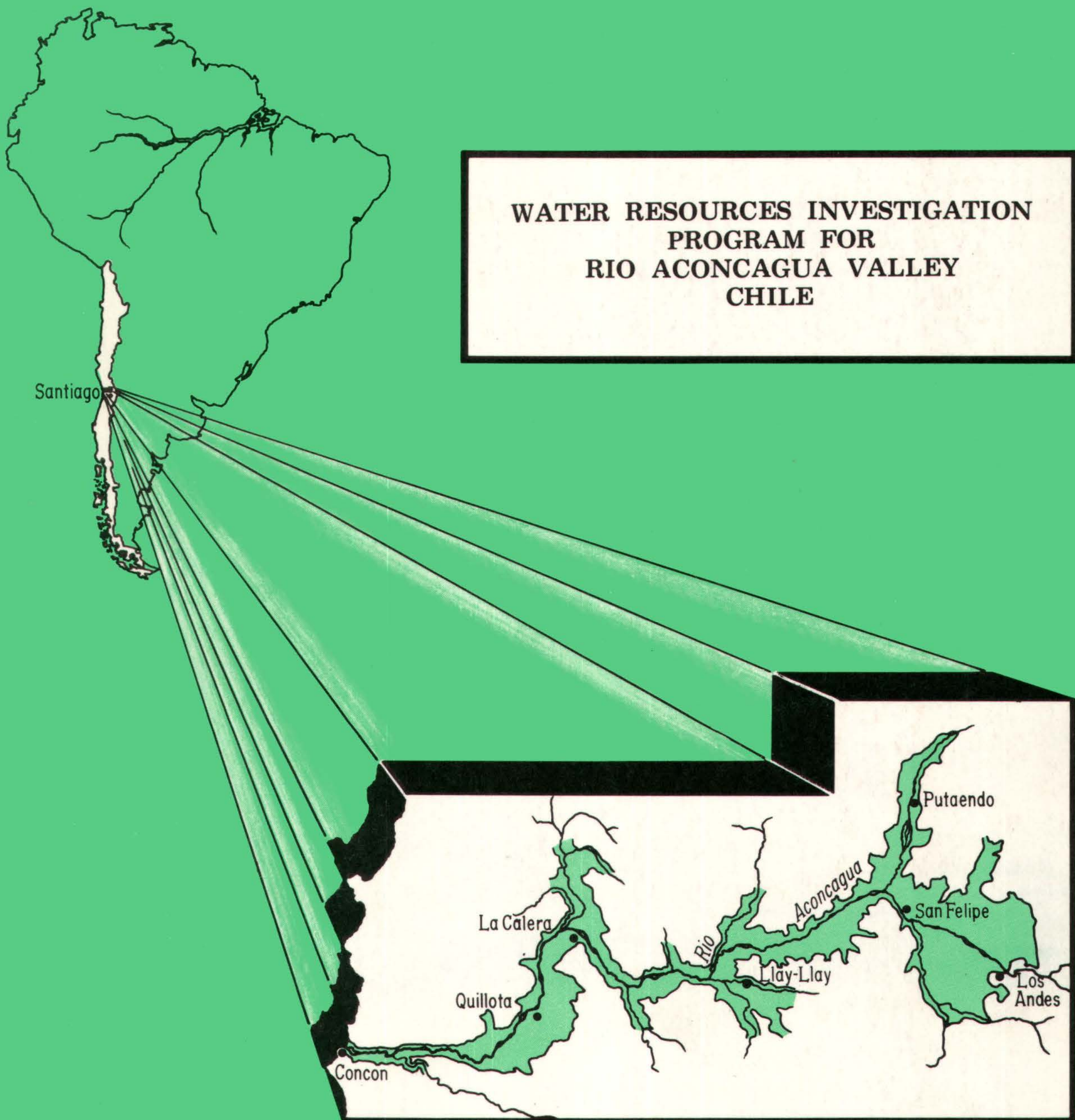
WATER RESOURCES INVESTIGATION PROGRAM FOR RIO ACONCAGUA VALLEY CHILE



Prepared by the United States Geological Survey
in cooperation with
the Government of Chile
under the auspices of the
United States Agency for International Development

WATER RESOURCES INVESTIGATION PROGRAM FOR RIO ACONCAGUA VALLEY, CHILE

By JOHN E. MOORE
U. S. GEOLOGICAL SURVEY

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OPEN-FILE REPORT

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FOR RIO ACONCAGUA VALLEY, CHILE

By JOHN E. MOORE

SUMMARY

The Rio Aconcagua valley is the second most productive irrigated valley in Chile. The valley extends from the Andes to the Pacific Ocean and lies about 100 km (kilometers) north of Santiago. The western part is the agricultural area. The major crops grown are grapes, fruits, corn, and garden vegetables, mostly for the Santiago market. The irrigated part, which is the main agricultural area, extends from Chacabuquito to the ocean, a distance of 113 km. The total irrigated area is 70, 000 hectares. This includes the main valley and four large tributary valleys.

The valley and its tributaries are underlain by an alluvial aquifer composed of sand, gravel, and clay. The Rio Aconcagua is hydraulically connected with the aquifer in most of the valley and is, in most years, a gaining stream. The total area of the alluvial aquifer is about 115, 000 hectares. The aquifer ranges from 1 to 13 km wide and averages about 3 km. The irrigation water supply depends primarily on snowmelt from the Andes Mountains. The mean annual precipitation in the irrigated area is only about 30 cm (centimeters). Some of the applied water recharges the alluvial aquifer and appears

in the river as return flow. A large part of the valley depends on this return flow as the major irrigation supply. Surface-water inflow to the irrigated valley has averaged 1,000 X 10^6 m^3 (cubic meters) per year for the past 30 years. During 1967 and 1968 the river flow was drastically reduced as a result of a severe drought. The inflow in 1967 was 500 X 10^6 m^3 and in 1968 was only 344 X 10^6 m^3. Return flow of ground water has decreased correspondingly.

The Government of Chile is seeking to provide a more dependable and regulated water supply to the valley. Proposals to provide such dependability and regulation include (1) construction of surface-water reservoirs above the present irrigated area, and (2) expanded use of ground water for irrigation. Engineers and hydrogeologists of the Corporación de Fomento de la Producción (CORFO) and the Dirección de Riego (RIEGO) are currently (1969) investigating the water resources to provide data essential for evaluation of these proposals.

This report, prepared at the request of the Government of Chile under the auspices of the U. S. Agency for International Development (US AID), is based on a 2-month assignment (Oct. 22 to Dec. 31, 1969) of the author and outlines a program of water-resources studies. The study program, if followed to its conclusion, will provide the basic hydrologic and hydrogeologic information and analysis essential for planning optimum future development and use of the water resources of the valley.

The proposed study is a basinwide quantitative evaluation of the ground- and surface-water resources. The approach to be used is as follows:

1. Collect and analyze all available hydrologic and hydrogeologic data that will be needed to define the stream-aquifer system.
2. Construct a preliminary digital simulation model of the stream-aquifer system for a part of the valley.
3. Collect additional hydrologic data to refine preliminary estimates and to provide the field data needed to refine the model.
4. Construct and calibrate a digital simulation model of the entire valley, including tributaries.
5. Use model to evaluate proposed management plans.
6. Make systems-analysis studies of optimum conjunctive use.

The digital simulation model is necessary for this program because of the many unknowns and variables whose interplay affect the viability of proposed investments for development of the valley, the large mass of data that must be programed, and the complex hydrologic relations. The model is a tool for integrating and analyzing the hydrologic data and related socioeconomic data. Ground water, surface water, and climatologic data will be simulated by the model to provide a quantitative description of the hydrologic system. The model will be calibrated or verified with data obtained from gaging stations, measurements of stream gain and loss, and ground-water-level changes.

Some of the possible uses of the digital analysis in the Rio Aconcagua valley are: planning field-data collection programs, evaluation of the potential to develop supplies of water for irrigation, evaluation of plans for changes in management of the surface-water supply, and planning for optimum conjunctive use of the ground- and surface-water supply of the valley.

An intensive data-collection program for ground-water and surface-water information was started by CORFO in 1967. Some data collected have been released in a basic-data report on wells (CORFO and IIG, 1969), and an evaluation of surface-water information by Rodriquez (1969). These reports and a preliminary report on hydrogeology (CORFO, 1969) provide information needed to construct and verify a digital stream-aquifer model. During November-December 1969, special purpose maps were prepared by CORFO engineers and geologists to describe the physical characteristics and boundaries of the ground-water system. Maps showing the water-table configuration, bedrock configuration, saturated thickness, and transmissivity have been completed. These maps form the basis for evaluation of field-data deficiencies and will be used to construct a preliminary model. In addition, data on recharge and discharge to the stream-aquifer system have been tabulated. This information will be used to indicate areas where surface-water data are deficient and will be a basis for providing recharge and discharge input to the model. The basic data needed for model verification, for the most part, have not been collected.

RECOMMENDATIONS

The following are the major recommendations for future water-resources investigations:

1. ORGANIZATION AND STAFFING OF THE ACONCAGUA WATER RESOURCES INVESTIGATION PROJECT

The formulation, implementation, and continuing operation of the Aconcagua Water Resources Investigation should be the responsibility of the Corporación de Fomento de la Producción (CORFO). The team assigned to the project should consist of a full-time project chief and, in addition, a hydrogeologist, a geologist, and a surface-water engineer, whose services would be used on the project as needed. Additional support by way of test drilling, formation sampling, and geophysical logging would be provided by the Well Construction Section, Hydraulic Resources of CORFO.

2. PROPOSED WORK

The Aconcagua Water Resources Investigations Project under the direction of CORFO should be set up for a 2-year period (Jan. 1970 to Dec. 1971).

First year activities should be mainly field studies. Such studies are necessary to refine the preliminary evaluation of physical characteristics of the aquifer and to provide data for model verification. The field program should include drilling about 30 test holes; installing about 130 observation wells; making about 50 aquifer tests; installing 8 continuously recording stream and canal gaging stations (or staff gage read daily); collecting and analyzing about 100 water-quality samples; geophysical studies; and geophysical logging.

Second year activities should emphasize model studies. The construction, modification, and verification of the digital model should be completed. In addition, a continuing program of data collection to refine the model and to provide data for additional calibration should be begun. A detailed report should be prepared to summarize the results of the analysis. Activities should be mainly analysis of water-management plans, using the digital model, and also stochastic systems-analysis studies. Plans for optimizing water use should be formulated and tested. Social, economic, and legal restraints should be incorporated in the model program.

3. SUPPORT BY THE U. S. AGENCY FOR INTERNATIONAL DEVELOPMENT

US AID would be asked to provide additional support for water-resources studies in the Rio Aconcagua valley as follows: Short-term (TDY) assignments of hydrologic specialists from the United States to work with CORFO, RIEGO, and EMCO (Empresa de Servicio de Computación) on new methodology such as simulation models and systems-analysis models; training of CORFO and RIEGO scientists and engineers in the United States to gain special experience, such as on-the-job training with U. S. Geological Survey offices currently engaged in hydrologic model and systems-analysis studies; assignment of Geological Survey hydrologists to teach short specialized seminar courses for CORFO and RIEGO; and coordination from US AID, Office of Engineering, in Santiago, Chile. The Office of Engineering would provide liaison and assistance for Geological Survey hydrologists assigned to Chile.

PROGRAMA DE INVESTIGACION DE LOS RECURSOS DE AGUA DEL VALLE DEL RIO ACONCAGUA EN CHILE

RESUMEN EN ESPAÑOL

El valle del río Aconcagua es el segundo en importancia de los valles regados de Chile y se extiende desde la Cordillera de los Andes hasta el Océano Pacífico. La porción al oeste de este valle es importante desde el punto de vista agrícola. Los cultivos más importantes son fruta, maíz, y verduras, principalmente para Santiago. La parte regada del valle se extiende desde Chacabuquito al Océano Pacífico, en 113 Km. (kilómetros). El área regada, que es la principal región agricultora, tiene una extensión de unos 70.000 hectares. En esta superficie están comprendidos los terrenos del valle principal y de cuatro tributarios importantes.

El valle posee un relleno aluvial que da lugar a un acuífero formado por arenas y gravas no consolidadas y arcilla. El relleno y el río en gran parte del valle forman un sistema hidráulico conectado, siendo el carácter del río afluente para la mayor parte de los años. El área total del acuífero aluvial tiene cerca de 115.000 hectares. El ancho del acuífero varía de 1 a 13 Km. con un promedio cercano a los 3 Km. La fuente de agua para riego depende primordialmente del derretimiento de las nieves de los Andes, porque la precipitación media anual en la parte regada alcanza solamente a 30 Cm. (centímetros). Parte de las aguas de riego recargan el acuífero aluvial y aparecen en la corriente del río como flujo de retorno. Una gran parte del valle utiliza estos flujos de retorno como su mayor fuente de agua para el riego. El volumen de agua que ingresa al valle regado tiene un promedio de 1000×10^6 m^3 (metros cúbicos) anuales durante los últimos 30 años. Sin embargo, como resultado de las severas condiciones de sequía, la corriente del río ha bajado considerablemente en los últimos dos años (1967 y 1968). El volumen de entrada en 1967 fue de 500×10^6 m^3 en 1968 solamente de 344×10^6 m^3. El flujo de retorno de las aguas subterráneas muestran una reducción similar.

El Gobierno de Chile desea proporcionar al valle un suministro de agua más regulado. Las dos posibilidades más importantes para proporcionar tales regulación y seguridad son (1) construir un embalse de aguas superficiales aguas arriba del área actualmente regada y (2) desarrollar los recursos de agua subterránea para el riego. Actualmente (1969) la CORFO y la Dirección de Riego están haciendo investigaciones de los recursos de agua del valle Aconcagua para proporcionar los datos que permitan evaluar estos proyectos.

Este informe preparado a solicitud del Gobierno de Chile bajo los auspicios de USAID esboza un programa de estudios de recursos de agua del valle del Aconcagua. El programa de investigación de recursos de agua proporcionará la información básica de hidrología e hidrogeología y el análisis necesario para planificar futuros desarrollos y usos de recursos de agua en el valle del Aconcagua. El autor empleó cerca de dos meses en un estudio del valle, desde el 22 de octubre hasta el 31 de diciembre de 1969.

El estudio que se propone será una evaluación cuantitativa de los recursos de aguas superficiales y subterráneas que abarque toda la hoya hidrográfica del valle del Aconcagua. La metodología que se usa en el estudio es la siguiente:

1. Compilación y análisis de todos los datos hidrológicos e hidrogeológicos disponibles que sean necesarios para definir el sistema río-acuífero.
2. Construcción de un modelo digital de simulación del sistema río-acuífero para una parte del valle.
3. Obtención de datos hidrológicos adicionales para precisar las estimaciones preliminares y obtención de datos de terreno para perfeccionar el modelo.
4. Construcción y calibración de un modelo digital de simulación del valle del Aconcagua, incluyendo algunos tributarios principales.
5. Empleo del modelo para evaluar los planes de administración que se propongan.
6. Realización de estudios de sistemas de análisis de utilización óptima de aguas superficiales y subterráneas.

El modelo digital de simulación es necesario para este programa de estudio debido a las muchas incógnitas, la gran cantidad de datos que deben ser empleados y lo complejo de las relaciones hidrológicas. El modelo es una herramienta de integración y análisis de los datos hidrológicos y datos socioeconómicos relacionados. Los datos de aguas subterráneas, aguas superficiales y datos climatológicos, se simularán por el modelo para proporcionar una descripción cuantitativa del sistema hidrológico. El modelo será calibrado o verificado con datos obtenidos de las estaciones de aforo, medidas de pérdidas y ganancias de flujo y mapas de fluctuación de niveles freáticos.

Algunos de los posibles usos del modelo digital en el valle del Aconcagua son: planeación de programas de obtención de datos hidrológicos de terreno, evaluación del potencial para el desarrollo de suministros adicionales de agua para riego, evaluación de planes de cambios de administración del suministro de agua superficial, y planeamiento de utilización óptima conjunta de aguas superficiales y subterráneas del valle.

Un programa intensivo de complilación de datos e informaciones sobre aguas subterráneas y superficiales fue iniciado por CORFO en 1967. Parte de esta información ha sido publicada en un informe básico sobre pozos (CORFO e IIG, 1969) y una evaluación de la información de aguas superficiales (Rodríquez, 1969). Estos informes y el informe hidrogeológico preliminar (CORFO, 1969) proporcionan la información básica preliminar que se necesita para construir y verificar un modelo digital río-acuífero. Durante los meses noviembre y diciembre de 1969 han preparado los ingenieros y geólogos de CORFO mapas describiendo las características físicas y los límites del sistema de aguas subterráneas y mapas que indican el nivel de las napas freáticas, la configuración de la roca basal, el espesor saturado y la transmisibilidad. Estos mapas constituyen la base de evaluación y las necesidades de datos de terreno y se utilizarán para construir un modelo preliminar. Además se han compilado datos de recarga y descarga en el sistema río-acuífero. Esta información se utilizará para indicar las áreas en que se necesitan datos adicionales de aguas superficiales y constituirán una base para proveer al modelo de los datos de recarga y descarga. No han sido aún compilados los datos básicos que mayormente se necesitan para la verificación del modelo.

RECOMENDACIONES EN ESPAÑOL

Las siguientes son las recomendaciones más importantes para las futuras investigaciones de recursos de agua del valle del río Aconcagua:

1. ORGANIZACION Y PERSONAL PARA EL PROYECTO DE INVESTIGAR LOS RECURSOS DE AGUA DEL VALLE DEL ACONCAGUA

Deberá encargarse del proyecto de investigar los recursos del valle del río Aconcagua la Corporación de Fomento de la Producción (CORFO). El personal del proyecto deberá contar con un Jefe de Proyecto a jornada completa y además un hidrogeólogo, un geólogo, y un ingeniero especialista en aguas superficiales. Los servicios de los tres últimos se utilizarán en el proyecto cuando sean necesarios. La sección de construcción de pozos de CORFO proporcionará ayuda adicional en forma de perforación de pozos de observación, obtención, y análisis de muestras de formaciones, y realización de registros geofísicos.

2. TRABAJO PROPUESTO

Deberá desarrollarse en un período de 2 años (enero de 1970 - diciembre de 1971) el proyecto de investigación de recursos de agua en el valle del río Aconcagua bajo la dirección de CORFO.

Primer año. Las actividades serán especialmente la obtención de los datos de terreno. Tales estudios son necesarios para refinar la evaluación preliminar que se ha hecho sobre las características físicas del acuífero y para proporcionar datos de verificación del modelo. El programa de obtención de datos deberá incluir la perforación de 30 pozos de reconocimiento, la instalación de 130 pozos de observación, la ejecución de 50 pruebas de bombeo, la instalación de 8 estaciones registradoras continuas de gasto y de aforo de tributarios y canales (o limimétricas de lectura diaria), obtención y análisis de unas 100 muestras para calidad de agua, estudios geofísicos, y registros geofísicos de todos los pozos.

Segundo año. Las actividades durante este año enfatizarán los estudios del modelo. La construcción, modificaciones, y verificaciones del modelo se deberán completar. Además se iniciará un programa continuo de obtención de datos para refinar el modelo y proporcionar datos para una calibración adicional. Además, se deberán iniciar un programa de compilación de datos para precisar el modelo y para proporcionar datos para calibración adicional. Se deberá preparar durante este año un informe detallado que resuma los resultados del análisis. Las actividades principales serán el análisis de planes de administración de aguas usando el modelo digital y también estudios analíticos de sistemas estocásticos. Se formularán y ensayarán planes para la optimización del uso del agua. Se deberán incorporar al programa del modelo las disposiciones legales, sociales, y económicas.

3. AYUDA DE LA AID

Se deberá pedir a la Agencia para el Desarrollo Internacional de los Estados Unidos (AID) que proporcione ayuda adicional para estudios de recursos de agua en el valle de Aconcagua. Dicha asistencia deberá incluir: Asignación de especialistas en hidrología de los Estados Unidos para trabajar por breves períodos con CORFO, RIEGO, y EMCO en nuevas metodologías tales como modelos de simulación y modelos de análisis de sistemas; entrenamiento de científicos e ingenieros de CORFO y RIEGO en los Estados Unidos para obtener experiencia especial, tal como el entrenamiento de trabajo en una oficina del Servicio Geológico de los Estados Unidos (USGS) que esté trabajando actualmente en modelos y estudios de sistemas de análisis; asignación de hidrólogos del Servicio Geológico de los Estados Unidos para dictar cursos cortos especializados para CORFO y RIEGO; y continuación de la actividad de coordinación de la oficina de Ingeniería de la AID. Ésta deberá proporcionar contactos y ayuda a los hidrólogos del USGS asignados a Chile.

INTRODUCTION

This report was prepared at the request of the Government of Chile, under the auspices of the U. S. Agency for International Development (US AID). In accordance with US AID PIO/T 513-000-0019, the U. S. Geological Survey assigned the author to a 2-month tour of duty (Oct. 22 to Dec. 31, 1969) in Chile to assist the Corporación de Fomento de la Producción (CORFO); the Ministerio de Obras Públicas y Transportes, Dirección de Riego (RIEGO); and the Servicio Agrícola y Ganadero (SAG) in problems related to their joint water-resources investigation in the Rio Aconcagua valley.

The Rio Aconcagua valley (fig. 1), one of Chile's foremost agricultural areas, is dependent on irrigation; the water used is largely snowmelt from headwater tributaries of the Rio Aconcagua in the Andes Mountains. During 1967 and 1968, the valley, in common with all of central Chile, suffered from one of the most severe droughts in recorded history of the region. For example, the water-inflow in 1968 to the valley was only 30 percent of long-term average. As a consequence of this drought, the Government of Chile is now seeking a more regulated and dependable irrigation water supply for the Rio Aconcagua valley. Proposals to provide such regulation and dependability include (1) construction of surface reservoirs upstream from the presently irrigated sections and (2) expanded use of ground water for irrigation.

The valley, underlain by a permeable alluvial aquifer, contains about 1×10^{10} m^3 of water in transient storage. The ground-water supply has been only partly developed for irrigation.

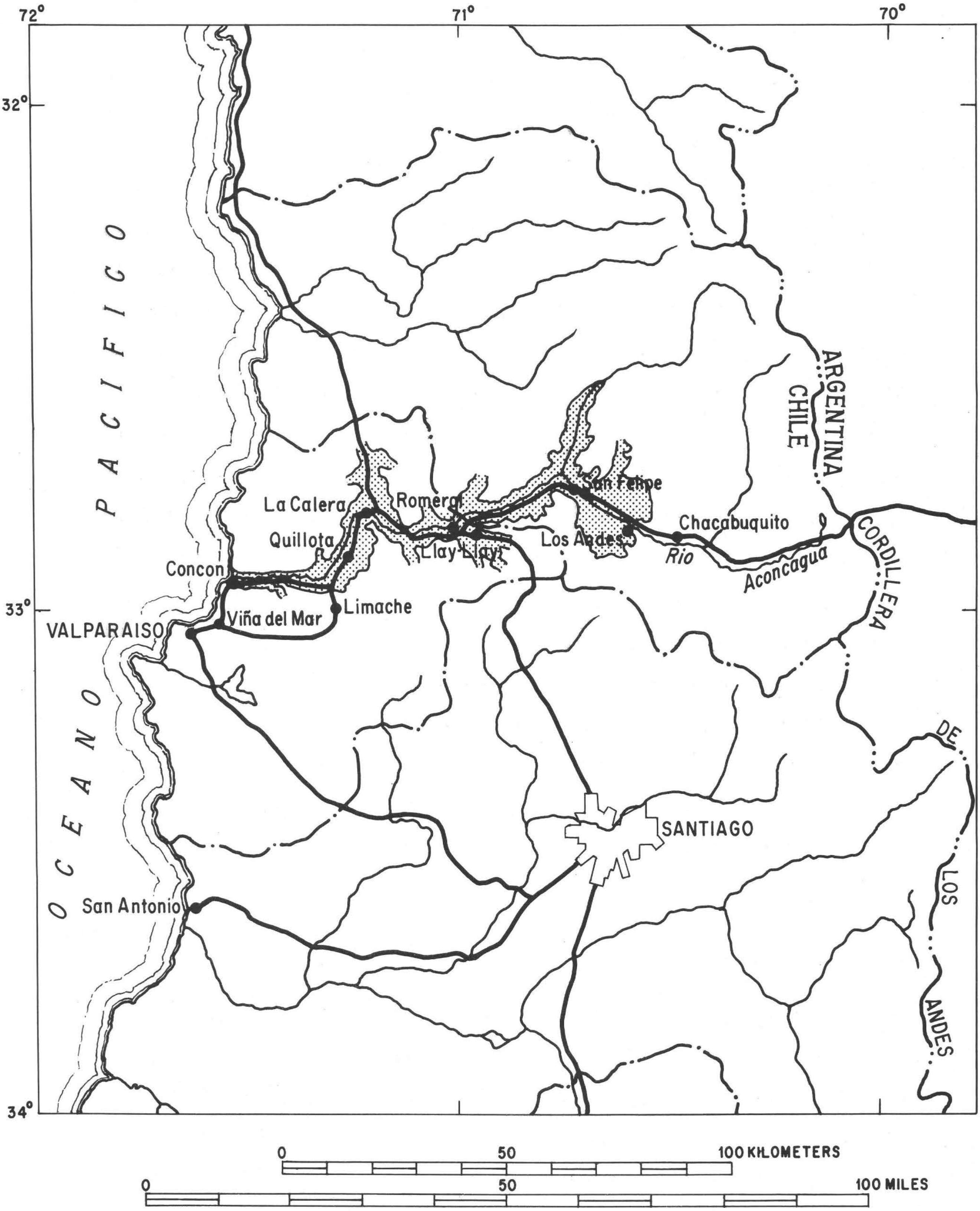

Figure 1.--Index map showing location of the Rio Aconcagua valley, (shaded) Chile.

Purpose and Scope of Report

Agencies of the Government of Chile are currently studying the water-resources of the Rio Aconcagua valley to provide data and analyses essential to evaluation of proposed changes in water development, use, and management. The author reviewed data on the water resources that have been collected by CORFO and RIEGO, and, on the basis of the review, prepared this report, which summarizes the current studies and proposes a program of future investigations. This report first evaluates the present knowledge of the water resources of the valley and then describes a proposed study program of water-resources investigations. The proposed study program should be a basinwide quantitative evaluation of the surface- and ground-water resources. The most essential feature of the study is the construction and verification of a simulation digital model of the stream-aquifer system. The digital model is a tool for analyzing the hydrologic data and, when calibrated, can be used to evaluate the effects of proposed changes in water development, use, and management.

Acknowledgments

During this study the author received valuable assistance from the U. S. Agency for International Development (US AID); the Corporación de Fomento de la Producción (CORFO); the Ministerio de Obras Públicas y Transportes, Dirección de Riego (RIEGO); the Instituto de Investigaciones Geológicas (IIG); and the Empresa de Servicio de Computación (EMCO). The cordial hospitality and the generous assistance of Enrique Sepúlveda (US AID), Pablo Kleiman (RIEGO), Fernando Peralta (CORFO), Agustín Hojas (CORFO), and Fernando Alamos (CORFO) are especially appreciated.

WATER RESOURCES OF THE RIO ACONCAGUA VALLEY

The Rio Aconcagua drainage system extends from the Continental Divide along the crest of the Andes to the Pacific Ocean, a total distance of 230 km. The valley, which lies about 100 km north of Santiago, is the second most productive irrigated area in Chile (figs. 2-6), and has been farmed and irrigated for more than 200 years. The lower part of the valley and contiguous lower reaches of tributary valleys constitute the irrigated agricultural area. The major crops are grapes, fruits, corn, and garden vegetables, grown principally for the Santiago market. The irrigated part of the valley (fig. 1) extends from Chacabuquito to the ocean, a distance of 113 km. There are about 70 major irrigation canals in the valley and 70, 000 hectares are irrigated. In addition to the main valley, there are four irrigated tributary valleys. The growing season is about 9 months.

General Hydrology and Hydrogeology

The irrigated area of the Aconcagua Valley contains a permeable alluvial aquifer of sand, gravel, and boulders interbedded with clay (fig. 7). Some of the material is very coarse, containing lenses with boulders greater than 70 cm in diameter.

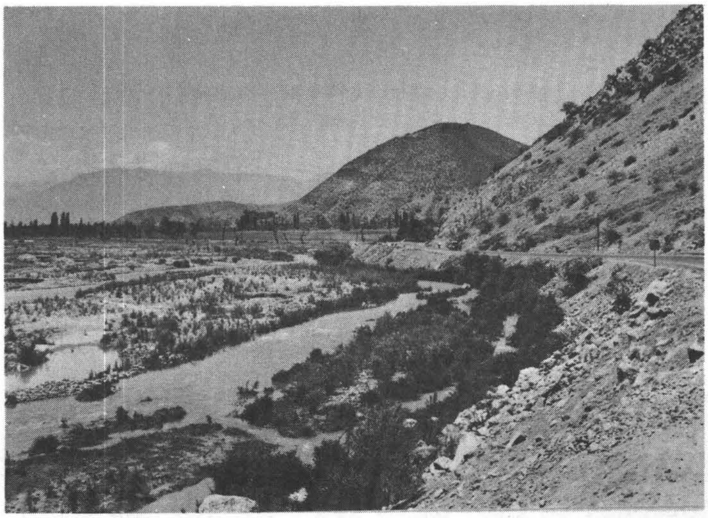

Figure 2.--Photograph of the Rio Aconcagua valley with view of edge of alluvial fill and bedrock valley margin.

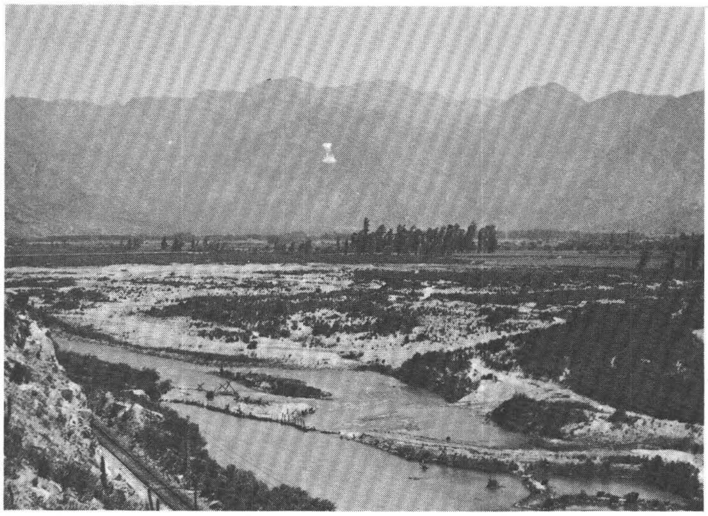

Figure 3.--Photograph of the Rio Aconcagua valley with view of alluvial fill, bordering mountains and temporary diversion dam.

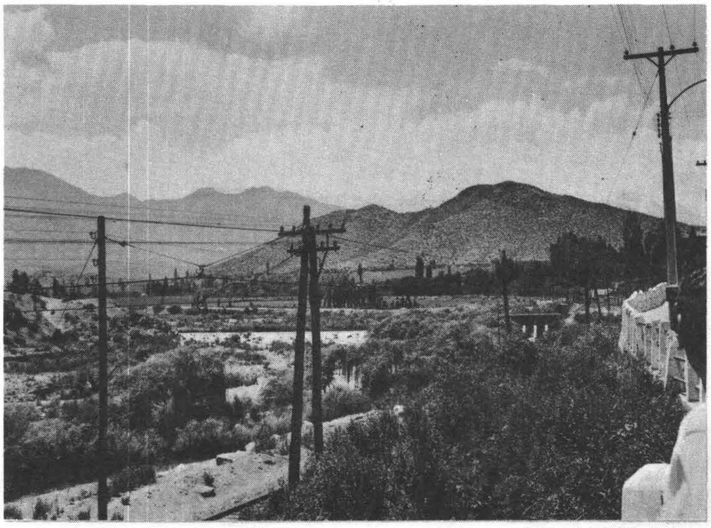

Figure 4. --Photograph of the Rinconada de Los Andes, view toward east.

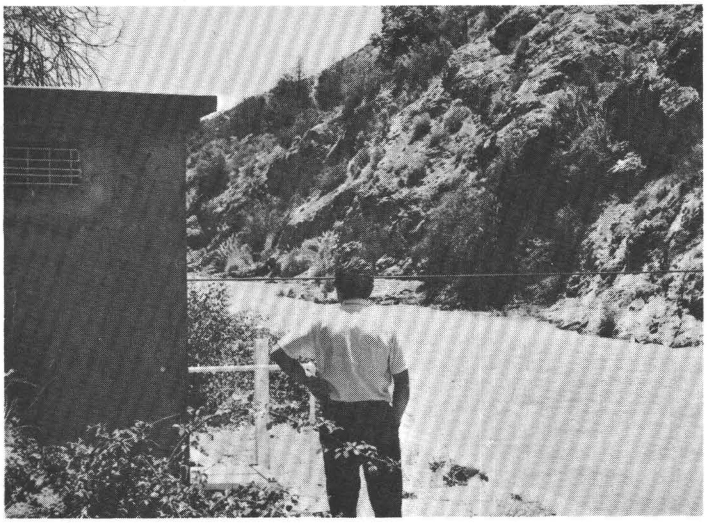

Figure 5.--Photograph of stream-gaging station and cableway on Rio Aconcagua at Chacabuquito, view looking downstream.

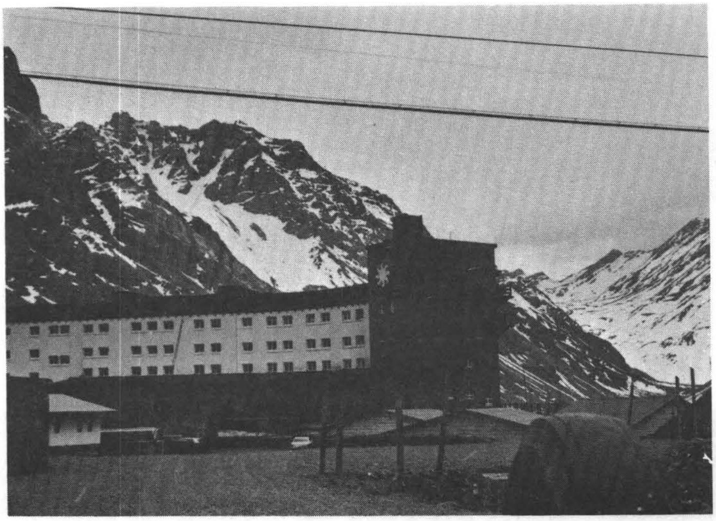

Figure 6.--Photograph showing the snowfields in the high Andes near the Continental Divide and the Portillo ski area.

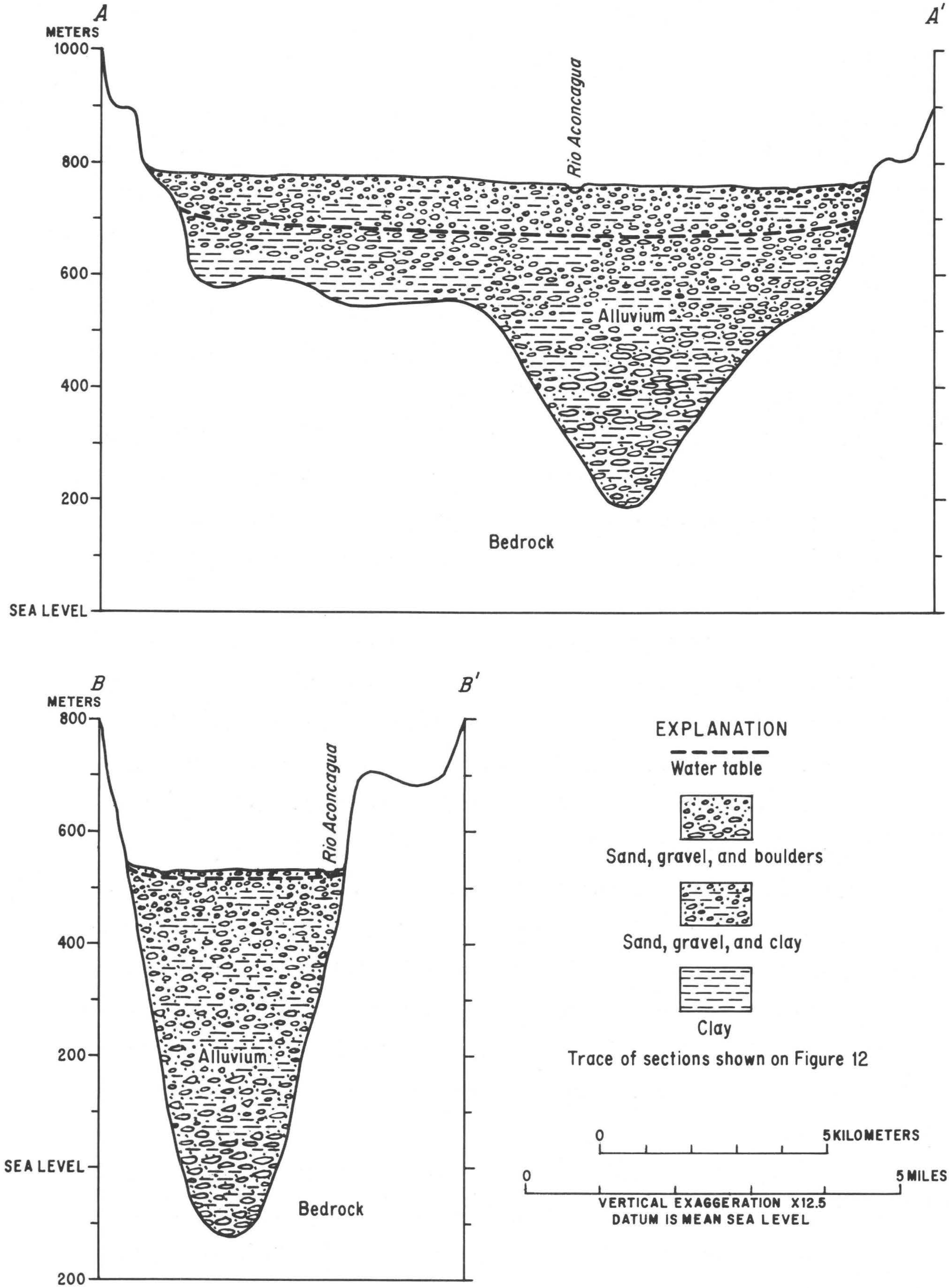

Figure 7. --Generalized north-south hydrogeologic sections of the Rio Aconcagua valley.

The aquifer is extremely heterogeneous, and the sorting grows worse, in general, from east to west. The alluvial aquifer lies in a bedrock trough of igneous and sedimentary rocks, which form the bottom and margins of the aquifer. The valley is enclosed on the north and south by high mountains. The total area of alluvial aquifer is about 115, 000 hectares, including the alluvial tributary valleys.

The region has been subject to major faulting, both before and during the deposition of the alluvium. Several reaches of the valley and its tributaries are, in fact, controlled by lines of structural weakness, and some may occupy downdropped fault wedges or blocks.

The alluvial valley ranges from about 1 to 13 km wide and averages about 3 km. The irrigation supply depends primarily on snowmelt from the Andes, as the mean annual precipitation in the irrigated area which is only about 300 mm (millimeters) and occurs mainly in the winter months (May to September). A large part of the water applied for irrigation (50 to 75 percent) recharges the alluvial aquifer and some appears as return flow in the Rio Aconcagua and its tributaries. The river acts as a natural drain (line sink) for the alluvial aquifer and, in most of the valley, is hydraulically connected with it. The river is normally a gaining stream for most of the year below San Felipe. A major part of the valley (San Felipe to La Calera) uses the return flow for irrigation supply.

Surface-inflow from the Rio Aconcagua at Chacabuquito (10 km upstream from Los Andes), the main inflow measurement station, to the irrigated area has averaged 1, 000 X 10^6 m^3 per year for the past 30 years (fig. 8). As a result of severe drought, however, the flow was drastically reduced during the past 2 years (1967 and 1968). The inflow was 500 X 10^6 m^3 in 1967 and only 344 X 10^6 m^3 in 1968. Return flow was also reduced correspondingly. The river flows in highly anastomosing channels and, along the lower two-thirds of the valley, its channel system averages about 300 m (meters) wide with flow commonly divided in 3 to 5 channels.

During the past 2 years the drilling of wells and development of ground water for irrigation have progressed rapidly as a result of the drought. There are, however, still (1969) only 67 large-capacity irrigation wells and 40 industrial wells in the valley. In addition, several hundred shallow wells supply stock water and domestic needs. The Government of Chile proposed to develop the ground-water supply in the lower part of the valley (Llay-Llay to Concon) still more, so as to be able to make more surface water available to the upper part of the valley. The quality of both the ground water and surface water is good, ranging from 300 to 600 mg per l (milligrams per liter) dissolved solids.

The valley is divided into four sections (reaches) for the administration of water rights. These same divisions also form natural hydrologic and geologic units. The first section, which contains the largest irrigated area, is a losing section of the river, the second and third are gaining because of return flow, and the fourth section is probably also gaining a small amount. The following is a summary of the hydrologic conditions in each section (the sections are discussed in downstream order, that is, east to west).

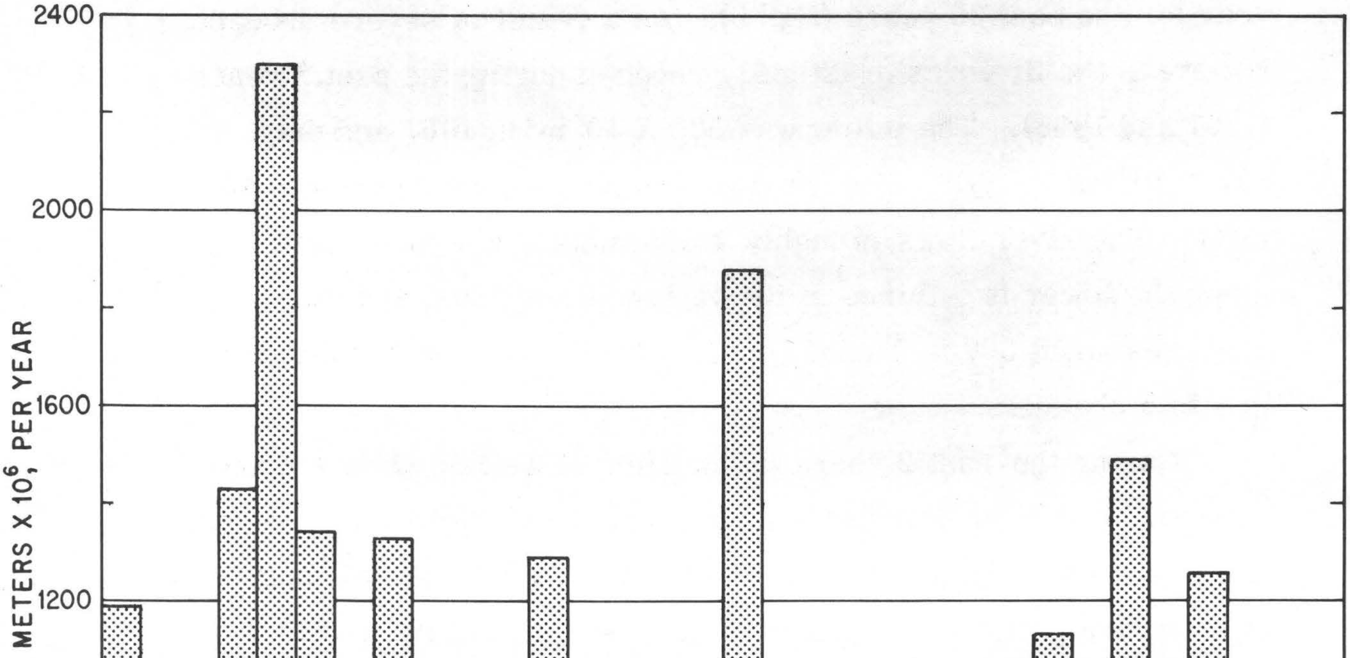

Figure 8.--Annual inflow (1937-68) at Chacabuquito to the Rio Aconcagua valley.

First Section

The first section, which extends from Chacabuquito to San Felipe, is 24 km long and 18 km wide. The total area is 39, 600 hectares. It contains the major irrigated section in the valley and contains about 24, 000 hectares of irrigated land. Legally, the irrigators in this section can divert the entire flow of the Rio Aconcagua. In practice, when the flow at Chacabuquito is greater than 30 m^3 per sec (cubic meters per second), the excess is allowed to go downstream. The water table in this section lies below the river level (see fig. 7, A-A'), from as much as 90 m at Los Andes to 10 m at San Felipe (1969). The river in this section, as shown by gain and loss studies (seepage runs), is losing a small amount of water. Since 1967, when measurements were started, ground-water levels have been declining rather dramatically in the entire section. The water-level decline between May 1968 and August 1969 ranged from about 10 m at Los Andes to 5 m near San Felipe (fig. 9). The decline is attributed to below-normal snowmelt and precipitation for 1967 and 1968. The water-table gradient in this section was about 6 m per km in 1969.

The average well yield in this section is about 80 l per sec (liters per second). The saturated thickness ranges from 5 m to greater than 500 m. Almost all the wells drilled thus far in the section are only partly penetrating, largely because of difficulties in drilling through the very coarse alluvium. Also, if well owners can obtain 60 l per sec or more from a relatively shallow well, they see no need to drill deeper. The lithologic logs and pumping-

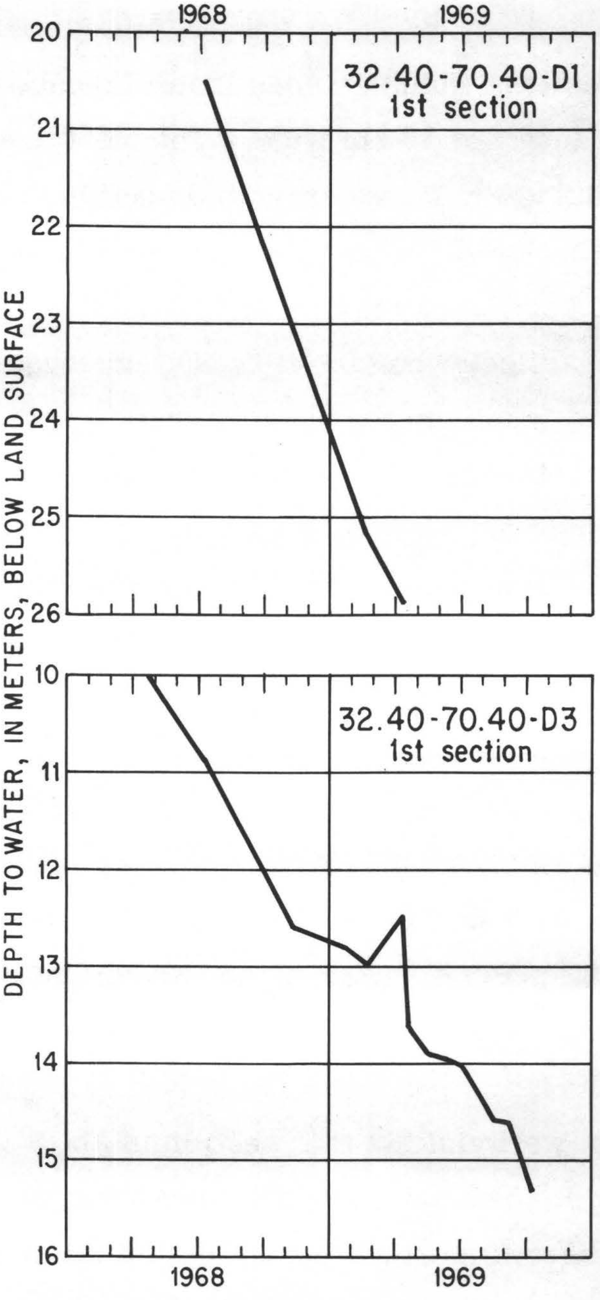

Figure 9. --Hydrographs of wells in the First Section of the Rio Aconcagua valley.

test data indicate that the aquifer in this section is more permeable than in the other sections of the valley. The aquifer consists of very coarse sand, gravel, and boulders and very few clay layers. The transmissivity is undoubtedly high and may range from 625 to 12, 500 m^3 per day per m (cubic meters per day per meter) and average about 5, 000 m^3 per day per m or more. It is difficult to define the transmissivity in this section because no tests using observation wells have been made. The tests completed thus far have been made in the pumped wells. In general, the transmissivity values obtained from the straight-line parts of the time-drawdown semilog plots are more than double those obtained from computations based on specific capacity. Moreover, the time-drawdown plots for many tests are almost flat.

Second Section

The second section, which extends from San Felipe to Romeral, is 32 km long by 3 km wide on the average. The total area is 18, 000 hectares, of which half is in tributary valleys. Water for irrigation is supplied by return flow of irrigation water, ground-water underflow from the Aconcagua and Putaendo valleys, and sometimes by surface flow that is excess to the needs of the first section. The ground water in this section is hydraulically connected to the river (see fig. 7, B-B'). The water table ranges in depth from 0 to 6 m below the land surface and the average depth to water is about 3 m. The river in this section, as shown by gain and loss studies, normally gains a large increment of flow (fig. 10). The gain in the reach San Felipe to Romeral

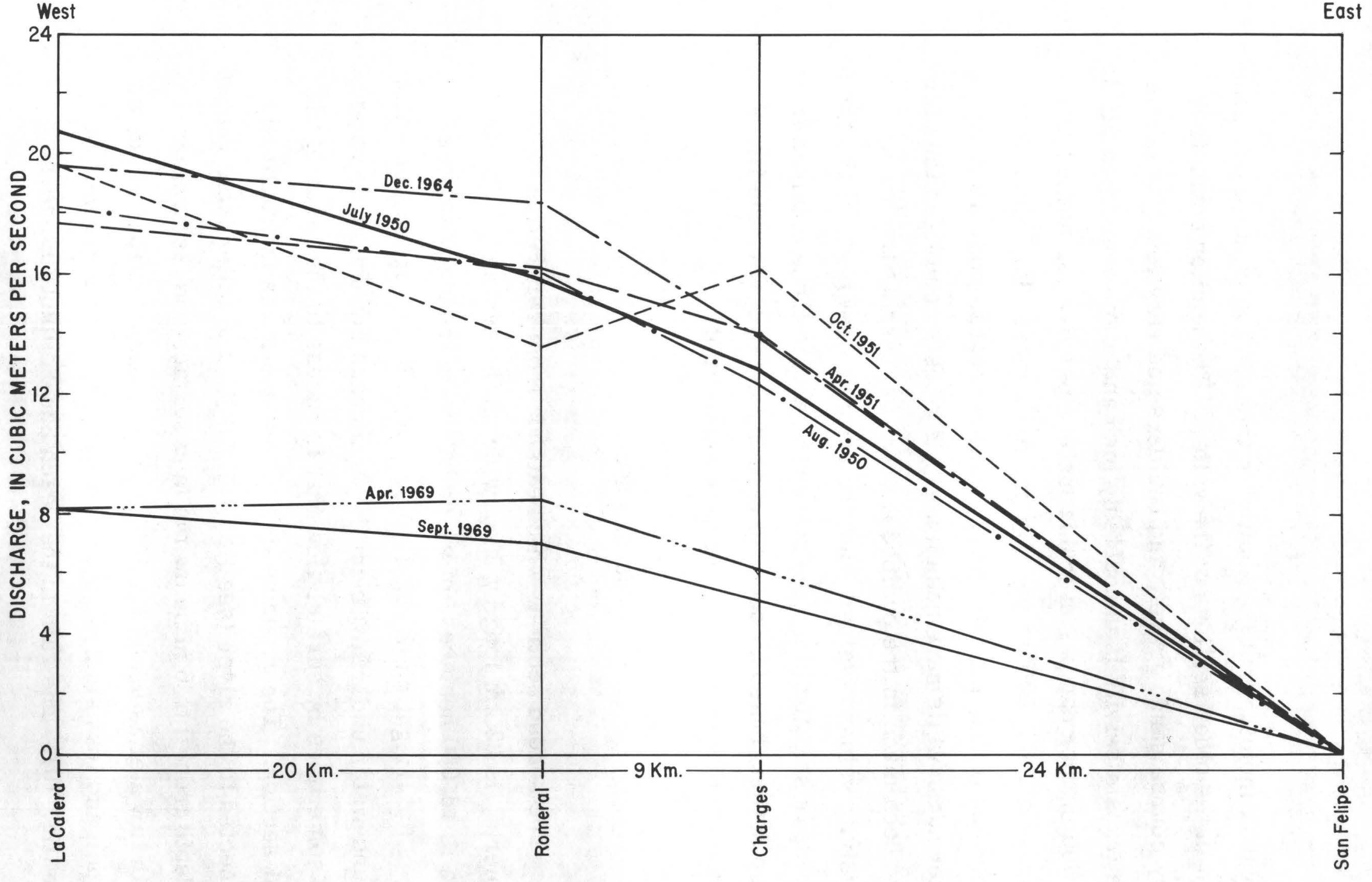

Figure 10. --Gain and loss studies in Rio Aconcagua.

ranges from 8 to 19 m^3 per sec. The average well yield is about 70 l per sec. The maximum saturated thickness is about 600 m and averages ~~40~~ 400 m. Little hydrologic data to define transmissivity are available for this section. Transmissivity data obtained from three tests indicate values ranging from 625 to 6,250 m^3 per day per m. The observed changes in ground-water levels between 1967 and 1969 have been smaller than those in the first section (fig. 11).

Third Section

The third section, which extends from Romeral to La Calera, is 17 km long by 3 km wide on the average and contains about 18,000 hectares. Irrigation water is provided by return flow to the river and by irrigation wells. Most of the existing irrigation wells in the valley are located in this section (about 50 wells). The available water supply in the third section is frequently insufficient for existing irrigated lands. The water table in the third section ranges from 0 to 6 m below the land surface and averages about 3 m.

In this section the river normally gains about 5 m^3 per sec. The average well yield is about 20 l per sec, and the average saturated thickness is about 200 m. The aquifer contains considerably more clay than the first two sections and, consequently, the average transmissivity probably is about 1,250 m^3 per day per m. The Las Vegas infiltration gallery which supplies water for Valpáraiso and Viña del Mar is located in this section. The gallery is excavated in alluvium and produces about 50×10^6 m^3 per year.

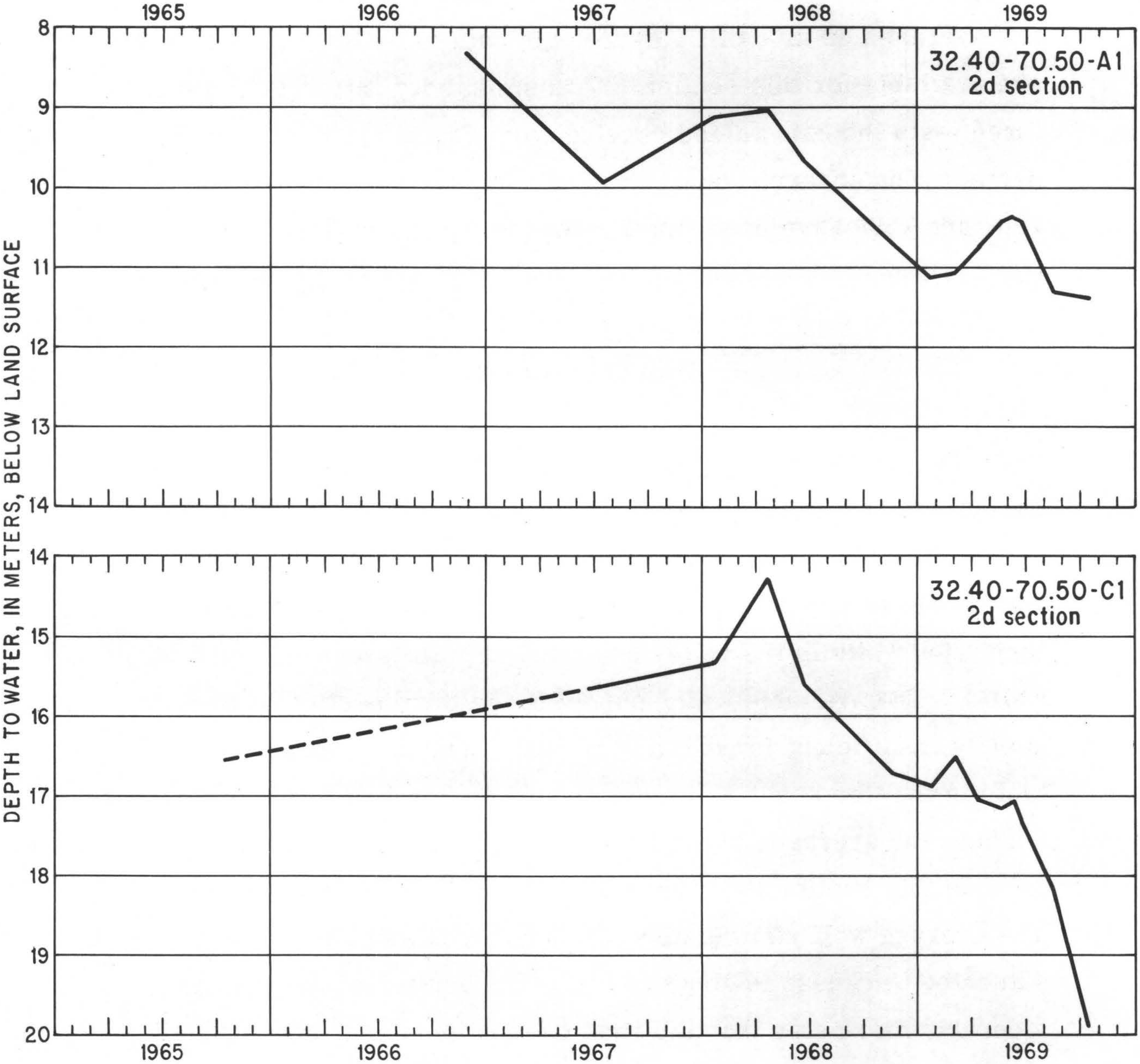

Figure 11. --Hydrographs of wells in the Second Section of the Rio Aconcagua valley.

Fourth Section

The fourth section, which extends from La Calera to Concon (Pacific Ocean), is 40 km long by about 3 km wide and contains about 8,000 irrigated hectares of a total of 18,000 hectares. Little hydrogeologic information is available for this section. The water table in this section averages about 2 m below the land surface. The water in the aquifer is both unconfined and confined. The upper (water-table) aquifer is about 6 m thick and is separated from a lower (confined) aquifer by an 18-m thick clay layer. The confined aquifer has an average thickness of 35 m. The average well yield, as determined from only a few tests, is about 20 l per sec. Salt-water intrusion may be a major problem in the coastal reach of this section in the future. Pumping of wells to supply water for cooling at the oil refinery near Concon has already resulted in some salt-water intrusion and contamination of the ground-water supply. The salt-water front in the aquifer is now about 1.6 km inland.

Data Available

An intensive hydrologic-data collection program for ground-water and surface-water information was started by CORFO in 1967. Some of the data collected have been published in a basic-data report on wells (CORFO and IIG, 1969) and a report on gain and loss studies (Rodriquez, 1969). These reports and a preliminary report on the hydrogeology (CORFO, 1969) provide the basic information needed for water-resources evaluation, future project planning, and digital model construction. Other reports on the hydrogeology of the valley are listed in the selected references. A list of available maps and aerial photographs of the area is shown in Appendix 2.

Current Investigation

During November and December 1969, maps were prepared showing the physical characteristics, boundaries, and water-level changes. Maps showing the configuration of the water table, the shape of the bedrock surface, the saturated thickness, and the transmissivity were prepared by CORFO engineers and geologists (figs. 12-15). These maps form the basis for the evaluation of field-data deficiencies and will be used to construct a preliminary digital stream-aquifer model. In addition, hydrologic data on recharge and discharge to the stream-aquifer system have been tabulated. The transmissivity map (fig. 15) was prepared by using the saturated-thickness map. As each valley section has different values of permeability, it was not feasible to make a direct conversion of the saturated-thickness map to a transmissivity map. Instead, a value of transmissivity compared to saturated thickness was established for each section; for example, in the second section, saturated thickness of 400 to 600 m $\approx$1,250 to 3,120 m^3 per day per m, and, in the first section, saturated thickness of 400 to 600 m $\approx$ 3,100 to 6,250 m^3 per day per m. The values of transmissivity may be low because test data are from wells that are only partly penetrating. A summary of pumping tests and problems related to the tests are given in Appendix 3.

CORFO has already started construction of a digital model using these maps. This preliminary pilot model (Chacabuquito to Chagres) will be programed for the period May 1968 to August 1969 and will be calibrated with water-level change maps and stream gain and loss data. This analysis is only preliminary, however, because data on recharge, discharge, and river gain and loss are incomplete. CORFO personnel are now collecting additional field data needed for model verification. The digital model is based on the computer program developed by Pinder and Bredehoeft (1968). CORFO personnel are using an IBM 360/40 operated by EMCO for the analysis.

The author made a critical evaluation of the completed maps to identify the major data deficiencies and reported his findings to the Chief, Department of Hydraulic Resources of CORFO. Based on these findings the author recommended a field data-collection program that includes additional geophysical studies; gamma-ray logging of wells; drilling of 167 observation wells and test holes; and 49 aquifer tests (using observation-well control). An evaluation of the recuperation studies and records of gaging stations indicated a definite need for additional gaging stations on the Rio Aconcagua and its tributaries. The author recommended that eight new gaging stations be installed on the main stream, tributaries, and canals and, in addition, that a water-quality sampling program be begun at selected ground-water and surface-water sampling stations. A summary of proposed additional field basic-data collection is shown in tables 1 and 2. This additional field data-collection program is needed (1) to refine the preliminary definition of transmissivity and (2) to provide essential data for input and verification of the digital model.

Table 1.--Summary of Existing Ground-Water Network and Recommended Additional Control

Section	Area (km^2)	Completed pumping tests (as of Dec. 1969)	Recommended additional pumping tests	Existing observation wells (as of Dec. 1969)	Recommended additional observation wells
First section	396	14	25	25	100
Second section	134	6	10	17	30
Third section	110	12	4	98	0
Fourth section	187	19	10	25	37
Total	827	51	49	165	167

Table 2.--Summary of Existing Surface-Water Network and Recommended Additional Control

Existing Gaging Stations	Period of Record
Rio Aconcagua at Chacabuquito (recording)	1937 - present
Rio Aconcagua at San Felipe (recording)	1962 - present
Rio Aconcagua at Romeral (recording)	1961 - present
Rio Aconcagua at Tabolango	1943 - 53
Rio Putaendo at Los Patos	1940 - present
Estero Pocuro (first section)	1931 - present
Estero Los Loros at Las Vegas (second section) . .	1962 - present
Estero Catemu (second section)	1962 - present
Estero Lo Campo (second section)	1962 - present
Estero Romeral (third section)	1962 - 67
Estero Rabuco (third section)	1962 - present

Proposed Gaging Stations (Recording or Daily Staff-Gage Measurements)

Rio Aconcagua at Los Andes

Rio Aconcagua at La Calera

Rio Aconcagua at Tabolango

Estero Limache, upstream from junction with Rio Aconcagua

Estero Llay-Llay and Ucuquer

Estero Catemu, upstream from junction with Rio Aconcagua

Estero Los Loros at Las Vegas, upstream from junction with Rio Aconcagua

Estero Los Litres (El Melon) at Panamerican Highway

PROPOSED INVESTIGATION PROGRAM

The program to investigate the water resources of the Rio Aconcagua valley proposes a 2-year period of intensive data collection and evaluation. After this period, a continuing program of data collection should be started to refine and verify the analyses. The emphasis should be on a basinwide quantitative evaluation of the water resources, both surface and underground, of the Aconcagua Valley. The program should provide the basic hydrologic and hydrogeologic information and analyses essential for planning the optimum development of the water resources. In order to achieve the goals set forth in this program, a project staff for the Aconcagua study should be established in the Department of Hydraulic Resources of CORFO. The team assigned to the project should consist of a full-time project chief, and in addition, a hydrogeologist, a geologist, and a surface-water engineer, whose services would be used on the project as needed. Additional support by way of test drilling, formation sampling, and geophysical logging would be provided by the Well Construction Section, Hydraulic Resources of CORFO.

The project chief should work directly under the Chief, Department of Hydraulic Resources of CORFO and should be a hydrologist (hydrologic engineer) with training and experience (at least 3 years) in ground-water hydrology and some experience in surface-water hydrology, computer programing, and water chemistry. The project chief, who will devote 24 months to the project, should supervise all basic-data collection of team members and should prepare data needed for the construction and verification of the digital stream-aquifer simulation model. He should maintain close liaison with RIEGO, SAG, EMCO, IIG, and US AID. The project chief should have the major responsibility for preparing interpretive reports on the investigation. Those individuals selected to work with the project chief should have, preferably, a minimum of 1 year's experience in their own discipline. These individuals will be expected to devote an aggregate of about 24 man-months to the project.

Project Activity

The project is planned to start January 1970 and continue to December 1971. The approach to be used in the study is as follows:

First year activities would consist of the collection of hydrologic and hydrogeologic field data that are needed to define the physical character and operation of the stream-aquifer system. Such data are necessary to refine the preliminary evaluation of transmissivity, specific yield, and boundaries of the aquifer. In addition, more refined data are necessary for evaluation of recharge and discharge. These data will be used to improve the accuracy of the description of the hydrologic system and the model analyses.

The field data-collection program should include the drilling and installation of observation wells and aquifer tests (table 1). The test holes should be drilled as open holes, 4- to 6-inch diameter, and to bedrock, if possible. As the purpose of these test holes is to collect hydrogeologic information, drilling samples should be collected and described in a uniform manner. Electric logs should be run on all test holes. After completion of each test hole, a $1\frac{1}{4}$-inch pipe with a well point on the bottom should be installed. Pumping tests should be made on finished wells equipped with reliable pumps, using one or more nearby observation wells (table 1). The wells should be tested and observed for at least 72 hours at a constant discharge rate. Some of the tests should be made with an observation well very close to the pumped well for making better estimates of well efficiency. Gamma-ray logs should be run on all wells that are accessible. This is necessary because the lithologic logs of the older irrigation wells are poor.

Additional gaging stations should be installed on the Rio Aconcagua, the tributary streams, and the irrigation canals and ditches to provide data for programing and calibrating the digital model. A list of proposed gaging station sites is given in table 2. The gages should be continuously recording, but, if not, then a staff gage should be read once or twice a day. A water-quality sample should be collected each time the station is inspected and should be analyzed in the laboratory for dissolved solids and other constituents.

The present observation-well monitoring program should be expanded. The expanded network should include the measurement of all newly constructed observation wells, the addition of selected domestic, stock, and new irrigation wells. An intensive mass-measurement of water levels should be made twice a year (spring and fall) and should include all observation wells. The elevation of observation wells should be determined instrumentally. Power-consumption data on all irrigation and industrial wells should be collected during these measurements. Water samples for complete chemical analysis should be collected from representative wells in the valley at least once a year.

A preliminary digital model of a pilot reach and, later, of the entire valley and its tributary areas should be constructed and partly calibrated. The model should be of great value in evaluating the proposed data collection. In addition, the model could be used to make some preliminary estimates of proposed changes in patterns of water development, use, and management.

The second year activities would emphasize digital-model studies but would also continue the data-collection program started in the first year. The construction and calibration of the digital model should be completed. When the model is calibrated it can be used to evaluate water development, use, and management plans. In addition, plans for optimizing water use should be formulated and tested. Systems analysis and stochastic-model studies should also be made. These models would include, of course, social, economic, and legal restraints. During this year, a future program of data collection should be set up. This program is needed to refine the model further and to provide additional data for calibration. Upon completion of the work in the second year, a detailed interpretive report or reports should be prepared.

Data Requirements for Digital Model

A digital simulation model is essential because of the many unknowns and variables whose interplay affect the viability of proposed investments for development of the valley, the large mass of data that must be programed, and the complex hydrologic relations. The model is a tool for integrating and analyzing the hydrologic data.

Ground water, surface water, and climatologic data will be simulated by the model to provide a complete quantitative description of the stream-aquifer system. The model will be calibrated with data from gaging stations, stream gain and loss studies, and ground-water-level changes. Following is a summary of the data needed to build the model, the basic assumptions, and a list of possible uses of the model.

Data Needed to Build the Digital Model

1. Map showing areal distribution of alluvium, rivers, tributaries, and canals.
2. Maps showing shape of water table, bedrock configuration, and saturated thickness of alluvial aquifer.
3. Map showing transmissivity and boundaries of alluvium.
4. Map showing the storage coefficient of alluvial aquifer.
5. Map showing irrigated areas.
6. Map showing ground-water pumpage.
7. Map showing depth to water, indicating evapotranspiration (phreatophyte areas and nonphreatophyte areas).
8. Table of discharge by wells (distribution in time and space).
9. Table of surface-water diversions.
10. Water-level-change maps.
11. Table of stream flow and river gain and loss measurements.
12. Graphs relating saturated thickness to transmissivity.
13. Graphs relating stream and aquifer.

Basic Assumptions for Digital Model

1. Alluvium is not hydraulically connected with the bedrock.
2. Alluvium has finite boundaries except where indicated.
3. Alluvium is hydraulically connected to the river (the hydraulic connection will not be complete when the water table is below the river).
4. Water in alluvium is under water-table conditions.
5. Recharge is from applied irrigation water, precipitation, canal seepage, tributary underflow, and sometimes from the river.
6. Discharge is by ground-water return flow, ground-water pumpage, evapotranspiration, and ground-water underflow into the Pacific.
7. Water can be salvaged from evapotranspiration by lowering water table.
8. Evapotranspiration is small where depth to water is greater than 3 m.
9. Soil moisture is constant from year to year.
10. Change in transmissivity caused by changes in saturated thickness and permeability can be averaged or modeled.
11. Evapotranspiration varies with depth to water, but can be averaged.
12. Tributary stream valleys, Putaendo, Catemu, Llay-Llay, and others should be modeled.

Possible Uses of the Digital Model

The digital model can be used for planning the project and for evaluation of development, use, and management plans. Some of the possible uses of the model are as follows:

1. Assist in identifying deficiencies in hydrologic field data.
2. Quantitative evaluation of stream-aquifer relations in the Rio Aconcagua valley.
3. Evaluation of the efficiency of the surface-water distribution system, including surface storage.
4. Define areas in the valley where additional pumping of ground water would be beneficial, such as salvage of ground water now consumed nonbeneficially.
5. Study of the effect of increased pumpage of ground water on return flow to the river, on evapotranspiration, and on aquifer storage.
6. Aid in the selection of sites where large-capacity wells can be developed for use in satisfying surface-water rights.
7. Evaluation of the most efficient spacing of irrigation wells in different areas.
8. Outline areas where growth of phreatophytic plants can be controlled by lowering the water table by pumping from wells, determine the number and spacing of salvage wells that would be required, and evaluate the effect of these wells on seepage to and from the river.
9. Measure the effects of the importation of additional surface water to the Rio Aconcagua valley.

10. Aid in the formulation of effective management criteria for the control and maintenance of favorable water quality.
11. Identify areas where additional water might be stored underground.
12. Provide a means of predicting water availability in different areas of the Rio Aconcagua valley under varying schemes of surface-water delivery and ground-water pumpage.
13. Optimize plans for utilizing both ground water and surface water based on economic, legal, and social constraints.
14. Use of additional water in the Putaendo and Catemu tributary valleys.
15. Study the effect of lining canals.

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APPENDICES

1. Metric-English conversion equivalents and abbreviations of names of organizations.
2. Available maps and aerial photographs in the Aconcagua Valley.
3. Pumping tests in the Aconcagua Valley.

APPENDIX 1

Metric-English Conversion Equivalents

1 meter (m)	=	3.28 feet
1 kilometer (km)	=	0.621 miles
1 hectare (ha)	=	2.47 acres
1 liter	=	0.26 gallons
1 $meter^3$ per second (m^3 per sec)	=	35.3 cubic feet per second
1 liter per second (l per sec)	=	15.85 gallons per minute
1 $meter^3$ per day per meter (m^3 per day per m)	=	80.5 gallons per day per foot

Abbreviations of Names of Organizations

CORFO	Corporación de Fomento de la Producción
EMCO	Empresa de Servicio de Computación
IIG	Instituto de Investigaciones Geológicas
RIEGO	Ministerio de Obras Públicas y Transportes, Dirección de Riego
SAG	Servicio Agrícola y Ganadero
US AID	United States Agency for International Development

APPENDIX 2

Available Maps and Aerial Photographs in the Aconcagua Valley

Soils Maps	Corporación de Fomento de la Producción
1:250,000	"Cartas preliminares"
1:25,000	Topographic Maps of entire Río Aconcagua Basin
1:70,000	Aerial Photographs of entire Río Aconcagua Basin
1:20,000	Aerial Mosaics
1:20,000	Land-Use Maps
1:20,000	Canal and "Estero" Map

APPENDIX 3

Pumping Tests in the Aconcagua Valley
(Summarized from a memorandum of Dec. 3, 1969 from John E. Moore to John G. Ferris, U. S. Geological Survey)

Pumping tests have been made in recent years on all wells drilled by CORFO for irrigation and industrial use. The transmissivity values shown were obtained from observations made in the pumping well. The tests are usually made in two steps. The first test, made after the well has been developed, consists of pumping at varying discharge rates for several hours. The second test is made by pumping the well for about 24 hours. During the test, measurements of water-level change are made every few minutes during the first part of the test and then on an hourly basis. Most of the tests appear to have been carefully run--that is the discharge was held at a constant rate, yield was measured accurately by orifice, discharged water was removed from the site, the water level was fully recovered before tests were made, and the measurements of water-level change were accurately determined. The following conditions, however, in well construction and testing procedures cause problems in determining aquifer constants:

1. Wells only partly penetrate the aquifer (three-fourths of saturated aquifer or less).
2. Wells are open to only part of the aquifer. Usually open to half or less of the saturated section. Usually they are perforated only opposite those zones that appear from the

drilling to be water yielding. Wells are perforated with torch slots.

3. Wells are not completely developed before the test is made. Some show definite signs of improvement or development during the 24-hour test.
4. Wells are pumped at too low a rate and, therefore, the drawdown is small during many tests. The drawdown is less than 30 cm in some tests.
5. Tests were not made using observation wells.
6. Most wells are drilled by cable tool.
7. Geophysical logs have not been made.

There is a large discrepancy between the value of T (transmissivity) obtained from the time-drawdown plot (straight line part) and the value obtained by using specific capacity. The value from the straight line part of the semilog plot will be 10 times that obtained from specific capacity 6,250 versus 65,000 m^3 per day per m and 3,250 versus 11,900 m^3 per day per m. The difference between the two values is of significance mainly in the first section. Included are several "representative" time-drawdown graphs. The reason for the discrepancy between the values is apparent on the semilog graphs. During the first 6 to 10 minutes of the test there is a rapid water-level decline, and then the curve becomes flat and remains so until the end of the test. A calculation of T based on this flat part of the curve is most risky because a slight change in the way the line is drawn results in quite a change in T. Recovery tests were also made in some wells, and these tests indicate a still higher T value. The value of the recovery measurements is doubtful, because the pump column contains no valve control and the well is "slugged" with water when the pump is shut off.

Discharge was plotted against specific capacity for several tests. A line was drawn through the points until it intersected zero discharge. It was felt that this would, in part, remove the well-efficiency difficulty. In general this correction gave a value somewhat higher than the original specific-capacity determination.

Because of these problems and because of a need for more T control, it has been suggested that observation wells be installed and that some of these tests should be rerun then. The next tests should be made at higher discharge rates, if this is possible.

There are several possible explanations for the discrepancy between specific-capacity data and time-drawdown data. These are listed below in order of importance.

1. Delayed yield from storage may be important. The lenticular nature of the aquifer, coarse well-sorted gravel and boulders separated by poorly sorted material.
2. Large differences between horizontal and vertical permeability, as much as 1,000:1, may result in leaky artesian conditions.
3. Well efficiency is probably low, 40 percent to 60 percent.

If I were forced to select a value where the discrepancy exists, I would probably use the tests having the higher specific-capacity values and would be cautious about using the value obtained from the time-drawdown plot. With my assistance, the CORFO engineers and geologists on the project are now constructing bedrock-contour and saturated-thickness maps of the first section. The data from the pumping tests will be added to the maps, and this may assist us in further analyzing the data.

Summary of Pumping Tests in the Aconcagua Valley
First Section

Well and location	Depth (meters)	Saturated thickness (meters)	Specific capacity (liters per meter)	Transmissivity from specific capacity (meters^3 per day per meter)	Transmissivity from Δs (meters^3 per day per meter)
3250-7040-B1	99	58.5	26	3,250	11,900
3250-7040-B2	90	41.5	50	6,250	65,000
3250-7040-D2	98	44.6	30	3,730	11,000
3240-7030-C6	118	49.5	15	1,850	704
3240-7030-C5	100	33.0	16	2,040	5,150
3240-7030-C7	105	49.5	15	1,850	2,440
3240-7030-C4	94	23.0	3	365	881
3240-7040-D13	90	52.5	8	960	5,550
3240-7040-D14	50	38.3	6	717	3,200
3240-7030-A1	76	37.9	2	212	-----
3240-7030-D2	102	70.0	17	2,060	-----
3240-7040-B3	40	9.2	5	675	-----
3240-7040-D5	64	53.8	28	3,450	-----
3240-7040-D6	58	46.5	22	2,800	-----
3240-7040-D7	60	48.7	31	3,870	-----
3240-7040-D8	86	45.0	9	1,140	-----

Summary of Pumping Tests in the Aconcagua Valley
First Section--Continued

Well and location	Depth (meters)	Saturated thickness (meters)	Specific capacity (liters per meter)	Transmissivity from specific capacity (meters^3 per day per meter)	Transmissivity from Δs (meters^3 per day per meter)
3240-7040-D9	100	50.0	20	2,500	-----
3240-7040-D10	90	39.0	5	650	-----
3240-7040-D11	80	33.2	6	760	-----
3240-7040-D12	47	27.0	4	512	-----
3250-7030-A1	128	51.5	4	500	-----

Summary of Pumping Tests in the Aconcagua Valley
Second Section

Well and location	Depth (meters)	Saturated thickness (meters)	Specific capacity (liters per meter)	Transmissivity from specific capacity (meters^3 per day per meter)	Transmissivity from Δs (meters^3 per day per meter)
3240-7040-B4	139	85.6	8	1,060	2,040
3240-7040-A3	182	33.0	27	3,420	10,850
3240-7040-A4	125	79.0	27	3,340	10,750
3240-7050-A1	37	29.0	54	6,820	7,540
3240-7040-A2	65	22.6	6	760	-----
3240-7040-C1	20	17.2	5	640	-----
3240-7040-C2	45	41.2	13	1,640	-----
3240-7050-D1	20	18.7	3	425	-----
3240-7050-A1	46	46.0	2	188	-----

Summary of Pumping Tests in the Aconcagua Valley
Third Section

Well and location	Depth (meters)	Saturated thickness (meters)	Specific capacity (liters per meter)	Transmissivity from specific capacity (meters^3 per day per meter)	Transmissivity from Δs (meters^3 per day per meter)
3250-7100-A4	92	88	18	2,310	4,410
3250-7100-A1	88	86	1	138	250
3240-7100-C3	92	86	1	126	135
3240-7100-C4	50	49	3	360	396
3240-7100-C6	51	48	3	365	460
3240-7100-C8	44	42	1	128	317
3240-7100-C7	50	45	1	177	529
3240-7100-C5	45	44	2	227	121
3240-7110-D7	20	19	13	1,610	2,640
3240-7110-D18	52	51	2	210	204
3240-7110-D26	45	34	6	390	450
3240-7110-D21	45	35	2	315	703
3240-7110-D14	40	29	10	1,260	1,400
3240-7110-D6	51	50	2	240	253
3240-7110-D20	40	33	7	895	1,050

Summary of Pumping Tests in the Aconcagua Valley
Third Section--Continued

Well and location	Depth (meters)	Saturated thickness (meters)	Specific capacity (liters per meter)	Transmissivity from specific capacity (meters^3 per day per meter)	Transmissivity from Δs (meters^3 per day per meter)
3240-7110-D22	43	34	4	491	381
3240-7110-D24	49	39	3	325	462
3240-7110-D25	45	39	2	214	244
3250-7110-B25	41	36	1	176	76
3250-7110-B11	42	39	1	113	51
3250-7110-B24	44	39	3	404	1,490
3250-7110-B21	43	42	2	215	113
3250-7110-A16	43	41	1	164	29
3250-7110-C8	60	58	2	240	132
3250-7110-C11	40	39	1	76	27
3250-7110-C12	34	30	5	600	273
3240-7110-B9	30	26	3	362	-----
3240-7110-B10	28	23	6	762	-----
3240-7110-B16	38	36	3	325	-----
3240-7110-D4	45	40	3	325	-----

Summary of Pumping Tests in the Aconcagua Valley
Third Section--Continued

Well and location	Depth (meters)	Saturated thickness (meters)	Specific capacity (liters per meter)	Transmissivity from specific capacity (meters^3 per day per meter)	Transmissivity from Δs (meters^3 per day per meter)
3240-7110-D13	50	45	16	2,040	-----
3240-7110-D19	40	26	6	700	-----
3240-7110-D23	40	29	6	725	-----
3250-7100-A2	51	49	4	462	-----
3250-7100-A7	36	35	1	137	-----
3250-7100-A11	30	29	6	725	-----
3250-7100-B4	35	33	2	250	-----
3250-7100-B9	56	55	2	250	-----
3250-7100-B13	40	38	3	325	-----
3250-7100-B23	54	52	1	175	-----
3250-7100-D2	26	16	3	388	-----
3250-7100-D4	35	34	1	150	-----

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