares of land to help combat erosion is planned for the project area. The planting of trees and construction of erosion control structures is already underway near the proposed project demonstration farm and the grazing of animals is not being permitted in the sections which are being planted. Conservation practices, range management and forestation are important elements to project planning. Their effects will have far reaching impacts on the Bolivian agricultural community.

The development of the San Jacinto Project presents many important advantages and opportunities for irrigated agriculture in Bolivia. It will have a complete and effective irrigation and soil conservation program, planned, designed and constructed by a team of professionals. The physical and institutional structures have the potential to provide the capability to develop crop varieties, irrigation skills and farmer competence to levels comparable with modern agricultural

projects elsewhere in the world.

The physical facilities include a research and experimental station and a project demonstration farm. The farm would conduct research in agronomy, improved crop varieties, plant breeding, fertilizers, pest and disease control. The demonstration farm would provide farmers with training in irrigation water application methods, water management and the cultivation of specific crops.

Extension services to farmers will be provided on a ratio of one extension agent for each group of approximately eighty farmers. The extension service will have the research and experimental station and the project demonstration farm as a base and support for their services. Extension workers will then provide the farmer with latest information and instructions to keep the farmer fully informed on the latest research and experimental results that would be beneficial to himself and the project community.

In addition to increases in direct agricultural benefits in the form of higher crop yields and increased family income, the project could, indeed, serve as a model and source of inspiration to other Bolivian farmers. The application of modern technology in irrigation methods and soil conservation practices in the project areas should establish high quality standards to serve as a goal for other farmers in the region.

V. TROPICAL LOWLANDS

A. Introduction

The climate of Santa Cruz area is warm and humid in the summer (December-February) and dry in the winter, but varies considerably with location. Most of the precipitation occurs during the period October through April with the remaining months being quite dry. At Santa Cruz, the mean rainfall is about 45 inches (1,140 mm), more than 75 percent occurring during October through April. The rainy season becomes of much shorter duration with increasing distance to the south and east. Temperatures, rarely fall below freezing, except in the higher elevations and at Santa Cruz during June and July, average about 68°F (20°C). During the rainy season, average temperatures are about 78°F (26°C).

There is a high proportion of good quality land which is covered with sub-tropical scrub forest and requires extensive clearing efforts for agricultural use. Crops can be produced during the entire year. However, maximum production for most crops depends upon the use of irrigation to supplement natural rainfall. Soils of the eastern plains compose a vast deposit of alluvium. The soil resource potential offers the possibilities for sustained agricultural development over a long period of time. Principal crops grown in the Santa Cruz zone are cotton, soy beans, wheat, sugar cane and rice. Some vegetables are also grown in the area.

B. Field Investigation

1. Status of projects

Neither SNDC or DDC have been actively involved with irrigation projects in the Santa Cruz area. They are currently making preliminary investigations to determine the extent of needs for small projects. SNDC indicated the potential for small irrigation projects is west of Santa Cruz in the Chaco and valley areas in the Department of Santa Cruz. Since they are not adequately staffed at present, the work will probably be done by the SNDC office in Cochabamba.

2. Project operations

Since the institutions did not have any projects in operation, we visited two privately developed irrigation farms and had an office review of the Abapó project in the offices of Corporacion Gestora para el Proyecto Abapó-Izozog.

One of the farms having about 72 hectares of land with 30 hectares under irrigation was owned by an individual and leased to a farm operator. The other farm, owned by a corporation (association) had 420 hectares under rain-fed agriculture and 60 hectares under irrigation.

Both of the privately developed farms were using sprinkler irrigation systems which were installed by private contractors. One of the systems was experiencing above average problems in operation and maintenance.

The other was a poorly designed system which was experiencing considerable problems. The system was supposedly designed to irrigate 80 hectares but the actual capacity was only about 60 hectares. The owners experienced considerable breakdown and malfunction of equipment and had to made frequent design changes and repairs. The owners indicated there were about ten privately developed sprinkler systems in the area and that most of the operators were experiencing design and operation problems with their units. However, apparently knowledgeable people, not associated with sprinklers, indicated a large part of the problems were caused by the farmers themselves as they did not properly understand sprinkler irrigation systems.

3. Irrigation

Both farms use sprinkler irrigation. The farm under single ownership grows vegetables for commercial markets,where the corporation produces cotton, soy beans and wheat. The vegetable farmer, with the aid of public and private irrigation consultants, has developed a crop water requirement budget and is generally able to satisfy the consumptive needs of the plants. During peak consumptive periods, his system is in operation four days a week. The corporation employs an irrigation engineer to manage irrigation schedules and applications. While he encountered considerable difficulties with design deficiencies and repairs, he claims, he is now operating the system at 75 percent efficiency.

Sprinkler irrigation in the area is more practical than surface application methods due to the high intake rates of the soils and the relatively flat topography. However, winds are a problem with sprinkler operation and

constant care is needed in the layout of sprinkler sets to obtain maximum efficiency. Some wind erosion is also evident in the area and some erosion control must be considered in developing future irrigation projects.

4. Crops and cost returns

Rainfall amount and distribution is usually only sufficient to produce about half of a maximum yield possible with a full moisture supply. Production will depend upon the crop grown and the rainfall characteristic of the particular year. However, this generalization applies to average conditions around Santa Cruz. Needs for irrigation increase to the southeast of Santa Cruz and decrease to the north and northwest.

Discussion with the farm operator indicate that returns on investment are marginal. They are pumping from wells having approximate depths of 170 m (558 ft.), operation and maintenance costs are high. While the vegetable farmer saw no significant improvements in cost-return relationship over the near term, the cotton grower expected to better his cost-return relationships once his sprinkler system was brought up to better performance standards. Return from cotton and soy beans appear to offer better returns on investment. Wheat productions are good but prices received for the product are too low to provide satisfactory returns.

5. Irrigation institutions

As previously indicated, SNDC and DDC have not been inactive in irrigation projects. However, the Corporacion Gestora para el Proyecto

Abapó-Izozog is involved in an interesting project at Abapó. This project is the result of a cooperative effort by the Bolivian Government, FAO and BID, with consulting services provided by Hydrotechnik GmbH. The project provides for the development of about 2,500 hectares for irrigation in the Abapó area. The program was started in 1969 and will be completely developed by 1981. Operations of the farms will be carried out by two cooperatives, each having 150 families owning about 7 hectares each. Farmers for the project will be preselected on the basis of irrigation adaptability and experience and will have intensive training in farm and irrigation water management.

All irrigation water supplies will be pumped from wells having an approximate depth of 475 ft.,(145 m). There is currently a staff of 24 professional technicians operating an experimental station on 80 hectares and cultivating 420 hectares for commercial production, of which 180 hectares are being irrigated by sprinkler and 240 by surface systems. The commercial operations are presently producing excellent yields of cotton, soy beans and wheat. It is anticipated these high yeilds will continue after the cooperatives and their families assume farm operation in 1981.

6. Underdeveloped irrigation potential

While definitive data is not available on the soil and water resources in the area, it is estimated there are in excess of 25 million hectares of land having suitable soils for irrigated agriculture. The Rio Grande, Rio Piray and other smaller rivers have untapped

waters in significant quantity. The quantities of available ground water are unknown. Aquifer characteristic are variable and depths to aquifers vary. Wells in the area indicate depths of from 164 ft.,(50 m) to over 656 ft.,(200 m). However, the surface waters coupled with underground souces indicate a significant supply of water available for irrigated agriculture.

7. Irrigation priorities

At present, there is little need for establishing irrigation priorities in the Santa Cruz area. Developments will occur as a matter of course. The impulse will be toward the larger projects providing for both large and small ownerships, and both types of projects should be supported to the extent possible.

ANNEX 1

Terms of Reference for the Project

The terms of reference for the assessment of irrigation activities in Bolivia are:

A. The Irrigation Consultant shall:

1. Review studies and reports on Bolivian irrigation;

2. Interview SNDC (National Community Development Service), MACA (Ministry of Agriculture and Compesinos Affairs), DDC (Departmental Development Corporation) and other personnel working in agricultural development and irrigation;

3. Visit rural irrigation projects and other rural areas;

4. Interview farmers, and prepare a final report on his findings and observations.

The Consultant's time shall be divided as follows:

20 percent in lowlands;

40 percent on altiplano;

40 percent in the valleys.

The study shall focus on two to four small and medium sized irrigation activities in each region.

B. The Contractor shall answer the following:

1. What is the current status of previous irrigation projects?

Are they still functioning? How is the maintenance performed? What are the major problems? How were systems constructed? How are users organized? What crops are irrigated? Are crop/water budgets developed and in effect?

2. What institutions are involved in irrigation development and management? What are the institutional deficiencies in this area and how could they be eliminated?

3. What are returns from irrigated vs. non-irrigated crops? What crops benefit most from irrigation? What are cost: benefit returns from existing irrigation systems?

4. What underdeveloped irrigation potential exists in Bolivia and how should it be further developed? What type of irrigation would be most cost effective? How can major problems with irrigation and water use be avoided? What irrigation activities should be priorities?

ANNEX 2

List of Persons Met

- Gary Alex, Project Manager, Rural Development, USAID - La Paz
- Juan Steer, Agronomist, Rural Development, USAID - La Paz
- Isaac Torrico, Economist, Rural Development, USAID - La Paz
- Steve Wingert, Acting Chief, Rural Development, USAID - La Paz
- Richard Peters, Project Manager, Agricultural Sector Projects, Rural Development, USAID - La Paz
- Edgar Uberhuaga, Acting Director, MACA - La Paz
- Edgar Sosa, Irrigation Engineer, SNDC - La Paz
- D. W. James, Ph.D., Co-Director of Research, CID - La Paz
- Blanca Laguna de Vera, Economist, CORDEPAZ - La Paz
- Angel W. Mier, Engineer, Micro Irrigation, SNDC - Oruro
- Walter Contreras Lima, Civil Engineer - Oruro
- Javier Gallardo G., Regional Engineer, SNDC - Oruro
- Miguel Cayetano Paredes, Agronomist, System Operations Assistant, SNDC - Oruro
- Jaime Sejas A., Engineer, Agricultural Engineering Director, MACA - La Paz
- José Herrera, Engineer, Head of Irrigation Department, MACA - La Paz
- Humberto Taboada, Head of Livestock Department, MACA - Sucre
- Gustavo Tellez Orias, Engineer, Department Director, MACA - Sucre
- José Luis Hernaiz Salinas, Dairy Technician - Sucre
- Mateo Romero, Operations Manager, CORGEPAI - Santa Cruz
- Don Kidman, Irrigation Agronomist, CID - Santa Cruz
- Jorge Navarro Angulo, CID Student - Santa Cruz
- Oscar Salinas, Engineer, Algodonera Boliviana, S.A. - Santa Cruz
- Nelson Ríos, Engineer, Algodonera Boliviana, S.A. - Santa Cruz
- Jan Piet Heederik, Civil Engineer, Irrigation Agriculture Development, FAO-MACA - Cochabamba

- Luis Guamán P., Engineer, SNDC - Cochabamba
- Carlos Rico Soliz, Engineer, Manager, Asociación San Jacinto - Tarija
- Hernán Diaz, Civil Engineer, CODETAR - Tarija
- José Sanchez Gareca, Credit Agent, SNDC - Tarija
- Gonzalo Castillo P., Zone Engineer, SNDC - Tarija
- Eulogio Ruiz Pantoja, Agronomy Engineer, Departmental Director, MACA - Tarija
- Carlos Roca Avila, Engineer, Director of Department of Agriculture - Santa Cruz
- Jaime Aguilera C., Engineer, Head of Department of Animal Husbandry, CORDECRUZ - Santa Cruz
- Albert van Varst, Irrigation Agronomist, FAO-MACA - Cochabamba
- Fidel Amurrio, Engineer, Integrated Rural Division, CORDECO - Cochabamba

ANNEX 3

bibliography

Studies, Papers, Reports and Directories

Bolivia - Overseas Bechtel Incorporated - Prudencio Claros y Asociados - Agrar und Hydrotechnik GmbH. Feasibility Report, Río Grande - Rositas Project, Volume I, Executive Summary. San Francisco - La Paz - Essen: April 1977.

Government of Bolivia. El Potencial Agrícola del Uso de la Tierra en Bolivia, Un Mapa de Sistemas de Tierras, 1973. Misión Británica en Agricultura Tropical; Ministerio de Agricultura. La Paz, 1973.

Government of United States. Agricultural Development in Bolivia, A Sector Assessment, 1974. United States AID Mission to Bolivia. La Paz: 1974.

Utah State University. Bolivian-Utah State - USAID Study Team. Irrigation Analysis for Selected Crops, Santa Cruz, Bolivia.