3.2.5 Accuracy of Data

1) Methods for Checking the Accuracy of Data

As described in another section, the data for the Water Supply Database was collected and input by each CORDE in accordance with the Data Input Format prepared by the Study Team. This Data Input Format is mainly comprised of the following two parts:

(1) Basic Data - 5 pages, 109 items

a) Socioeconomic data

b) Water supply status data

c) Well inventory

(2) Supplemental Data - 6 pages, 205 items

a) Data on the water supply system Level II (74 items)

b) Data on the water supply system Level III (131 items)

These collected and input data were checked by using the following two methods:

Check Method 1 : collate the input data with the data obtained by the Study Team or the CORDES through the field surveys.

Check Method 2 : making the relative comparison between these data themselves.

2) Check Method 1

In this check, there are 3 kinds of data obtained by the Study Team as described below.

a) Data obtained from the field confirmation studies.

Among the data obtained from these studies, the following 11 items were collated:

- Type of water source
- Implement agency
- Service level of water supply system
- Organization in charge of operate and manage the water supply system
- Water intake method and equipment
- Water usage
- Water quality and treatment
- Seasonal water supplying ability
- Average daily water supply quantity
- Served population
- Number of served households

b) Data obtained from the community questionary survey.

The following table shows the items derived from the questionaires of this questionary survey, and the method of collation that had been used for the data checking.

Items of the Community Questionnaires	How Used in Data Collation
I · Type of water source	· As type of water source
· Level of water supply system	· For determination of Level I, II or III
· Population data	· As socioeconomic data
II · Number of public facilities.....................	· As reference for amount of water consumption
· Water supply system	· For determination of Level I, II or III
· Installation status of faucets and meters	· For determination of Level I, II or III
III · Water supply quantity............................	· As reference for amount of water consumption
· Water quality	· As reference for quality of drinking water

c) Data collected from the supplemental hearing surveys.

These data were collected through the hearings with the representatives of the Water Cooperative of the water supply blocks where it exists a water supply system of service level II or level III.

Table 3-2-2 shows the number of water supply blocks which were checked by the Check Method 1.

Table 3-2-2 Number of Water Supply Blocks Checked by Method 1

Department	Number of Checked Blocks			
	By collating with data obtained from field confirmation studies	By collating with data obtained from community questionary survey	By collating with data obtained from supplemental hearing surveys	Total
Chuquisaca	16	5	11	32
S. La Paz	17	4	7	28
Oruro	13	9	12	34
Tarija	11	11	10	32
Santa Cruz	18	19 + 101 *	10	148
Total	75	48 + 101 *	50	274

*Note: * 101 water supply blocks were studied by the CORDECRUZ. The rest of the water supply blocks were studied by the Study Team.*

3) Check Method 2

In this case, the following steps were carried out.

a. Checking of the data input work

· The data that was handwritten into the data input format were collated with the raw data collected by each CORDES.

· The data input in the computer were collated with the data that was handwritten into the data input format.

· The population growth rate and the equation used by the CORDES to estimate the future population were checked with those authorized and used by the public functions concerned.

b. Efforts were made to find suspicious data by comparing data. If data was found to be suspicious, the reason therefor was examined and the CORDES was requested to carry out the study again if necessary.

4) Results of the Data Checking

Table 3-2-3~5 shows the results of data checking by Method 1.

According to these results, by collating the input data with the data obtained from the field confirmation studies, the average accuracy of the five Departments for 11 items is 85.33% (Table 3-2-3).

Besides, by collating the input data with the data from the questionary survey, the average accuracy of the five Departments for 6 items is 84.46% (Table 3-2-4). This result was obtained by using data of 48 blocks those were sent from the communities through the questionary survey. The results for the remaining 101 data carried by CORDECRUZ are as follows.

- There are zero errors in the code numbers of water supply blocks, in other words, the accuracy is 100%.

- There are zero errors in the names of water supply blocks, in other words, the accuracy is 100%.

- 4% of the data regarding population are in error, in other words, the accuracy is 96%.

And, the results by collating the input data with the data obtained from the supplemental hearing surveys are shown by Table 3-2-5, as an example.

The results show that, in case of Santa Cruz, the accuracy of 18 data items relating to water supply condition and household sanitation is 87.8%. The same trend is seen in cases of other Departments.

It can be said that these data have appropriate accuracy as input data for the Database.

Table 3-2-3 Result of Data Check by Collating with Data Obtained from Field Confirmation Studies

	Accuracy of input data (%) of each Department					
Items	Chuqui-saca	S. La Paz	Oruro	Tarija	Santa Cruz	Average
1.Water source type	64.29	83.33	66.67	77.78	100.00	79.63
2.Implement institution of WSS	100.00	91.67	100.00	71.43	100.00	90.63
3.Service level of WSS	100.00	50.00	-	66.67	100.00	90.91
4.Organization in charge of oparate and manage the WSS	90.00	100.00	100.00	80.00	0.00	85.00
5.Water intake method, equipment	100.00	87.50	13.67	62.50	80.00	70.27
6.Water usage	100.00	-	100.00	-	100.00	100.00
7.Water quality and treatment	100.00	90.00	33.3	0.00	-	78.57
8.Seasonal production status	100.00	-	-	-	-	100.00
9.Average productivity	100.00	-	66.67	100.00	80.00	88.24
10.Served population	100.00	66.87	100.00	85.71	100.00	91.48
11.Served family	100.00	33.33	100.00	85.71	100.00	85.71
Average	94.17	81.82	60.00	74.07	92.98	85.33

Table 3-2-4 Result of Data Check by Collating with Data Obtained from Questionary Surveys

	Accuracy of input data (%) of each Department					
Items	Chuqui-saca	S. La Paz	Oruro	Tarija	Santa Cruz	Average
Water source type	83.3	100.00	77.78	85.71	50.00	78.57
Service level of WSS	100.00	100.00	100.00	100.00	62.50	93.02
Served population	100.00	100.00	68.67	100.00	87.50	90.70
Average daily supply quantity	-	100.00	-	-	-	100.00
Water quality and treatment	100.00	0.00	37.50	66.67	83.33	62.07
Number of public facilities	85.71	80.00	100.00	92.86	100.00	91.43
Average	92.86	90.91	75.61	89.71	73.53	84.46

Table 3-2-5 Result of Data Checking by Collating with Data Obtained from Supplemental Hearing Surveys (in case of Santa Cruz as an example)

	Item for collation	Difference between (1)input data and (2)data obtained from supplemental hearing surveys																			
		Block 1		Block 2		Block 3		Block 4		Block 5		Block 6		Block 7		Block 8		Block 9		Block 10	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
	No. of water sources	1	1	1	1	1	1	3	1	1	2	1	1	2	1	1	1	2	1	1	1
	Type of water source	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C
	Implemented agency	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	Level of service	C	C	C	C	C	C	C	B	B	C	C	C	C	C	C	C	B	B	A	C
	Owner of the system	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	0	B
	Extraction method	A	A	A	A	A	A	A	C	C	A	A	A	A	A	A	C	A	A	C	A
	Water usage	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	Water quality	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	Seasonal production	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	0	A
	Served population	E	E	B	E	E	E	E	E	E	E	E	E	E	E	E	E	C	D	0	D
	Served family	E	E	C	D	E	E	E	E	E	E	E	E	E	E	E	E	C	D	0	D
In urban area	Number of flush toilet with sewer	5	y	-	-	-	-	18	y	1	y	6	n	6	n	4	y	-	-	-	-
	Number of flush toilet with septic tank	253	y	-	-	-	-	531	y	48	y	701	y	592	y	132	y	-	-	-	-
	Others flush toilet	0	y	-	-	-	-	0	y	0	y	0	y	0	y	0	y	-	-	-	-
	Number of toilet without sewer	8	y	-	-	-	-	10	y	14	y	22	y	3	y	1	y	-	-	-	-
	Number of toilet without septic tank	35	y	-	-	-	-	84	y	6	y	134	y	45	y	12	y	-	-	-	-
	Other toilet	455	y	-	-	-	-	717	y	421	y	711	y	698	y	198	y	-	-	-	-
	No sanitary toilet	349	y	-	-	-	-	381	y	192	y	587	y	507	y	202	y	-	-	-	-
In rural area	Number of flush toilet with sewer	-	-	0	y	0	y	-	-	-	-	-	-	-	-	-	-	0	y	0	y
	Number of flush toilet with septic tank	-	-	8	y	2	y	-	-	-	-	-	-	-	-	-	-	0	y	12	y
	Other flush toilet	-	-	0	y	0	y	-	-	-	-	-	-	-	-	-	-	0	y	0	y
	Number of toilet without sewer	-	-	0	y	1	y	-	-	-	-	-	-	-	-	-	-	0	y	0	y
	Number of toilet without septic tank	-	-	1	y	2	y	-	-	-	-	-	-	-	-	-	-	1	y	0	y
	Other toilet	-	-	12	y	120	y	-	-	-	-	-	-	-	-	-	-	15	y	18	y
	No sanitary toilet	-	-	9	y	8	y	-	-	-	-	-	-	-	-	-	-	68	y	2	y
	Result of collation	18/18		16/18		18/18		15/18		15/18		17/18		16/18		17/18		15/18		11/18	
		Total of affirmable data= 158/180 = 87.8%																			

Note: *Block 1: LaGuardia (701030103),* *Block 2: Quebrada Seca (701030128)*
Block 3: Taruma (701030144), *Block 4: Cotoca (701010201)*
Block 5: Pailon (705020301), *Block 6: Warnes (702010101)*
Block 7: Portachuelo (706010101), *Block 8: Saavedra (710020101)*
Block 9: Azusqui (702010202), *Block 10: Naranjal don Bosco (702010206)*
y : input data is affirmable *n : input data is not affirmable*
☐ *input data is not the same with collated data*

3.2.6 Processing the Graphic Data

Table 3-2-6 shows all of the kinds of graphic data that are required for the Water Supply Database.

Table 3-2-6 Number of Necessary Graphic Data

	Chuqui-saca	La Paz	Oruro	Tarija	Santa Cruz	Total
1. Canton District Map	116	139	152	181	138	726
2. Province Administrative Map	10	4	16	6	15	50
3. Department Administrative Map	1	1	1	1	1	1
4. Well Geographic Column Map	50	0	21	16	88	175
5. Road Network Map	All 9 Departments (s = 1/2,000,000)					18
6. Hydrological Map	All 5 Departments (s = 1/1,000,000)					32
7. Geological Map	All 5 Departments (s = 1/1,000,000)					32
8. Topographic Map	All 5 Departments (s = 1/1,000,000)					32
9. Land Use Map	All 5 Departments (s = 1/1,000,000)					32
10. Administrative Map	All 5 Departments (s = 1/1,000,000)					32
11. Hydrogeological Map	All 5 Departments (s = 1/2,000,000)					18
12. Natural Environmental Map	Wild Fauna Map, All 9 Departments (s= 1,500,000)					24

Among these maps (graphic data), (1) the canton district maps, (2) the province administrative maps and (3) the department administrative maps also include several information program codes required for program execution. Other maps are standing just as the image data that can be processed, displayed on the screen of the monitor or printed out.

The CORDES share the work of processing these graphic data by preparing the canton district maps related to their own department through the four steps described below:

Step 1) Tracing the canton district maps which include several important information such as canton border lines, major rivers, major road network, locations of villages (communities, localities, etc), locations of major wells, etc.

Step 2) Scanning these traced canton district maps and storing them in the computer on the image data file format with the defined files names.

Step 3) Using the image-processing program software to put on these image data several important information such as names of the villages, names of the cantons (or provinces, or departments, etc.) , names of the rivers, etc.

Step 4) Attaching the codes on these image data as defined previously to combine these maps with the database program.

The Study Team has the responsibility to process other graphic data.

3.2.7 Development of the Water Supply Database Program

A powerful database application software named "Paradox for Windows" is used to handle the Water Supply Database. A program has been developed based on this Paradox for Windows program language that can cover not only the 5 departments in the Study Area, but also the other departments of Bolivia as well. This program was named the "**BADAA Program**" from the Spanish name, "Base de Datos para el Aprovisionamiento de Agua" (Water Development Database).

As shown in Figure 3-2-5, the functions of this program are:

(1) to facilitate data input,

(2) to combine numerous tables of data that form the database and

(3) to facilitate the utilization and the management of the database.

This program was developed based on the following policies:

(1) allow anyone, whether expert or not, to access the database easily and quickly.

(2) allow easy data input, data renewal, data retrieval,... at any time, by anyone, by interactive mode.

(3) allow easy extension and utilization to the rest of the departments of Bolivia.

(4) prevent the program from becoming stuck regardless of any mistakes are made by the user.

(5) prevent as much as possible any incorrect data input which may caused by mistyping

(6) contains comprehensive structure and is easy to modify whenever needed.

Figure 3-2-7 shows the flow chart of this program in general, and Figure 3-2-8 shows it in more detail.

Using this program, one can access the database easily by simply clicking the mouse at a command (or a number, or a name) on the screen of the monitor, and follow the instruction displayed on the screen to input commands or click the mouse to go to any part of the database, or to print out the needed information.

The methods of installation, execution, modification, and use of this BADAA Program are described in detail in the User's Manual, which has been prepared and provided to the CORDES.

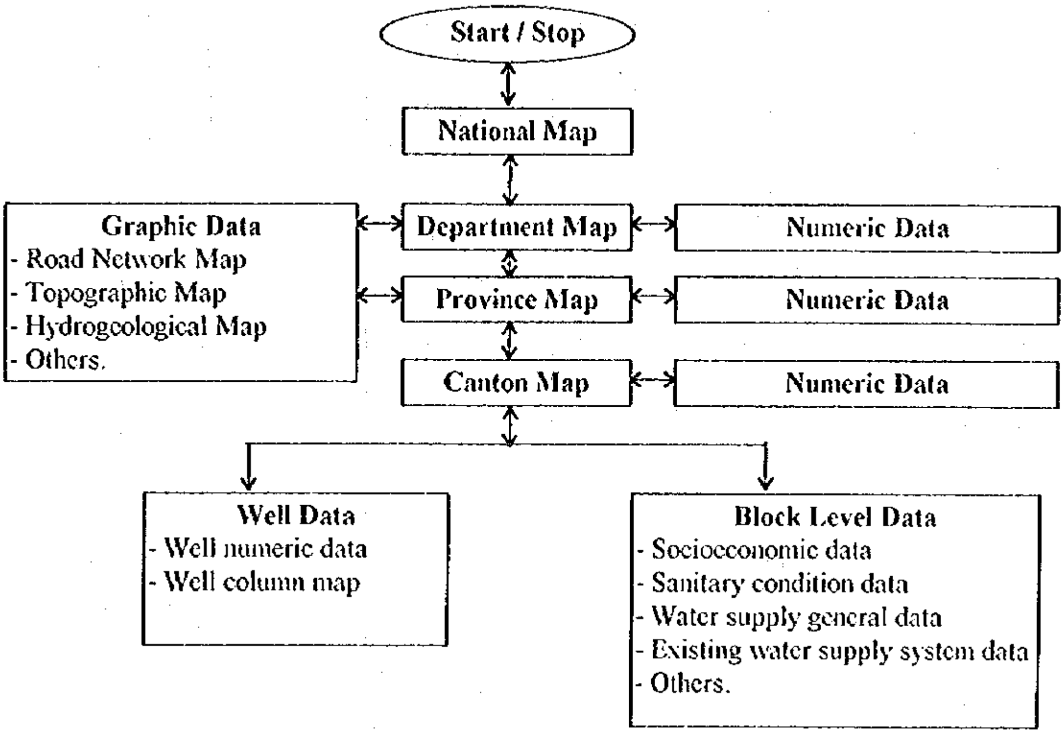


Figure 3-2-7 The Principal Flow-Chart of the Water Supply Database Program

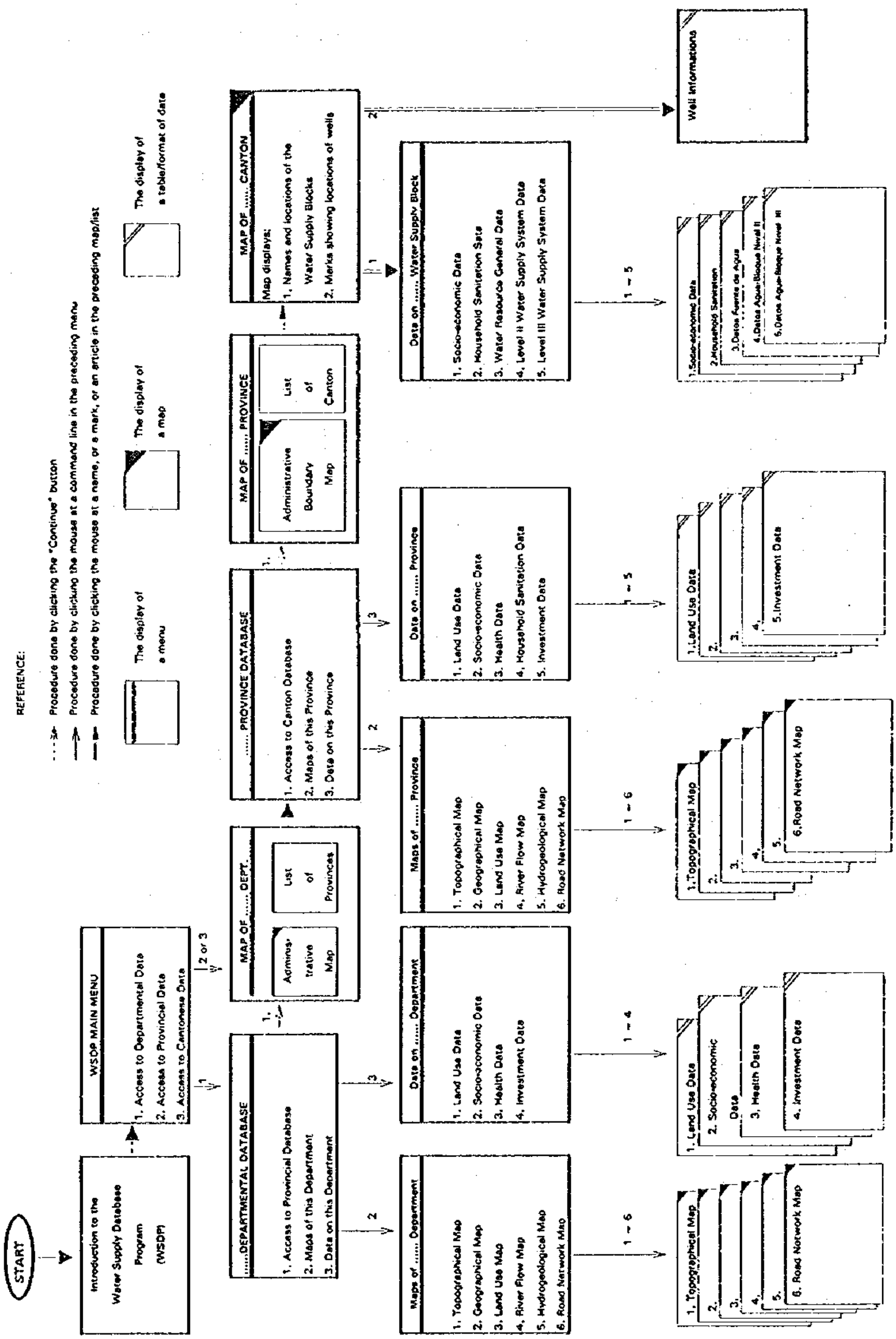


Figure 3-2-8 The Flow-Chart of the Water Supply Database Program

3.3 Using and Maintaining the Water Supply Database

3.3.1 Some Usages of the Database

Beside the categorization of the water supply block, which is described in detail in another section, the Water Supply Database can be analyzed and used in many ways to verify the characteristics of each department. Below are some presentations of the usage of this Water Supply Database.

a) Population Distribution

Table 3-3-1 and Figure 3-3-1 show the population distribution patterns of the five departments.

In general, a majority of the 4,265 blocks is of Group 7, ie. with a population of between 100 and 199 persons. Chuquisaca, Oruro, Tarija have the same population distribution pattern, with numerous blocks of Group 7. The Southern Part of La Paz has a different pattern, where a great part of the blocks (346 blocks) is of Group 8 (population of between 50 and 99 persons). Santa Cruz, in contrast to La Paz, has 402 blocks (33% of total blocks) of Group 6 (population of between 200 and 299 persons). Generally speaking, Southern Part of La Paz, and Oruro have a dispersed population distribution while Santa Cruz has a concentrated one.

Table 3-3-1 Number of Blocks by Population Groups

Group	Population Rank	Chuquisaca	S. La Paz	Oruro	Tarija	Santa Cruz
Group 1	>=2000 pers.	4	2	8	5	41
Group 2	1999~1000pers.	11	7	10	7	34
Group 3	999~500pers.	54	15	15	28	90
Group 4	499~400pers.	59	18	17	28	87
Group 5	399~300pers.	131	25	33	65	180
Group 6	299~200pers.	286	82	69	154	402
Group 7	199~100pers.	458	267	198	188	391
Group 8	99~50pers.	220	346	194	36	0
Total		1,223	762	544	511	1,225
Grand Total		4,265				

Source: Water Supply Database, 1994 Population

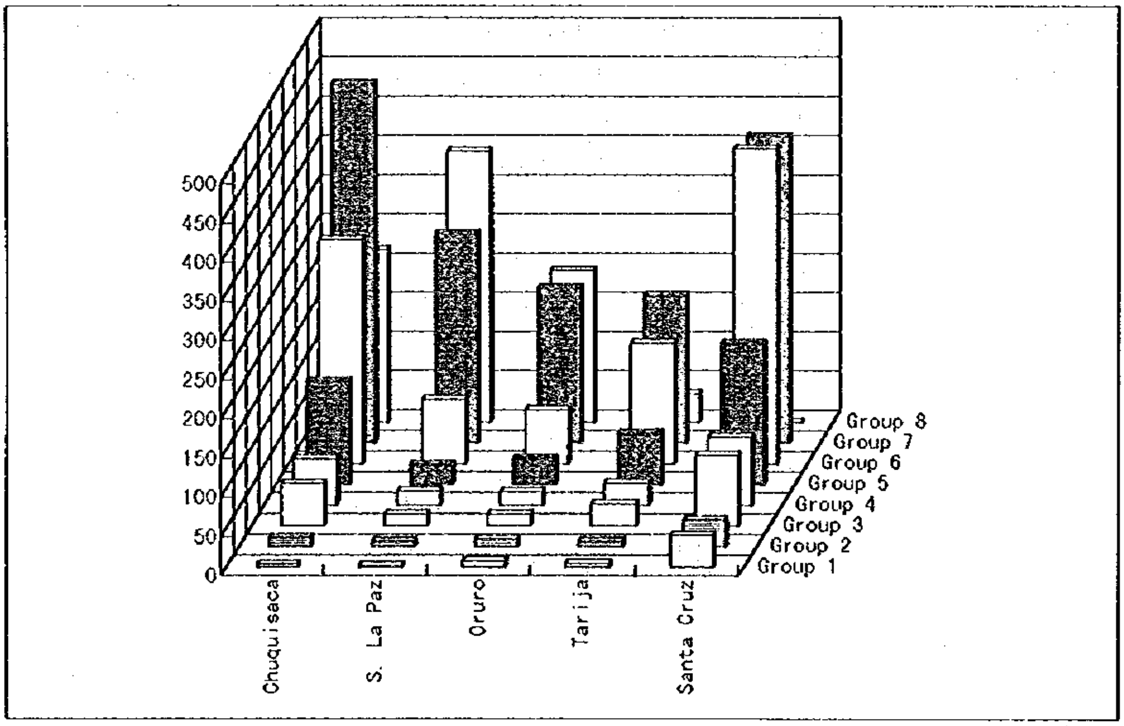


Figure 3-3-1 Number of Blocks by Population Groups

b) Type of Water Source

Table 3-3-2 and Figure 3-3-2 show the types of water sources that are in use at the communities of the five departments in the Study Area.

It is clear that, in the case of Chuquisaca, the majority of the water sources are springs while, in Southern Part of La Paz, almost all of the water sources are dug wells. Tarija and Santa Cruz are special departments in that they have various types of water sources. The people of Oruro depend strongly on surface water intake as the daily water supply source.

Table 3-3-2 Type of Water Source

Type of Water Source \ Dept.	Chuquisaca	S. La Paz	Oruro	Tarija	Santa Cruz
a) Dug Well	4	724	17	34	141
b) Drilled Shallow Well	2	10	1	22	318
c) Drilled Deep Well	9	1	22	98	610
d) Infiltrate Gallery / Well	3	0	1	0	0
e) Spring	1,016	10	0	102	20
f) Surface Water Abstraction	169	6	0	172	49
g) Surface Water Intake	1	45	251	60	172
h) Rain Collector	33	0	0	8	248
x) Others	0	180	462	137	0
Total	1,237	976	754	633	1,558

Source : Water Supply Database

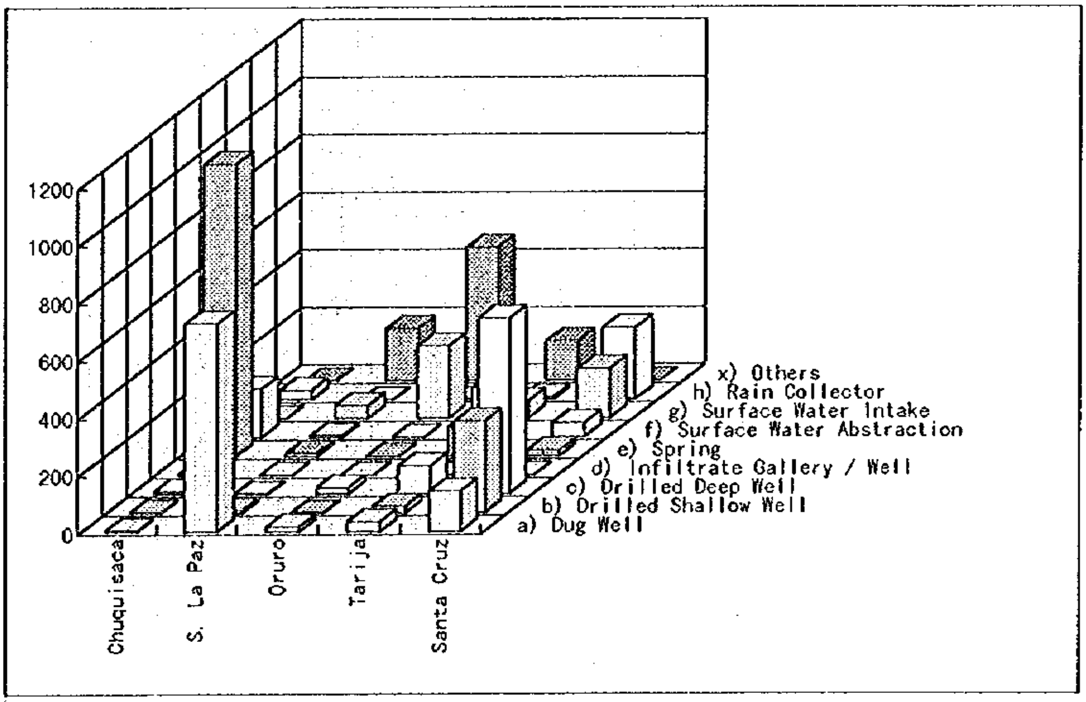


Figure 3-3-2 Type of Water Source

c) Water Quality

Table 3-3-3 and Figure 3-3-3 show the number of blocks classified according to water quality. A major part of the blocks (1,889 blocks) is classified as having significant problems in water quality. Another part (1,447 blocks) is classified as a group for which the water water quality is unknown.

In Chuquisaca, 969 blocks (78% of the total of 1,235 blocks) are classifed as a group for which the water quality is unknown. Besides these blocks, a majority of the blocks in La Paz (713 blocks, 73% of the total of 976 blocks) is classifed as a group whose water quality is turbid, coloured and having a foul smell. Oruro is special in that 346 blocks (53% of the total of 647 blocks) have water sources with high chloride content.

Table 3-3-3 Water Quality

Type of Water Source \ Dept.	Chuquisaca	S. La Paz	Oruro	Tarija	Santa Cruz	Total
a) Insignificant problem	266	1	286	157	1,129	1,839
b) High iron / manganese cont.	0	0	0	6	0	6
c) High chloride content	0	5	243	73	0	321
d) Turbid / coloured / smell	0	713	15	29	96	853
e) Polluted / contaminated	0	0	0	5	0	5
f) Chlorinated	0	5	0	13	0	18
g) Treated	0	0	0	18	0	18
h) Others / Unknown	957	38	0	210	0	1205
Total	1,223	762	544	511	1,225	4,265

Source: Water Supply Database

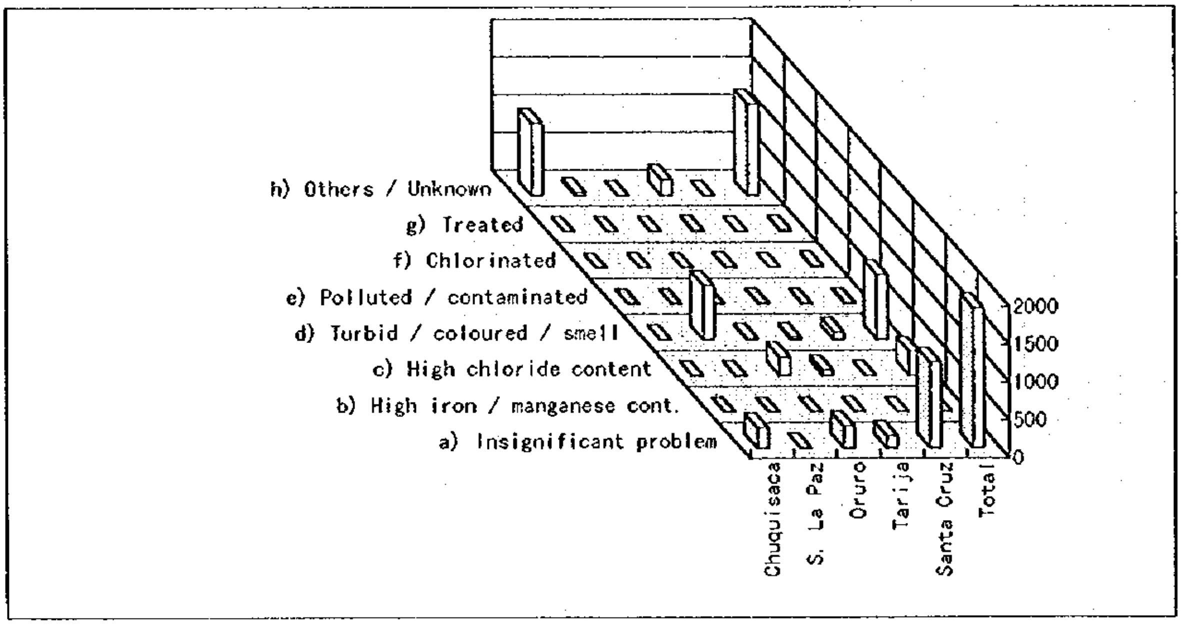


Figure 3-3-3 Water Quality

3.3.2 Operation and Maintenance of the Database

As with other common databases, the Water Supply Database needs to be updated at all times.

There are two major items relating to the Water Supply Database that need to be examined and renewed everyday.

1) the numeric data and graphic data that had been input and stored in the database.

2) the DABAA Program that handles the database.

As was pointed out many times in the previous meetings and workshops, the CORDES must be responsible for updating the data files of their own departments and DINASBA must be responsible for the management, maintenance and retrieval of the entire system, including the BADAA Program.

Given these responsibilities, the persons in charge at the CORDES and at DINASBA have to build up a communication system for efficient and easy exchange of informations.

A communication system using telephone line and modems is desirable and their establishment is now being examined at DINASBA. The telephone network in Bolivia is on the way to being improved and such a communication system can probably be realized in the near future. But, at the present time, the best way to exchange the data and information needed to update the Water Supply Database between the CORDES and DINASBA, is probably the use of floppy disks.

At the workshops that were held at the CORDES, some agreements had been made between the person in charge at DINASBA and the ones at CORDES. The first thing that had been agreed upon was the common understanding of the importance of the operation and maintenance of the database. The second was the agreement on the sharing of responsibilities between DINASBA and the CORDES. Based on these agreements, the persons in charge at CORDES shall send to DINASBA, the floppy disk(s) with the newest data input at the CORDES stored therein, at fixed periods. And on other side, the person in charge at DINASBA shall improve the entire system and provide the CORDES with the newest information on system utilization, development, management, etc.

The person in charge at DINASBA serves the important role of operating and maintaining the database. As a technical transfer process to improve the ability of the person in charge at DINASBA, several training workshops were held to instruct the person in charge at DINASBA about the basic technique required for daily work such as:

- The structure of BADAA Program
- Method to building up the system for operation and maintenance of the database
- Basic knowledge of Paradox for Windows
- Content and execution of BADAA Program
- Data input and modifying, etc.
- Attach program codes to the graphic data
- Print-out of data files

- Basic knowledge of Object Pal program language
- Database programming method
- Method of extending use to the other departments

3.3.3 Extending the Use of the Database to Other Departments of Bolivia

Table 3-3-4 shows the outline of the socioeconomic circumstances of the four departments of Bolivia which were not included in this Study Area.

Table 3-3-4 Outline Frame of the Four Departments Outside the Study Area

	Cochabamba	Potosí	Beni	Pando
Area (km^2)	55,631	118,218	213,564	63,827
Population (person)	1,110,205	645,889	276,174	38,072
Number of Village Note 1)	1,327	1,648	624	445
Number of Province	16	16	8	5
Number of Canton	93	256	30	18
Capital of Department	Cochabamba	Potosí	Trinidad	Cobija

Souce of data: 1992 INE Census Data

Note 1) Data includes all villages with populations of less than 50 persons (INE Census Data, Atlas Censal 1982)

Among these departments, the one which has biggest number of villages is the Department of Potosí (1,648 villages). But, it is thought that the number of population-concentrated villages in Potosí does not exceed 1,000, due to the fact that the population of this department is only 645,889, or nearly half of the population of Department of Santa Cruz (1,364,389 persons).

From the comparison of the population scales and the socioeconomic factors of the above four departments with those of the Department of Santa Cruz, we can be conclude that it is possible to extend and utilize our Water Supply Database program and framework to the se t four departments of Bolivia, which are not included in this Study Area.

3.4 Recommendations Concerning the Water Supply Database

Up to this present time, the persons in charge at the CORDES had spent much time and effort to define the blocks and to collect data on the blocks. Thanks to these efforts, all numeric data had been collected and input into the database. These data had been checked and used to formulate the Groundwater Development Strategies.

In the future, more efforts are requested to make more field surveys to collect more accuracy data for the database.

The field surveys, the filling-in of blanked fields of data, the checking and the modifying of incorrect data in the database are strongly requested to upgrade the degree of usefulness of the database.

Finally, the lack of an efficient information exchange system between DINASBA Office and the CORDES, is still a worrisome problem. More efforts have to be made to improve and utilize the database, but, first of all, there must be an appropriate recognition of the necessity of the database. This correct recognition will lead to appropriate interest and investments in the operation and maintenance of the Water Supply Database.

The lack of technical expertise at the INE Regional Office presently is causing an undesirable delay of data processing there. We strongly demand that the counterparts at DINASBA and CORDES try their best to prevent the same things from happening to the operation and maintenance of our Water Supply Database.

CHAPTER 4

HYDROGEOLOGICAL INVESTIGATION

CHAPTER 4 HYDROGEOLOGICAL INVESTIGATION

4.1 Natural Conditions

4.1.1 Physiography

The Republic of Bolivia can be divided into the following seven physiographical zones (Figures 4-1-1 and 4-1-2).

1	La Cordillera Occidental	(Complejo Volcanico)
2	El Altiplano Andino	(Altiplano)
3	La Cordillera Oriental	(Cadena Montanosa)
4	Las Seranias Sub-Andinas	(Zona Sub-Andina)
5	La Llanura Chaco-Beniana	(Llanura Chaco-Beniana)
6	Las Seranias Chiquitanas	(Sierras Chiquitanas)
7	El Escudo Central	(Escudo Cristalino)

The division into these zones reflects the geological and structural characteristics.

1) Cordillera Occidental (Complejo Volcanico)

This zone occupies the western part of Bolivia and extends in the N-S direction along the border with Peru. This zone comprises the western wall of the Altiplano with altitudes reaching 6,000 m. Volcanic lava and ignimbrite of the Tertiary system are dotted along a line running in the same direction as this zone. Volcanic rocks of the Quaternary Period are also distributed in this zone.

2) Altiplano Andino (Altiplano)

This zone comprises a belt with a width of approximately 100 km between the mountain ranges of "Cordillera Occidental" and "Cordillera Oriental" and extends in the N-S direction from Peru, through the Department of La Paz, and to Argentina. The mean altitude of "Altiplano Andino" is 4,000 m in northern Bolivia and 3,600 m in southern Bolivia.

"Altiplano Andino" is closed off from other water basins and has Lake Titicaca at the northern part, Lake Poopo and the Coipasa Salt Pan at the central part, and Uyuni Salt Pan at the southern part. Lake Titicaca, is located at an altitude of 4,000 m and its waters flow via the Desaguadero River to Lake Poopo at an altitude of 3,600 m and evaporate there.

3) Cordillera Oriental (Cadena Montañosa)

This zone, which occupies a great part of the Republic of Bolivia, extends from the southern part of Peru to the northern part of Argentina through the northeastern and southern parts of Bolivia and comprises the eastern wall of the Altiplano. This zone has been subjected to strong tectonic folding and uplift activities. The mountain ridges reach altitudes of 6,000 - 7,000 m and are covered with perpetual snow.

On the severely eroded mountainsides are formed rivers that flow parallel to the tectonic axis as well as numerous rivers that flow at right angles to the tectonic axis.

4) Seranias Sub-Andinas (Zona Sub-Andina)

This zone has been subjected to strong folding activity and has narrow anticline belts and wide syncline belts. The erosion on the mountainside is an important factor in this zone, though the degree of the uplift is not as great as that of "Cordillera Oriental." The drainage system of this zone exhibits a lattice pattern and the rivers stream parallel to the folding axis and cross the directions of folding axes at the nodes of the lattice structure.

5) Llanura Chaco-Beniana

This zone extends between "Seranias Sub-Andinas" and "Escudo Central" in northwestern Bolivia and between "Seranias Sub-Andinas" and "Seranias Chiquitanas" in southeastern Bolivia. This zone is characterized by the lack of relief. It is partitioned into a few parts by great meandering rivers with low gradient and high flux.

The plain of Beniana is notable for the lakes (e.g. Rogagua, Rogaguado) which dot the area in a line. This is due to the structure of "Escudo Central," in which the basement rock underlying the Quaternary bed inclines very gently from the eastern side of this zone to the sedimentary basin of Beniana.

In the plain of Chaquena, great rivers flow beneath sands or dunes at locations where the rivers cross the direction of the folding axes at the nodes of the above-mentioned lattice structure.

This nearly flat plain is filled with unsolidified Quaternary deposits, dividing into four zones as follows.

(1) Low Hill Zone (Pando)

This landform, located in the western part of the Department of Pando, is characterized by low hills eroded by small rivers.

(2) Plain of Beni

This is a vast plain that stretches along the Amazon river basin in the Department of Beni and the northern part of the Department of Santa Cruz. It is characterized by an extremely gradual incline and a significant part of this plain becomes submerged and turns into a marsh in the rainy season.

(3) Pedimental Plain Zone

A low hilly pediment in the northern area at the part of transition from the Plain of Santa Cruz and Plain of Beni to the foothills of the Andes. This zone has high rainfall and is rich in forest resources.

(4) Plain of Chaco

The plain of Chaco is a vast plain which extends from the southern part of the Department of Santa Cruz, through the eastern lowlands of the Departments of Chuquisaca and Tarija, and to Paraguay. The precipitation is low and the vegetation is sparse.

6) Seranias Chiquitanas (Sierras Chiquitanas)

This zone is situated in the eastern side of the Department of Santa Cruz, that is, in the southern region of "Escudo Central." "Seranias Chiquitanas" is comprised of Paleozoic and Mesozoic rocks that are exposed at the surface in the E-W direction.

7) Escudo Central (Escudo Cristalino)

This zone occupies an extensive area in the easternmost part of Bolivia. "Escudo Central" is a nearly level plain that undulates gently and has a discharge pattern which flows into Itenes-Guapore river. The drainage pattern indicates that the lithological condition is homogeneous.

Bolivian lands are often classified into the three general zones of ① Altiplano zone, ② hill zone, and ③ valley zone based on geographical and socioeconomic conditions. The "Cordillera Oriental" and "Seranias Sub-Andinas" zones are collectively included in the valey zone while the "Seranias Chiquitanas" and "Escudo Central" zone are included in the plain zone.

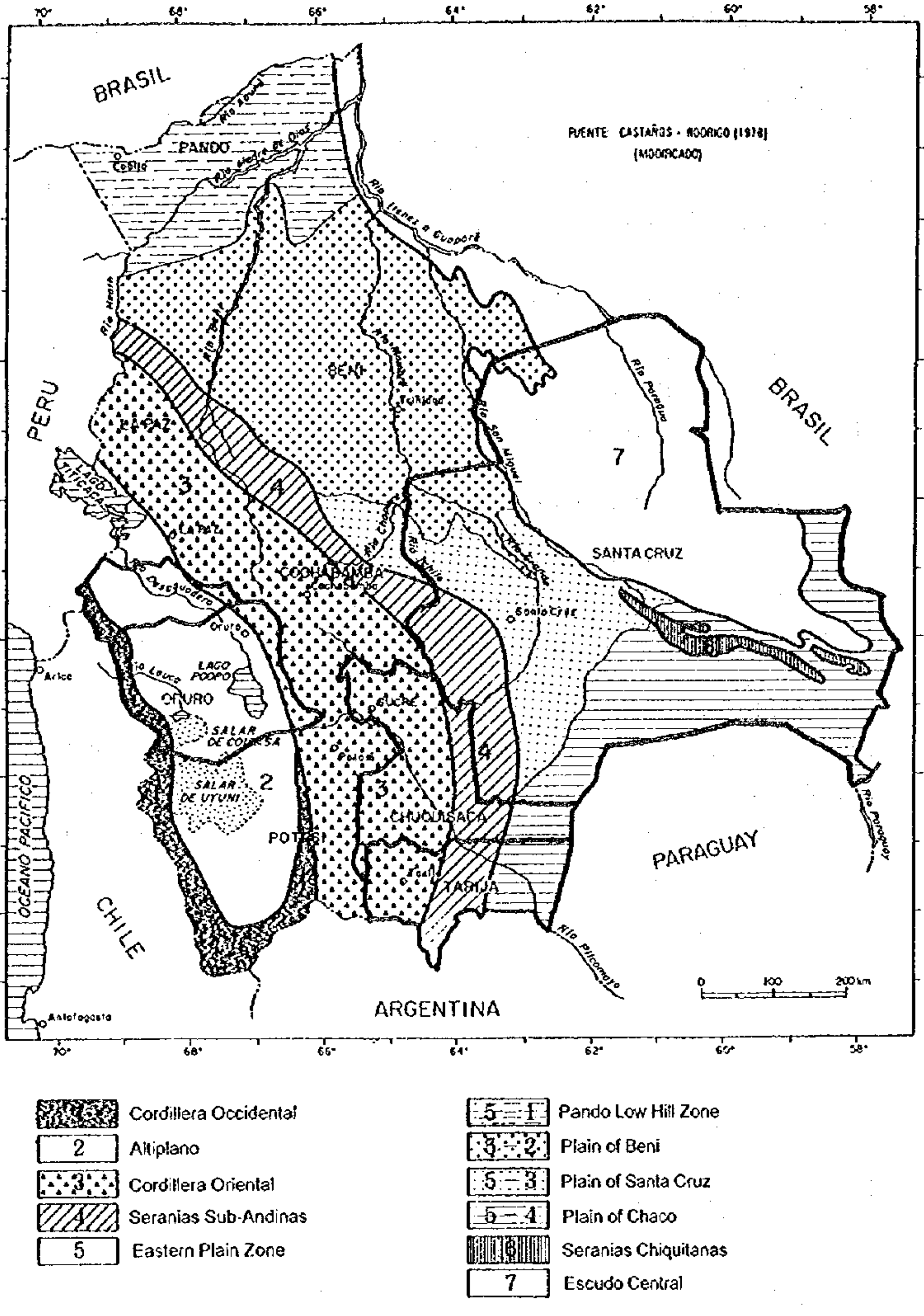


Figure 4-1-1 Physiographycal Zone of the Republic of Bolivia

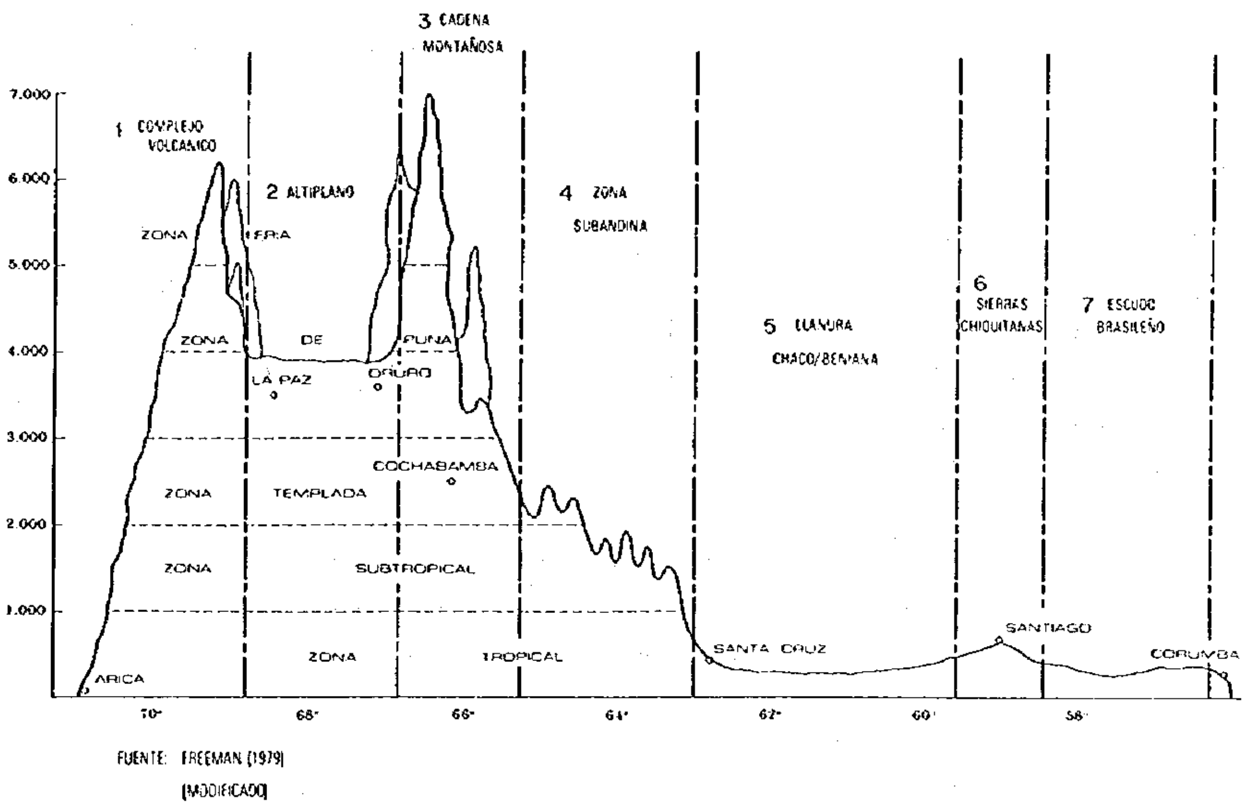


Figure 4-1-2 Physiographycal Profile of the Republic of Bolivia

4.1.2 Geology

The geology of Bolivia consists of Pre-Cambrian, Paleozoic, Mesozoic and Cenozoic groups (Table 4-1-1, Figure 4-1-3). The surface distributions of each group have the characteristics described below.

1) Pre-Cambrian group

This group is widely distributed in "Escudo Central" and found in restricted areas in "Seranias Sub-Andinas" and in "Seranias Chiquitanas". Although the Pre-Cambrian group is not exposed at the surface in Altiplano Andino, it is known to exist at a depth of 2,800 m.

In Escudo Central, the Pre-Cambrian group is comprised of a. the Cristalino Chiquitano complex, b. the Petas formation, and c. the Sunsas formation.

a. Cristalino Chiquitano Complex

This formation comprises the largest exposure from Pando to Santa Cruz (ie. not the city) in Escudo Central. This formation is composed of granite, migmatitic granite, granodyolite, and microgranite and has weathered and lateritized zones of a small scale.

b. Petas formation

This formation overlies the Cristalino Chiquitano complex in an irregular and unconforming manner. The Petas formation is principally composed of meta-sediments such as gneis, schist, and micaschist.

c. Sunsas formation

This formation is comprised of ortho-quartzite and sand with intercalation of limonite. The Sunsas formation reaches 1,600 m in thickness and forms the principal range of hills (serranias) on the great mesa of metamorphic rock.

2) Paleozoic group

The Paleozoic group is widely distributed in "Cordillera Oriental," "Seranias Sub-Andinas," and "Seranias Chiquitanas."

The distribution of the Cambrian system is limited to "Cordillera Oriental" and "Seranias Sub-Andinas" in southern Bolivia and to "Seranias Sub-Andinas" in central Bolivia (Cochabamba). In Seranias Chiquitanas, the Cambrian system is located at the easternmost part as a morpho-structure.

The Ordovician system is widely distributed, with N-S extensions in all of "Cordillera Oriental" and exposed on a small scale in "Altiplano," "Seranias Sub-Andinas," "Seranias Chiquitanas," and "Escudo Central".

The Silurian system has exposures extending in the N-S direction in "Cordillera Oriental," small exposures in "Altiplano Andino" and "Seranias Sub-Andinas," and even smaller exposures in "Seranias Chiquitanas."

The age of some parts of the Silurian system in "Altiplano Andino" and "Cordillera Oriental" is not clear. Such parts are named the Silurian-Devonian system.

The Devonian system has a major extension parallel to the distribution of the Ordovician system in "Cordillera Oriental," a limited extension in "Seranias Sub-Andinas" and "Seranias Chiquitanas," and a more minor exposure in "Altiplano Andino."

The Carboniferous system occupies a principal area of "Seranias Sub-Andinas" and minor areas of "Cordillera Oriental," "Altiplano Andino," and "Llanura Chaco-Beniana."

The Permian system exists at the northern parts of "Altiplano Andino," "Cordillera Oriental," and "Seranias Sub-Andinas".

3) Mesozoic group

The Mesozoic group is widely distributed in "La Cordillera Oriental" and "Las Seranias Sub-Andinas."

The Triassic system is present in "Las Seranias Sub-Andinas" and is exposed in a line-like manner at the eastern part of "La Cordillera Oriental."

The Cretaceous system has major extensions in "Altiplano Andino," "Cordillera Oriental," and "Seranias Chiquitanas" and has minor exposures in "Cordillera Occidental" and "Seranias Sub-Andinas." Numerous petroleum drillings and seismic data indicate that the Cretaceous system exists over an extensive area of "Llanura Chaco-Beniana."

4) Cenozoic group

The Cenozoic group consists of the Tertiary system and the Quaternary system.

The Tertiary system is exposed extensively in "Altiplano Andino" and "Las Seranias Sub-Andinas." Minor exposures are seen in "Cordillera Oriental," "Llanura Chaco-Beniana," and "Seranias Chiquitanas".

The Tertiary system in "Altiplano Andino" and "Seranias Sub-Andinas" consists of various formations (Tig, Tl / Tyd, T, Tig, Tl) with different compositions. The Tertiary system in the other zones are simple (T).

The compositions of the formations are as follows :

"Tyd" : diapiric gypsum

"T" : sandstone, conglomerate, claystone, gypsum

"Tig" : rhyodacitic ignimbrite

"Tl" : andesitic lava, dacite, tuff, breccia

The Quaternary system consists of volcanic formations and alluvial sedimentary formations. The volcanic formations consist of andesitic to dacitic lava and is distributed along "Cordillera Occidental.". The sedimentary formation occupies a wide area in "Altiplano Andino" and "Llanura Chaco-Beniana."

(5) Intrusive rock

Intrusive rocks are spotted along with mineral deposits along the ridge of "Cordillera Occidental" and "Cordillera Oriental" from the northern part to the central part of the Republic of Bolivia.

Table 4-1-1 Stratigraphy of the Republic of Bolivia

E R A			MORPHO-STRUCTURAL ZONE						
			C.OC	A PA	C.OR	S.SA	L.CB	S.CQ	E.CE
SENOZOIC	QUARTERNARY	Dep,Alv,Fluv	Q	Q	~Q		Q		
		Salt lake	Qs	Qs					
		Volcanic bed	Qev	~Qev					
		Intrusive r.	~Qi?	~Qi?					
	TERCIARY	Volcanic r.	Tl	Tl	Tl				
		Ignimbrite	Tig	Tig	Tig				
		Sediment. r.		T	T	T	T	T	
		Diap. Gypsum		~Tyd					
		Intrusive r.	~Ti?	~Ti?	Ti				
MESOZOIC	CRETACIOUS	Creta. bed	~K	~K	K		~K	K	
		Gy,Mar,Salt		~Kd					
		Triassic bed			~TR	TR			
PALEOZOIC	PERMIAN	Permian bed		P	P	P			
	CARBONIAN	Carbonian b.		~C	~C	C	~C		
	DEVONIAN	Devonian bed		~D	D	D	~D	D	
	SIL. - DEV.	Sil ° Dev b.		~S-D	S-D				
	SILURIAN	Silurian b.		~S	S	S		S	
	ORDOVICIAN	Ordovician b		~O	O	O		~O	~O
	CANBRIAN	Canbrian b2			~C	~C		~C-2	~C-2
		Canbrian b1							~C-1
PRE-CAMBRIAN		Sediment. r.							PC-A
		Metamor. r.							PC-B
		Compl metam.							PC-C
		Acidic plut.				~PC		~PC	PC

C.OC: La Cordillera Occidental
A PA: El Altiplano Andino
C.OR: La Cordillera Oriental
S.SA: Las Seran as Sub-Andinas
L.CB: La Llanura Chaco-Beniana
S.CQ: Las Seran as Chiquitanas
E.CE: El Escudo Central

~ : Small Scall Distribution
[box] : Principal distribution

Abbreviations are based on the regend of thegeological map of Volivia (MAPA GEOLOGICO DE BOLIVIA, 1978)

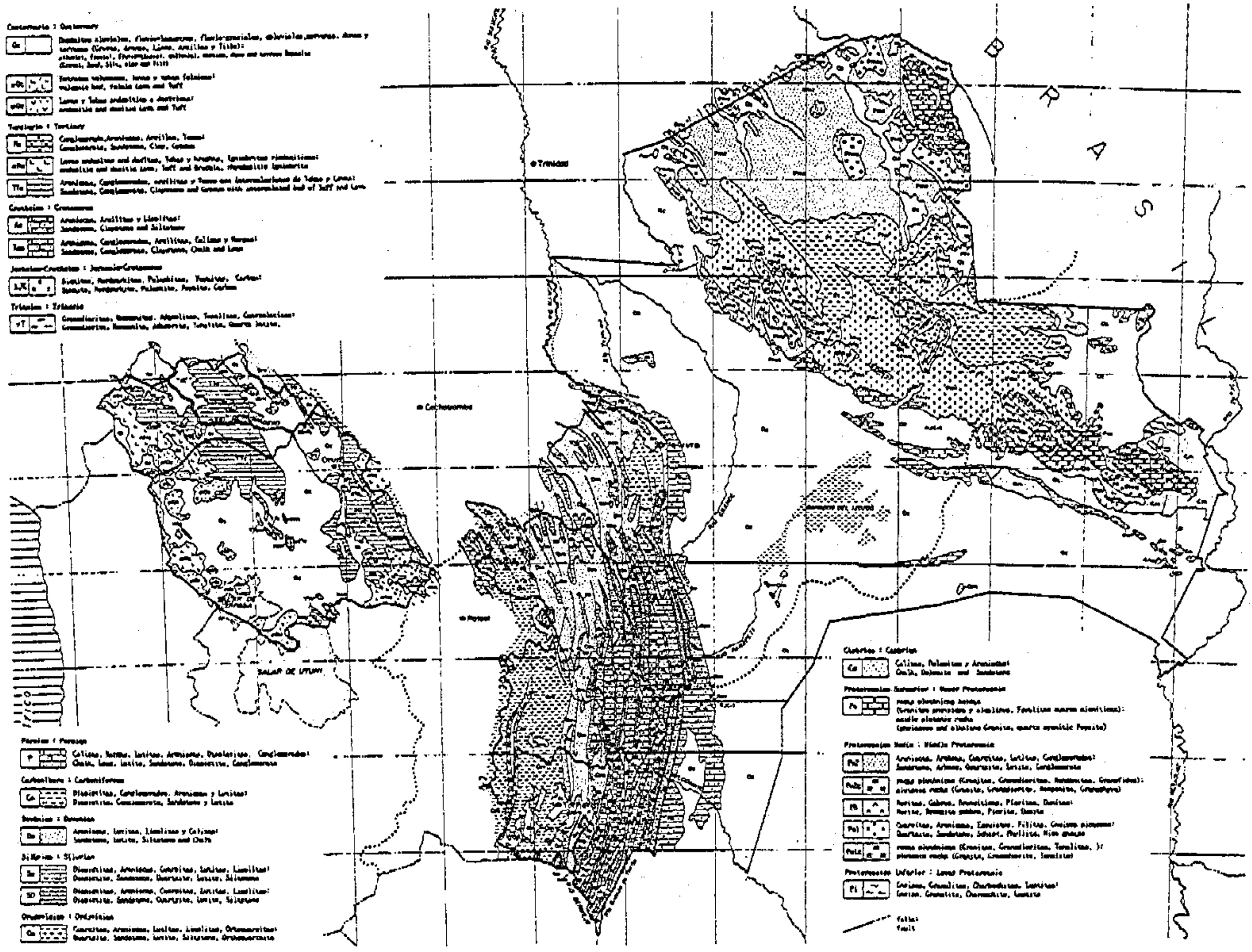


Figure 4-1-3 Geological Map of the Republic of Bolivia

4.1.3 Hydrology and River Basin

The river basins of Bolivia can be largely classified into the Altiplano basin (area: 145,081 km^2), the Amazon river basin (area: 724,000 km^2), and the La Plata river basin (area: 229,500 km^2) which respectively comprise 13.2%, 65.9%, and 20.9% of the total land area of the nation (Figure 4-1-4).

The Altiplano is a closed river basin with a total area of 190 thousand square kilometers and which is sandwiched by the Andes mountain range at the eastern and western sides. This river basin extends over the southeastern part of Peru and the Departments of La Paz, Oruro, and Potosi. It inclines gradually from north to south, with the altitude in the vicinity of Uyuni Salt Pan being the lowest.

The major rivers of the Amazon river basin include the Madre de Rios river, Beni river, Mamore river, Itenez river, etc. The Mamore river divides into the Rio Grande river, Ichiro river, etc. and the Itenez river divides into the Paragua river, San Miguel river, etc.

The Pilcomaya river, Bermejo river, and Paraguay river are among the rivers in the La Plata river basin.

The river basin divisions zones in the Study Area are as shown according to Department in Table 4-1-2. The southern part of La Paz and Oruro are located in the Altiplano while Tarija is located in the La Plata river system. The watershed between the La Plata and Amazon river systems runs through Chuquisaca and the southern part of Santa Cruz.

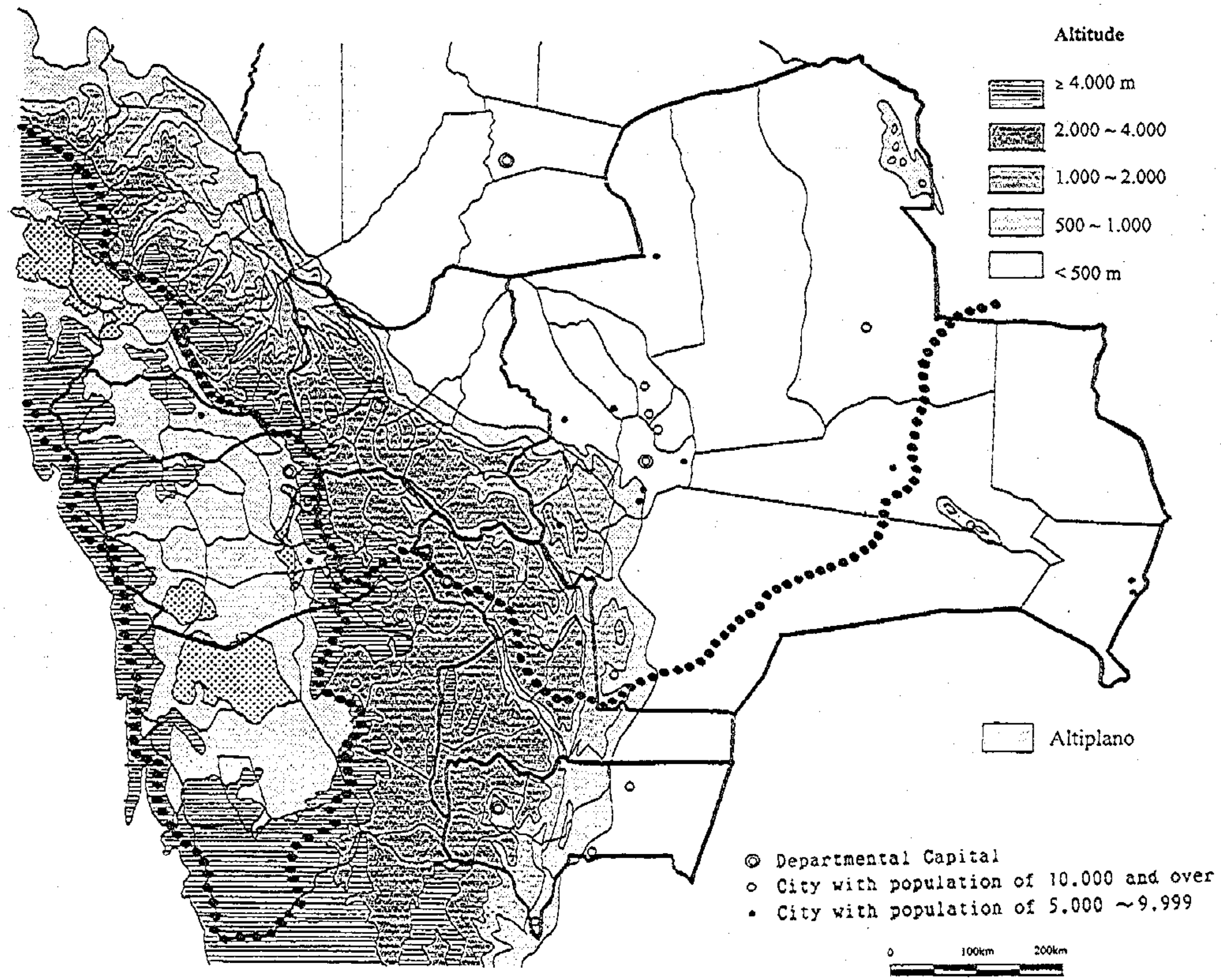


Figure 4-1-4 The River Basins of the Republic of Bolivia

Table 4-1-2 Areas of the River Basin Divisions in the Study Area

(Unit: square kilometers)

River basin Division		Chuqui-saca	South of La Paz	Oruro	Tarija	Santa Cruz	Total
Altiplano	Lake Titicaca		583				583
	Lake Poopo		18,422	22,973			41,395
	Coipasa Salt Pan			23,247			23,247
	Uyuni Salt Pan			3,125			3,125
	Subtotal		19,005	49,345			68,350
Amazon	Madre de Rios river						
	Beni river						
	Mamore river	22,634		2,270		97,567	122,471
	Itenez river					151,757	151,757
	Subtotal	22,634		2,270		249,324	274,228
La Plata	Bermejo river				11,623		11,623
	Pilcomaya river	28,893		1,973	25,785	2,100	58,751
	Paraguay river					119,197	119,197
	Subtotal	28,893		1,973	37,408	121,297	189,571
Total		51,527	19,005	53,588	37,408	370,621	532,149

4.1.4 Meteorology

Although Bolivia is located in the tropical to subtropical zone in terms of latitude, its climate varies in a complex manner due to vertical and spatial topographical variations presented by the plateau zone with altitudes of approximately 4,000m,the hill zone with altitudes of 1,000 to 3,000, and Llanura Chaco-Beniana with altitudes of 200 to 500m. In terms of seasons, the dry season and the rainy season can be distinguished clearly, with the dry season continuing from April to October and the rainy season continuing from December to March of the subsequent year. The characteristics of the climates of the Study Area are as follows.

1) Altiplano

The climate of the Altiplano zone is a cool, dry climate with an annual mean temperature of 10° C and an annual mean precipitation of about 120~350 mm. During the winter, there is hardly any rain and there are times when freezing occurs. In general, the rainfall is lower at the western part of the Altiplano.

2) Valley Zone

This zone is represented by Sucre, Tarija, etc. The precipitation is low in general and there are parts which receive hardly any rain during the dry season (May to August). The annual mean temperature ranges from 20 to 30° C and the annual precipitation is about 500~700 mm.

3) Plain Zone

This zone can be divided into a humid area in northern part of the 18~19-degrees-south-latitude, in which Santa Cruz City is located, and a dry zone called the Chaco region. Although the former area is characterized by an annual mean temperature of 22° C and an annual precipitation of 1,000~1,500 mm, there are years in which drought occurs and causes damage. The latter area has a hot dry climate with an annual mean temperature of 22~26° C and an annual precipitation of 500~1,000 mm, the rainfall being low from June to September.

Figure 4-1-5 shows the precipitation distribution of the Study Area and Figure 4-1-6 shows the monthly variations in precipitation at the major observation points.

Table 4-1-3 shows the water balance calculated for each Department based on the distribution maps for annual precipitation and evapotranspiration. The annual precipitation of the entire Department is 40 billion tons for Chuquisaca, 6.7 billion tons for the southern part of La Paz, 11 billion tons for Oruro, 30 billion tons for Tarija, and 470 billion tons for Santa Cruz. The evapotranspiration is greater than the precipitation in the southern part of La Paz and Oruro and it is presumed that there is inflow of groundwater from neighboring upstream areas of the Altiplano.

Table 4-1-3 Water Balance in the Study Area

(Unit: mm/year)

	Chuquisaca	South of La Paz	Oruro	Tarija	Santa Cruz
Precipitation	780	352	212	800	1,284
Evapotranspiration	620	366	296	593	997
Infiltration · Runoff	160	▲ 14	▲ 84	207	287

(Note) The average value for each Department was calculated on the basis of the river basin areas of the corresponding river basins and the precipitation and evapotranspiration distribution maps.

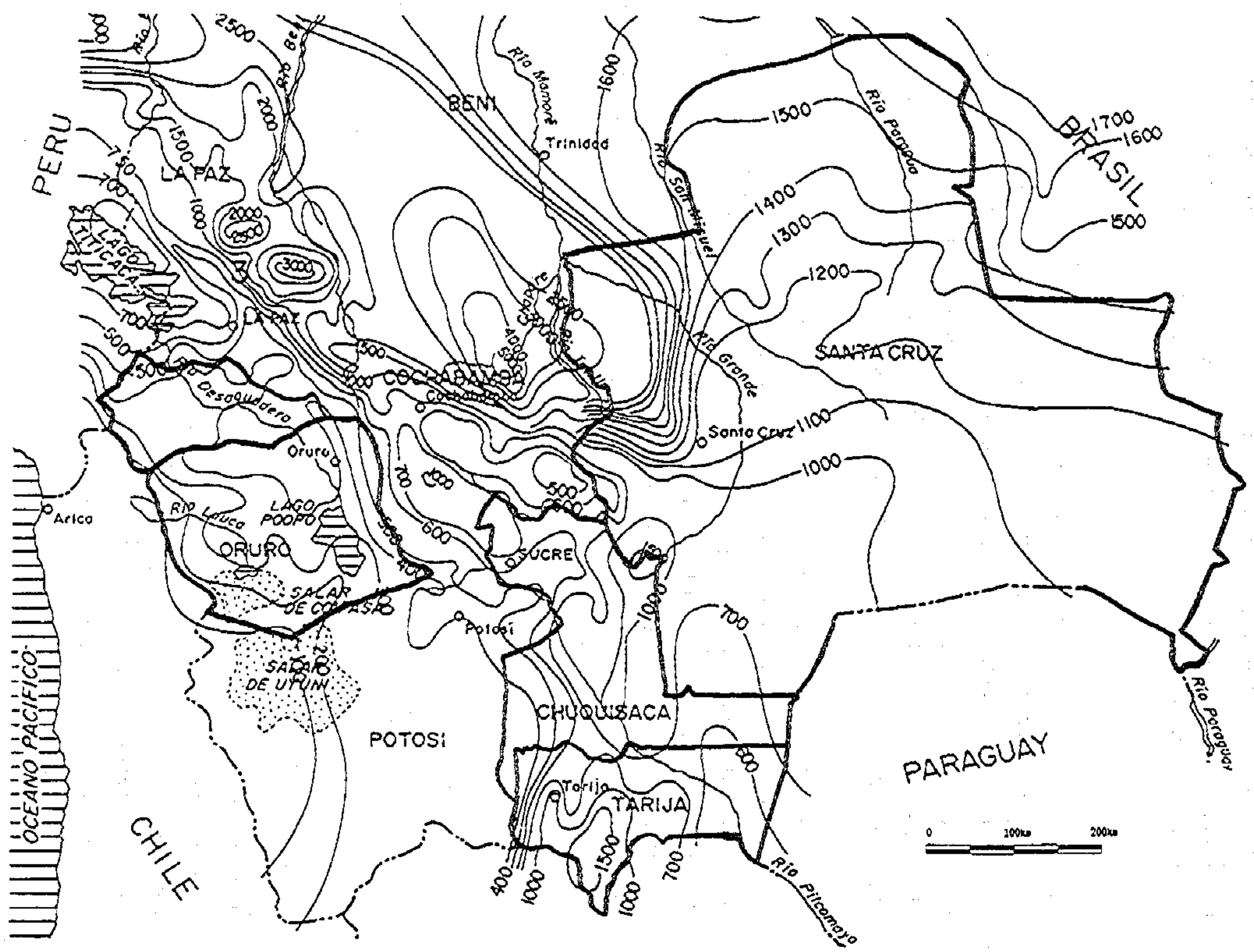
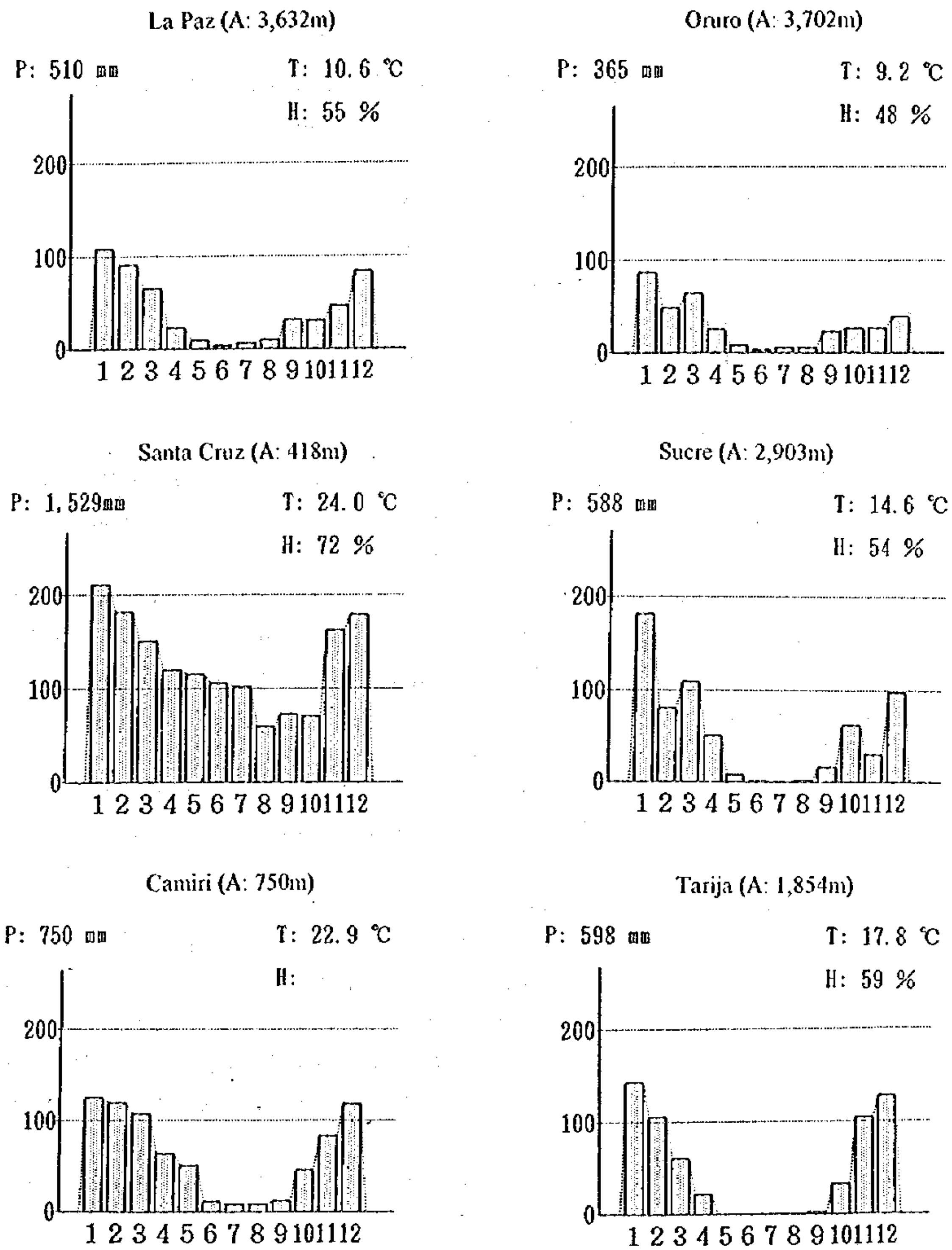


Figure 4-1-5 Precipitation Distribution of the Study Area



Note: A: Altitude P: Annual Precipitation T: Annual Mean Temperature
H: Annual Mean Humidity

Figure 4-1-6 Monthly Variations of Precipitation in the Study Area

4.1.5 Hydrogeology

The Republic of Bolivia is divided into the following five hydrogeological provinces (Figures 4-1-7), which almost coincide with the physiographical zones.

1. La Cuenca Endorreca del Altiplano Andino
2. La Cordillera Andina - Vertiente Atl ntica
3. La Cuenca del Amazonas
4. La Cuenca Pantanal Chaco - Pampeano
5. El Escudo Central

1) Cuenca Endorre ca del Altiplano Andino

This province exists between "Cordillera Occidental" and "Cordillera Oriental" and coincides with the physiographical zone of "Altiplano Andino," which has a mean altitude of 3,800 m.

The climate of this province is characterized by low precipitation and low temperature. The precipitation and the temperature change gradually from being high at the northern part to being low at the southern part. The annual mean precipitation is 500 mm at the northern part and decreases gradually to a few hundred mm at the southern part. The annual mean temperature varies from 10° C at the northern part to 6° C at the southern part.

The vast plain of "Altiplano Andino" is not a single basin but consists of numerous divided sub-basins. The central zone of these sub-basin accompanies the artesian condition.

"Cuenca Endorreca del Altiplano Andino" is filled with glacial sediments from the surrounding mountains and lake deposits.

The sediment is characterized by fine Quarternary clay or mud components. This causes the permeability of the Quaternary sediment to be low to medium.

The Quaternary sediment is about 150 m thick and is known to have a comparatively high permeability down to a depth of approximately 80 m. However, the thickness of the Quaternary sediment reaches 300 m in the central parts of the Altiplano and the permeability there is presumed to be low.

The hydrogeological conditions of "La Cuenca Endorreca del Altiplano Andino" are as follows:

Transmissivity : 100 - 620 m^2/day
Specific Capacity : 0.9 - 4.3 l/sec/m
Storativity : 1×10^{-3} - 1×10^{-5} (semiconfined to confined)

The area, from Oruro to Caracollo, which is located at the foot of the mountains of "Cordillera Oriental," is characterized by the following conditions:

Thickness of the Quaternary Bed : 120 m

Available Depth of Aquifer : down to 70 m from surface (according to past studies)

Transmissivity	:	120 - 600 m^2/day
Specific Capacity	:	0.85 - 5.17 l/sec/m
Storativity	:	2×10^{-2} - 5×10^{-3} (unconfined to confined)

The quality (salinity) of the groundwater is as follows:

Northern Part of "El Altiplano Andino" (near Lake Titicaca)

High altitude locations	:	150 - 400 mg/l (good)
Low altitude locations	:	750 mg/l (normal)

Central Part of "Altiplano Andino"

Sub-basin from Oruro to Caracollo

General	:	(good)
Areas affected by hot spring	:	7,000 mg/l
		CO_2(3,000 mg/l)

Along the "Rio Desaguadero"

Northern part (near Eucaliptos)	:	1,764 mg/l
Southern part (near Lago Uruuru)	:	8,015 mg/l

Hot springs and minerals, associated with modern volcanic activity during the Pliocene to the Pleistocene, are known to exist along "Cordillera Occidental." The influence of such volcanos is seen in the existence of heavily mineralized water and gassy/bicarbonated alkaline water with temperatures reaching between 60° C and 80° C.

Numerous hot springs exist in Oruro, Poopo, Challapata, Potosi and Uyuni, along the eastern side of "La Cuenca Endorreca del Altiplano Andino" and the outer edge of "Cordillera Oriental."

2) La Cordillera Andina - Vertiente Atlantica

This province coincides with the zones of "Cordillera Oriental" and "Seranias Sub-Andinas."

The climate of this province is characterized by the variation from cold climates in the high mountainous areas to temperate climates with moderate rainfall. The annual mean precipitation is 550 mm at Cochabamba and Sucre and 650 mm at Tarija. The annual mean temperature is 18° C in the valleys of Cochabamba and Tarija and 16° C at Chuquisaca.

The general geology of the Andes is characterized by heavily folded impermeable rocks such as slate, "limolitas," and sandstone. The base rock was therefore not considered important as an aquifer previously. However, with the recent improvements in the capacities of drilling equipment and drilling techniques, the importance of the base rock as an aquifer is being recognized anew and deep wells, targeted at the "fissure water" in cracks in the base rock, are beginning to be dug.

"Cordillera Oriental" is accompanied by a long and narrow sub-basin with thick alluvial deposits. This structure is very similar to that of an underground dam and is optimal as an aquifer. Such structures can be seen in Cochabamba, Sucre, and Tarija.

In the case of Cochabamba, the underground dam structure is located between Cochabamba and Sacaba, between Punata and Cliza, and at the sub-basin of Santibanez.

The sub-basin between Cochabamba and Sacaba is located at an altitude of 2,530m - 2,700m and constitutes a tectonic-fosa filled to a thicknessof 200 m with Quaternary sediments.

The hydrogeological conditions of the sub-basin between Cochabamba and Sacaba are as follows:

Transmissivity	:	30 - 165 m^2/day (normal)
		300 - 1,000 m^2/day (high, at center of fan)
Specific Capacity	:	0.3 - 5.0 l/sec/m

The sub-basin between Punata and Cliza is located at an altitude of 2,800 m and the hydrogeological conditions are as follows :

Transmissivity	:	2,500 - 3,000 m^2/day (upper side of fan)
		100 - 300 m^2/day (center of fan)
		10 - 100 m^2/day (damp zone)
Specific Capacity	:	0.5 - 12.0 l/sec/m
Storativity	:	3.0×10^{-4} - 7.3×10^{-3} (at Cliza)

The thickness of the Quaternary bed in the sub-basin of Santibanez is estimated to be 60 m to 80 m. The yields of the four existing wells in this province are as follows:

Yield	:	6.0 - 10.0 l/sec

The sub-basin of Tarija is principally covered with recent alluvial deposits. The thickness of the deposits is estimated to 180 m.

The properties of the known aquifer is as follows:

Transmissivity	:	20 - 300 m^2/day
Specific Capacity	:	0.22 - 1.50 l/sec/m

"Cordillera Oriental" has numerous mineralized water springs and hot springs associated with the regional tectonics. The water is characterized by a high content of sodium bicarbonate and is highly contaminated with SiO^2 and CO^2.

"Seranias Sub-Andinas" has tectonic structures and deposit structures similar to the above-mentioned "Cordillera Oriental." Although the thickness of the sediments is only 30 m to 50 m, development aimed at the "fissure water" in the bedrock has begun to be carried out recently. It is known that the groundwater quality of this province is fit to drink.

The following point should be noted.

It is known that there are areas with high concentrations of groundwater sources associated with petroleum and gas deposits in "Seranias Sub-Andina." The groundwater in such areas is characterized as sulfurous and salty mineralized water with temperatures ranging from low to as high as 80° C.

3) Cuenca del Amazonas

This province coincides with "Llanura Beniana," which belongs to "Llanura Chaco-Beniana."

A remarkable point of this province is that numerous lagoons dot the vast plain in a line-like manner. This distribution is due to the structure in which a thin and extensive Quaternary bed overlies the continental basement. Many rivers, such as the tributaries of Rio Amazonas, Rio Mamore, Rio Grande, Rio Beni, and Rio Madre de Dios, flow over the extensive Quaternary bed.

The climate of this province is characterized by extremely high precipitations which reach 5,000 mm/year in El Chaocre and 2,000 mm/year in Cobija, Riberalta, and Rurrenabaque and by high temperatures of 24° C in El Chapere and 26° C to 28° C in Rurrenabaque, Cobija, and Riberalta.

Although some information are available on the hydrogeological conditions in Santa Cruz, Warnes, Andres, and Ibanes, the information is quite insufficient except for that of Trinidad at the north side of this province.

The hydrogeological conditions in Santa Cruz are as follows:

Transmissivity	:	12 - 475 m^2/day
Specific Capacity	:	0.10 - 2.00 l/sec/m

It is certain that the aquifer exists at a depth of 100 m to 120 m in Trinidad. The hydrogeological properties are as follows :

Specific Capacity	:	4.40 l/sec/m
Yield	:	18.0 l/sec

4) Cuenca Pantanal Chaco - Pampeano

This province coincides with "Llanura Chaco," which belongs to "Llanura Chaco-Beniana."

"Cuenca del Amazonas" and "Cuenca Pantanal Chaco - Pampeano" seem to be continuous with each other because of their similar geology and geological structures. However, it is reasonable to divide these two provinces based on the geological conditions shown on a geological map. The exposure of the Paleozoic formation at the north of Tucabaca in the Department of Santa Cruz serves as a watershed and the area south of this exposure corresponds to being the "Cuenca Pantanal Chaco - Pampeano."

The annual mean precipitation in this province is 500 mm to 700 mm and is less than that in "Cuenca del Amazonas." The annual mean temperature is between 24° C and 29° C.

With the exception of Villa Montes in the Department of Tarija, information on this province is very rare.

The hydrogeological conditions at Villa Montes are as follows:

Transmissivity	:	120 m^2/day
Specific Capacity	:	0.8 l/sec/m

The hydrogeological conditions for the other areas in this province are reported to be as follows:

** Cabezas: Dep.Santa Cruz **

Transmissivity	:	200 m^2/day
Specific Capacity	:	1.1 l/sec/m

** Border with the Republic of Paraguay **

Specific Capacity	:	0.01 ~ 0.60 l/sec/m

The depth of the aquifer varies widely from 100 m to 450 m. The water quality also varies, with salinity values ranging from 320 ppm to 5,300 ppm.

5) Escudo Central

This province is called by the same name as the physiographical zone. There are no continuous aquifers in this province. The circulation of groundwater is limited to the fissured zones, the strongly fluctuated zones, and the weathered/lateritized granite zones. The lateritized granite zones may accompany perched groundwater.

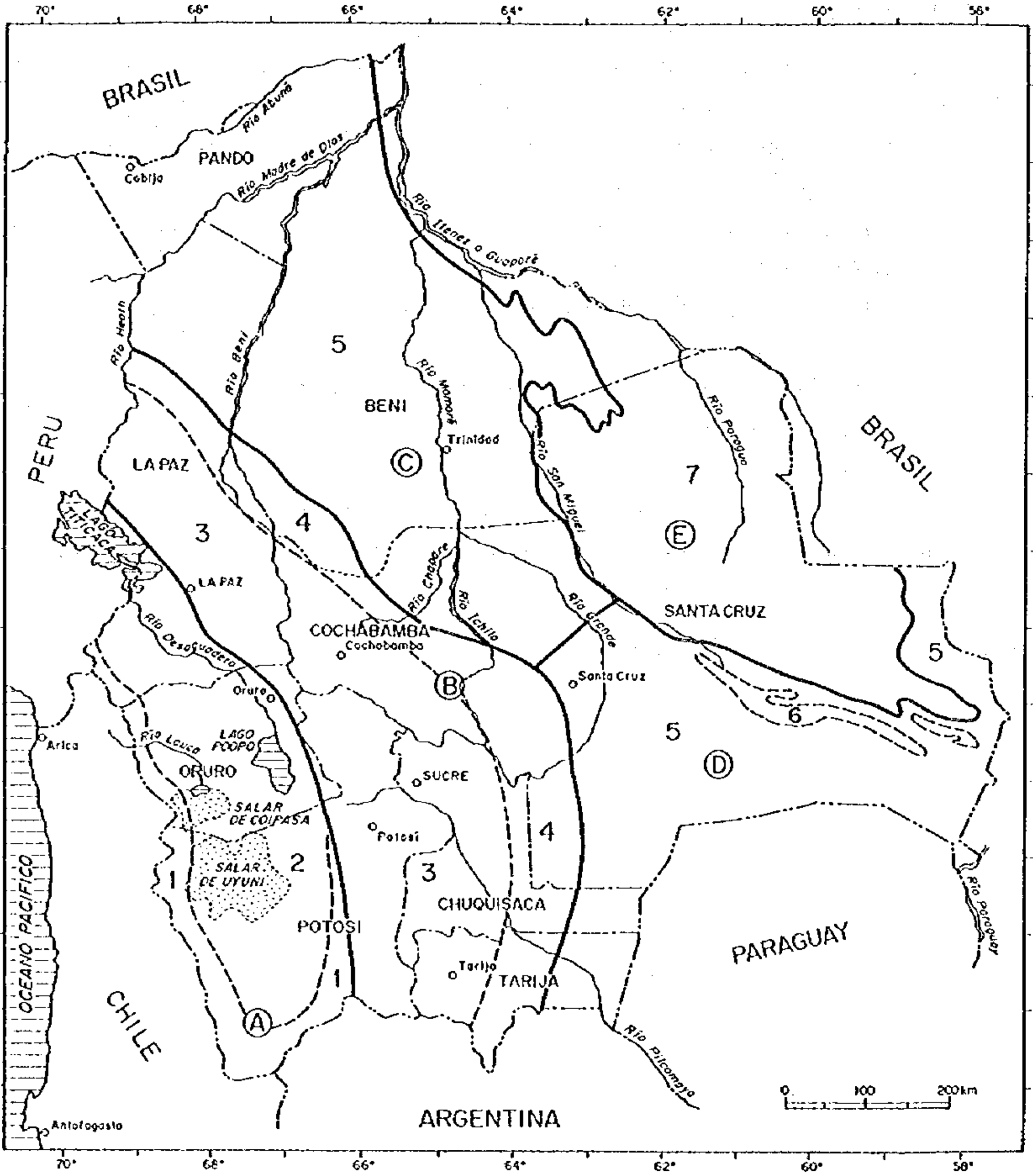
The annual mean precipitation ranges from 1,000 mm to 1,400 mm and the annual mean temperature reaches 24° C to 26° C.

The hydrogeological conditions of this province are reported to be as follows:

** San Ignacion, San Migel, Santa Ana : Dep. Santa Cruz **

Specific Capacity : 0.83 - 1.60 l/sec/m

Although the depth of the aquifer is generally estimated to be between 25 m and 70 m, there are areas where yields (pump discharge) of approximately 45-24 m3/hr may be obtained from wells with depths of 60-80 m.



REFERENCIAS

———	Limit of Hydrogeological Province	Ⓒ	La Cuenca del Amazonas
Ⓐ	La Cuenca Endorreca del Altiplano Andino	Ⓓ	La Cuenca Pantanal Chaco Pampeano
Ⓑ	La Cordillera Andina - Vertiente Atlantica	Ⓔ	El Escude Central

CORDILLERA DE LOS ANDES

1 La Cordillera Occidental	(Complejo Volcanico)
2 El Altiplano Andino	(Altiplano)
3 La Cordillera Oriental	(Cadena Montanosa)
4 Las Seranías Sub - Andinas	(Zona Sub - Andina)

LLANURA ORIENTAL

5 La Llanura Chaco - Beniana	(Llanura Chaco - Beniana)
6 Las Seranías Chiquitanas	(Sierras Chiquitanas)
7 El Escudo Central	(Escudo Cristalino)

Figure 4-1-7 Hydrogeological Provinces in the Republic of Bolivia

4.2 Field Survey

4.2.1 Geophysical Prospecting

1) Survey Area

Survey Area includes five departments such as Chuquisaca, the south of La Paz, Oruro, Santa Cruz and Tarija. It has more than 500 thousand square kilometers in total. The survey area is divided by four based on topography, meteorology and other morphological condition such as Altiplano, Valle, Llanura and Chaco. In the study Electric Method (Vertical Electric Sounding) and Electromagnetic Method (Transient Electromagnetic Method-TEM) have been implemented to know underground resistivity structure and to select test drilling points. Vertical Electric Sounding has been applied in Altiplano, Valle, Llanura and a part of Chaco with Schulumberger electrodes array and TEM in Chaco (see Figure 4-2-1, Table 4-2-1).

Table 4-2-1 Geophysical Prospecting Works

Zone	Progd Pts	Department	Realized Pts		Meas Depth	Method
Altiplano	100		100		100-200	VES
		Oruro		73		
		La Paz		27		
Valle			54		100-250	VES
		Santa Cruz		10		
		Tarija		34		
		Chuquisaca		10		
Llanura	50		50		100-250	VES
		Santa Cruz		50		
Chaco	100		101		100-500	TEM, VES
		Chuquisaca		101		

Note: Progd Pts = Number of programed Points
Realzd Pts = Number of realized Points
Meas Depth = Measured Depth
VES :verttical electric sounding (resistivity method)
TEM :transient electromagnetic sounding

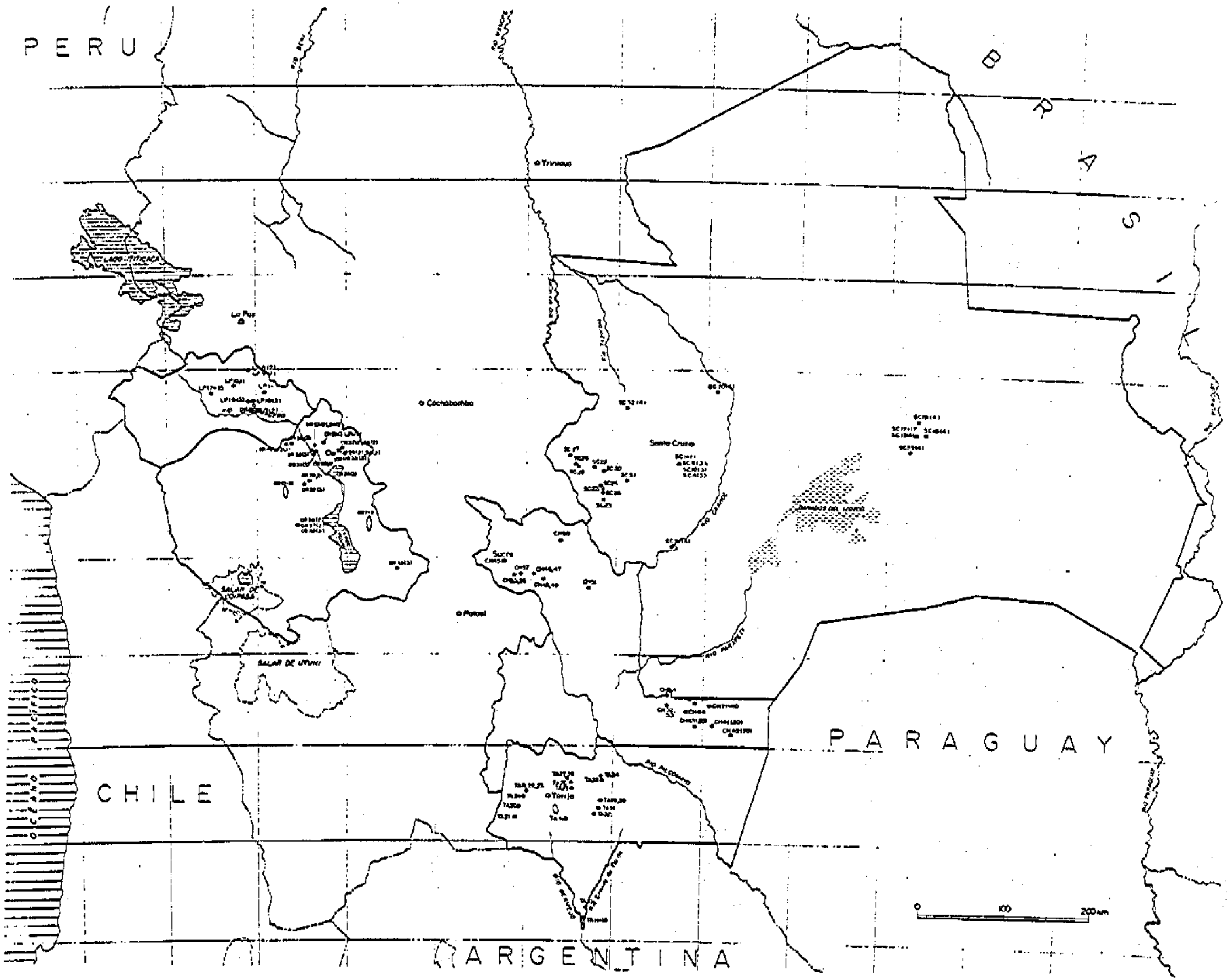


Figure 4-2-1 Location of Geophysical Prospecting Sites

2) Results of Geophysical Prospecting

In geophysical prospecting, here, a word an "aquifer-resistivity layer" is used for a layer which has possibility to be an aquifer by analyzing it's resistivity structure (see Figure 4-2-2).

Altiplano : The old age lake is extended widely here and has thick lacustrine deposits. In this zone in which lacustrine sediment formation is thick, an "aquifer-resistivity layer" lies in deeper . Generally lacustrine sediments contain salt water. It's difficult to apply Vertical Electric Sounding in the lake zone because of low resistivity of lacustrine deposits. But it became clear that in the shore zone and in the foot of the mountains or around the outcrops of the basement of the area an "aquifer-resistivity layer" lies. Then an "aquifer-resistivity layer lies in Patacamaya-LP, Cantu Santa Ana-OR Corque-OR, Rosapata-OR etc., under surface 20~200m in depth. Unfortunately in a zone of thick lacustrine deposits such as Toledo-OR an "aquifer-resistivity layer" has not been detected at least under 250m. In very closed zone around an island an "aquifer-resistivity layer" is about 10m in depth (Sillota Belen-OR, Wallchapi-OR etc.). But salt water exits under this "aquifer-resistivity layer". As going away from the island the thickness of an "aquifer-resistivity layer" reduces and on the contrary the upper surface of salt water rises (see Figure 4-2-3).

In Altiplano the "aquifer-resistivity layer" has a range of resistivity of 30~80 Ω-m.

Valle : In the Valle the "aquifer-resistivity layer" of each Department lies on closed depth affected by topography and geology.

In the Department of Chuquisaca, The "aquifer-resistivity layer" lies under surface 60~100m in depth and the tendency is toward deeper the depth from the west to the east. In some locations (Lavadero, Redencion Pampa) no "aquifer-resistivity layer" has been detected. In the Valle of this Department there are widely outcrops of Paleozoic basement and topographically the Valle forms a watershed between Amazon basin and Pilcomayo basin. Meteorologically this area is dry and annual precipitation is very small. Therefore the area has no good condition for groundwater. It is important to search groundwater in fissures in the basement. (See Figure 4-2-4).

In the Department of Santa Cruz, there is a Quaternary wide valley and in the center of there (Cochabambita) an "aquifer-resistivity layer" lies under surface 200m and the tendency is toward shallower it's depth to surrounding (see Figure 4-2-5).

In the Department of Tarija the tendency is toward deeper the depth of the "aquifer-resistivity layer" from the west (Iscayachi, 20m) to the east (100 m). In the west of the department it seems that the "aquifer-resistivity layer corresponds to Quarternary porous deposits superlaid on the basement. The old lake is filled with lucustrine sediments and an "aquifer-resistivity layer lies under surface 30 ~70m in depth. In Entre Rios valley in the east of the Department an "aquifer-resistivity layer" lies under surface 50~100m with 25~35 Ω-m. The "aquifer-resistivity layer lies deeper than in the west and in the center. In the north of Entre Rios (in Saladito, Lajitas) the formations contain salt and no "aquifer-resistivity layer" was detected at least 200m in depth.

In Valle the "aquifer-resistivity layer has a range of resistivity of 40~35 Ω-m but has resistivity of 30~50 Ω-m in lacustrine deposits.

Llanura : In the Llanura, it is known that the tendency is toward shallower the depth of the "aquifer-resistivity layer" from Costa (San Carlos, 150m) to the east (Okinawa I, 70m). In Chiquitania, the tendency is toward shallower the depth of the "aquifer-resistivity layer from Candelaria (100m) to the north and the south (Curva, 30m).

The range of effective resistivity of the "aquifer-resistivity layer" is 40~60 Ω-m.

Chaco : In the Chaco, the tendency is toward shallower the depth of the "aquifer-resistivity layer" from the west (Campo Leon, 350m) to the east (El Simbolar, 250).

The range of effective resistivity of the "aquifer-resistivity layer" is 25~80 Ω-m.

The depth and specific resistivity of an "aquifer-resistivity layer" of each area is shown as follows:

	"aquifer- resistyvity layer"	specific resistivity
Altiplano:	10m~250m	30~80 Ω-m
Valle:	20m~250m	40~60 Ω-m
(30~50 Ω-m in lacustrine layer)		
Llanura:	30m~250m	40~60 Ω-m
Chaco:	100m~450m	25~80 Ω-m

(See Table 4-2-2).

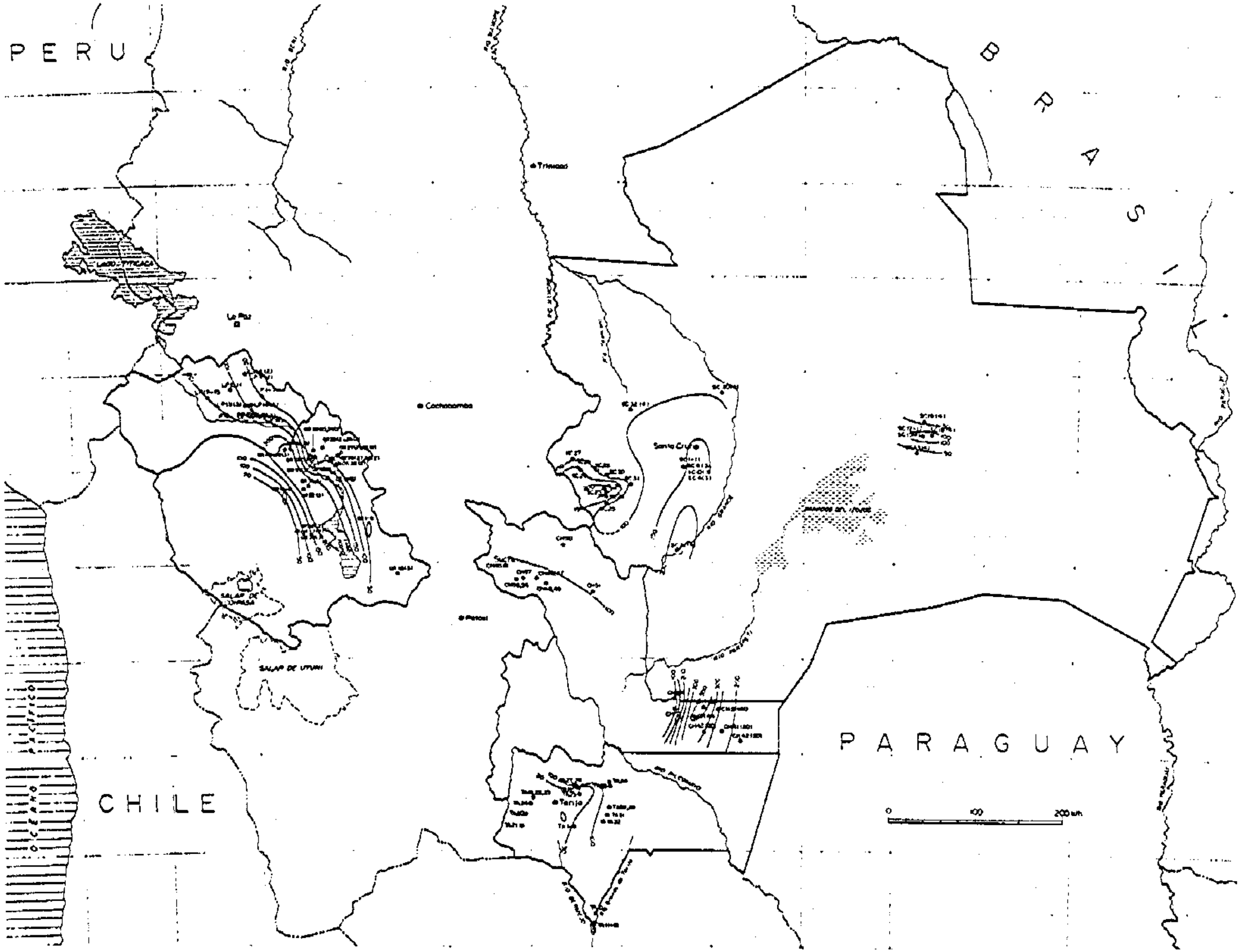


Figure 4-2-2 Iso-depth Map of Upper Surface of Aquifer-Resistivity Layer

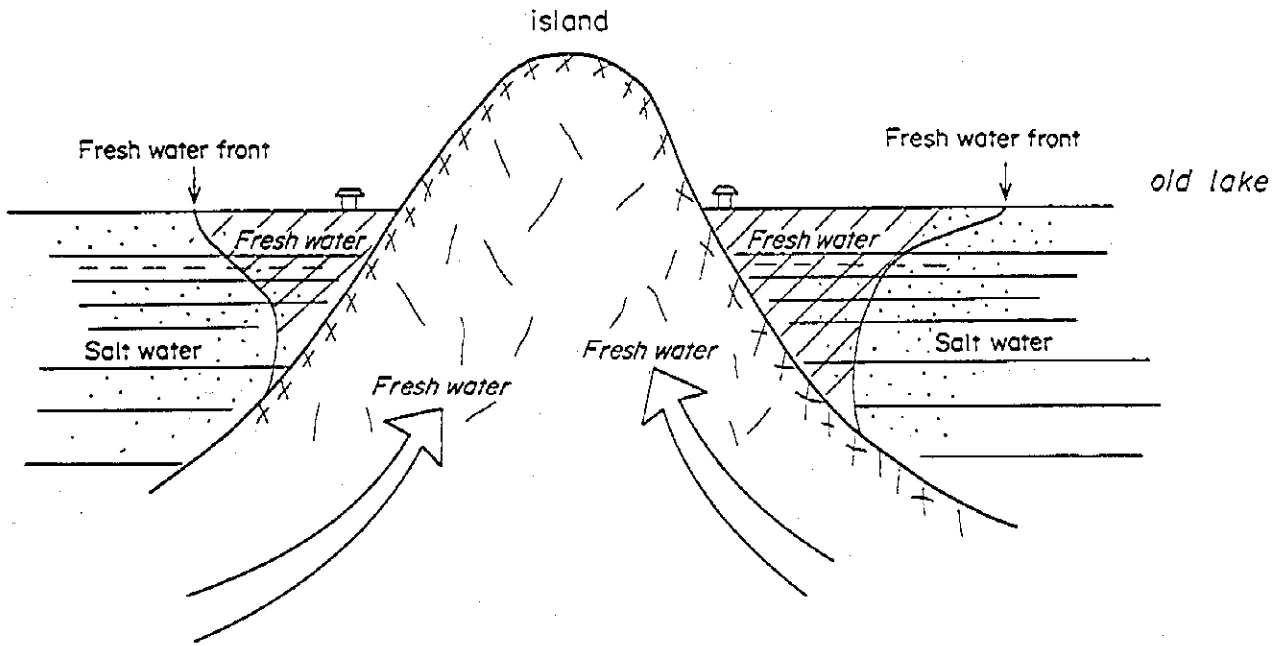


Figure 4-2-3 Sketch of the Relation between Fresh Water and Salt Water around Island in Old Lake, Altiplano

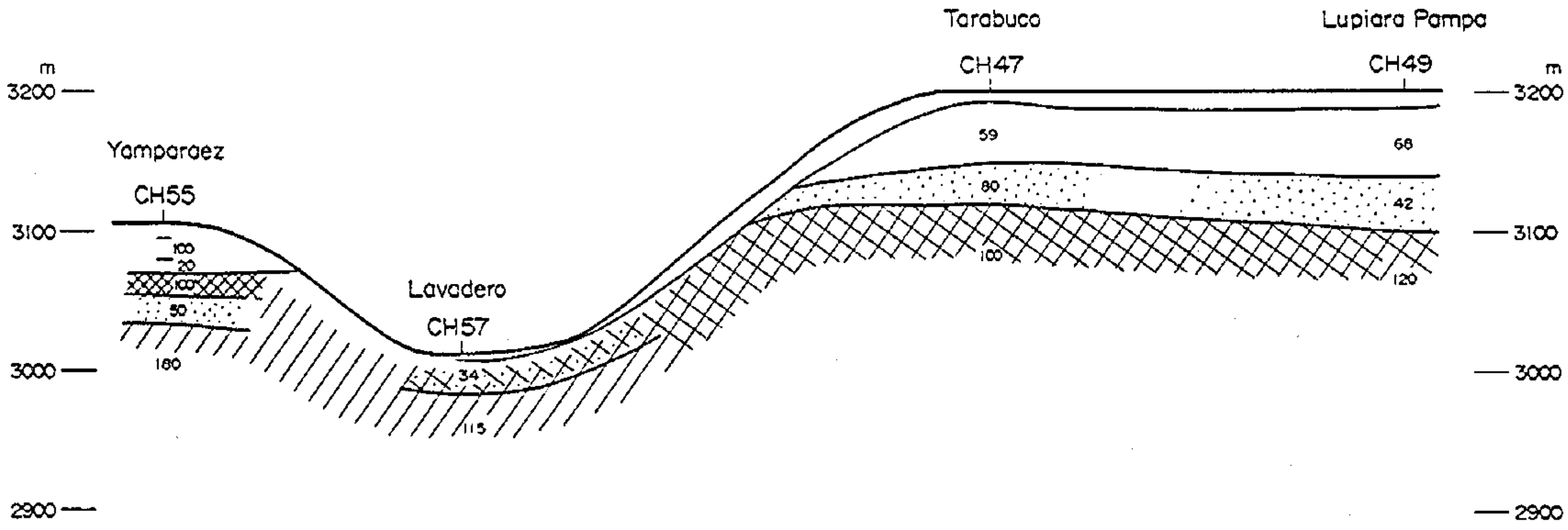


Figure 4-2-4 Resistivity Profile of the Valle in Chuquisaca

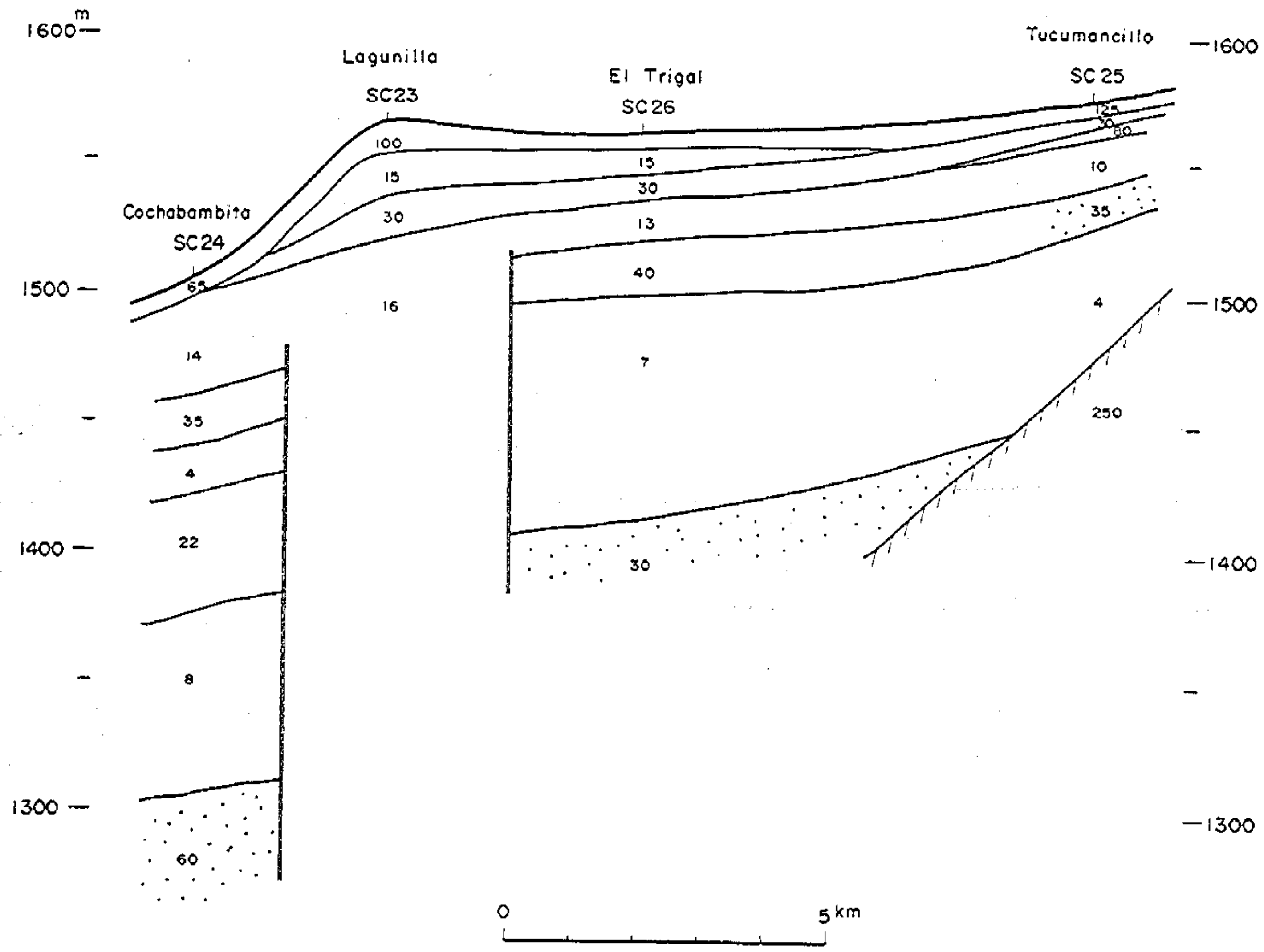


Figure 4-2-5 Resistivity Profile of the Valle in Santa Cruz

Table 4-2-2 Geophysical Station's Data

No.	Station No	Location	Depto	Eleva.	Latitude	Longitude	Depth of Aquifer	Res.	Zone	Note
1	LP1	Patacamaya	LP	3795	17 19 09	67 54 18	27-70, 102-	35	Al	behind Raileway Station
2	LP2	Patacamaya	LP	3820	17 13 53	67 54 29	40-70	30	Al	E side of the Community
3	LP3	Patacamaya	LP	3845	17 13 57	67 53 55			Al	site of new watertank
4	LP4	Patacamaya	LP	3785	17 14 52	67 54 13	20-50, 150-	60	Al	Cablebol's property
5	LP5	Patacamaya	LP	3790	17 14 38	67 54 00	35-65, 95-	60	Al	400m E of LP5
6	LP6	Patacamaya	LP	3800	17 13 40	67 55 24	70-110	30	Al	near to the Wicuma River
7	LP7	Joco Pampa	LP	3810	17 13 16	67 55 17	16-150	85	Al	Patacamaya
8	LP8(2)	Collana Tholar	LP	3980	16 58 59	68 05 01	60-	28	Al	behind the Community
9	LP9(2)	Collana Tholar	LP	3940	17 00 57	68 03 59	10-40, 56-	22	Al	W side of the Community
10	LP10	Topohoco	LP	4170	17 10 09	68 14 45	15-50	30	Al	1km W of the Community
11	LP11	Topohoco	LP	4160	17 09 57	68 14 44	120-	30	Al	300m N of LP10
12	LP12	Caquingora	LP	3870	17 14 47	68 29 33	35-70, 150-	80	Al	behind the church
13	LP13	Caquingora	LP	3870	17 14 08	68 29 51	70-110		Al	lake side
14	LP14	Caquingora	LP	3890	17 14 47	68 29 52			Al	well side
15	LP15	Caquingora	LP	3930	17 14 44	68 29 28	10-45, 150-	55	Al	north side of the church
16	LP16(2)	Umala	LP	3860	17 22 21	68 01 27	25-55, 100-	35	Al	entrance of the Community
17	LP17(2)	Umala	LP	3870	17 22 03	68 01 19	36-55	33	Al	behind the Community
18	LP18(3)	Canaviri	LP	3840	17 20 13	68 01 55	30-45, 100-	25	Al	behind the Community
19	LP19(3)	Copani	LP	3860	17 19 52	68 03 31	20-40, 55-130	40	Al	Center of the Community
20	OR1	Penas	OR	3810	18 41 09	66 46 00	100-	50	Al	near to the cemetery
21	OR2	Ichu Kkollu	OR	3805	18 41 12	66 49 40	50-	40	Al	Penas
22	OR3	Huacuyo	OR	3790	18 41 59	66 44 26	117-	47	Al	Penas
23	OR4	Penas	OR	3865	18 38 33	66 44 50	30-	35	Al	Qda. Chillihuani
24	OR5	Penas	OR	3880	18 38 44	66 44 49	30-105	38	Al	cemetery
25	OR6	Penas	OR	3895	18 37 14	66 45 30			Al	1km N from Wila Jakke
26	OR7	Tutuni	OR	4005	18 34 51	66 44 15	8-50	80	Al	Penas
27	OR8	Penas	OR	3915	18 35 45	66 45 09			Al	near to Ecia. Quebrada
28	OR9	Pena Vinto	OR	3840	18 40 41	66 45 29	16-	24	Al	Penas
29	OR10	Corque	OR	3730	18 20 35	67 40 42	40-	40	Al	500m N from Runway road
30	OR11	Huerta Mayu	OR	3745	18 20 03	67 40 47	25-200	45	Al	Corque
31	OR12	Corque	OR	3745	18 19 27	67 40 46	40-	45	Al	1.5km N from H. Mayu
32	OR13	Collun Chullpa	OR	3750	18 18 48	67 40 49	10-	55	Al	Corque
33	OR14	Corque	OR	3725	18 21 30	67 40 29	20-200	48	Al	SW corner of the runway
34	OR15	Corque	OR	3730	18 20 21	67 40 26	75-170	80	Al	500m E of OR10
35	OR16	Corque	OR	3745	18 20 14	67 40 45	22-	75	Al	between OR10 and OR11
36	OR17	Corque	OR	3740	18 19 48	67 40 46	25-	46	Al	between OR11 and OR12
37	OR18	Corque	OR	3755	18 17 08	67 40 55	28-150	55	Al	near to Choachilla Rvr

Table 4-2-2 Geophysical Station's Data

No.	Station No	Location	Depto	Eleva.	Latitude	Longitude	Depth of Aquifer	Res.	Zone	Note
38	OR19	Corque	OR	3740	18 19 20	67 40 32	40-	38	Al	Qda Tankhami
39	OR20	Toledo	OR	3710	18 11 25	67 24 30			Al	South of Toledo/roadside
40	OR21	Toledo	OR	3710	18 11 30	67 25 00	(1-13)		Al	SW
41	OR22(3)	Toledo	OR	3705	18 13 30	67 27 08			Al	500m W of the bridge
42	OR23(2)	Sillota Belen	OR	3725	17 48 33	67 20 40	12-80	120	Al	behind Community
43	OR24(2)	Sillota Belen	OR	3715	17 48 14	67 20 54	8-60	70	Al	in front of Community
44	OR25(2)	Janconuno	OR	3760	17 46 01	67 14 19	15-80	73	Al	behind the school
45	OR26(2)	Janconuno	OR	3765	17 46 04	67 14 17	8-160	50	Al	in front of the school
46	OR27(2)	Cantu Sta. Ana	OR	3715	17 50 13	67 02 49	13-130	36	Al	200m E of the school
47	OR28(2)	Cantu Sta. Ana	OR	3710	17 49 47	67 02 50	16-95	26	Al	200m N of OR26
48	OR29(2)	San Juan Pampa	OR	3730	17 52 16	67 04 19	12-40	32	Al	in front of the school
49	OR30(2)	San Juan Pampa	OR	3730	17 52 48	67 04 31	10-60, 150-	45	Al	700m S of OR29
50	OR31(3)	Sillota Witu	OR	3710	17 53 07	67 19 48	9-20	60	Al	school
51	OR32(3)	Wallchapi	OR	3740	17 51 35	67 21 00	7-45	56	Al	church
52	OR33(3)	Anacasi	OR	3745	17 50 59	67 23 08	4-55	66	Al	behind school
53	OR34(3)	Kochiraya	OR	3710	17 55 32	67 07 42			Al	behind Community
54	OR35(3)	Aeropuerto	OR	3710	17 58 12	67 04 44	20-75	68	Al	W side of Runway
55	OR36(2)	Rosa Pata	OR	3720	18 39 58	67 32 58	55-	45	Al	behind the school
56	OR37(2)	Rosa Pata	OR	3720	18 40 03	67 33 02	19-	30	Al	200m W of OR36
57	OR38(3)	Rosa Pata	OR	3720	18 40 13	67 32 49	18-50, 80-	40	Al	300m S of OR37
58	OR39(3)	Quimsa Chata	OR	3710	17 47 38	67 36 35			Al	behind the school
59	OR40	Nva. Llallagua	OR	3710	17 47 57	67 39 27	(5-17)		Al	W side of the Ground
60	OR41	Nva. Llallagua	OR	3710	17 47 44	67 39 15			Al	N side of the Community
61	OR42(3)	Nva. Llallagua	OR	3710	17 47 58	67 39 19			Al	S side of the Community
62	OR43(3)	Calacoto Huari	OR	4105	19 06 47	66 26 59	7-32, 62-	55	Al	50m S of the guide plate
63	CH1-20	Campo Leon	CH	800	20 31 39	63 08 35	320-450	50	Ch	school
64	CH21-40	El Simbolar	CH	570	20 31 19	62 56 48	220-300	40	Ch	school
65	CH41(20)	El Paraiso	CH	620	20 45 54	62 53 41	200-	14	Ch	ranch
66	CH42(20)	Cuatro Vientos	CH	570	20 51 48	62 41 15	170-	9	Ch	crossroads
67	CH43(20)	Carandayti	CH	810	20 40 17	63 05 48	165-	19	Ch	farm field
68	CH44	El Salvador	CH	850	20 37 15	63 10 40	325-	23	Ch	pasture
69	CH52	Ipati de Ivo	CH	1220	20 32 32	63 24 32	100-	50	Ch	school
70	CH53	Ipati de Ivo	CH	1220	20 33 05	63 24 54	100-	60	Ch	crossroads
71	CH54	Cuahuyuqui	CH	1030	20 24 46	63 24 36	16-	32	Ch	school
72	SC1	San Carlos	SC	560	17 58 39	63 19 00	150-225	37	Ll	in front of the School
73	SC2	San Carlos	SC	580	17 58 33	63 18 33	150-200	45	Ll	750m E from the school
74	SC3	San Carlos	SC	550	17 58 31	63 19 04	120-200	40	Ll	500m W from the school
75	SC4(3)	San Carlos	SC	540	17 58 15	63 19 38	135-	23	Ll	400m NW from the crossr.
76	SC5	San Juan	SC	565	17 58 40	63 19 25			Ll	500m from Cemetery
77	SC6	San Juan	SC	555	17 58 53	63 19 18	150-	20	Ll	north side of Community
78	SC7	San Juan	SC	560	17 59 14	63 19 10	140-	23	Ll	near to the Church

Table 4-2-2 Geophysical Station's Data

No.	Station No	Location	Depto	Eleva.	Latitude	Longitude	Depth of Aquifer	Res.	Zone	Note
79	SC8	San Juan	SC	565	17 59 24	63 19 03	100-	20	Ll	near to the creek
80	SC9(3)	San Carlos	SC	545	17 58 08	63 19 15	30-200	20	Ll	north creek
81	SC10(3)	San Juan	SC	590	17 59 52	63 19 02	135-	20	Ll	San Juan
82	SC11	San Carlos	SC	555	17 58 33	63 19 02	140-	40	Ll	between SC1 and SC3
83	SC12	Quituquina	SC	290	17 39 05	60 41 58	130-	60	Ll	150m from the school
84	SC13	Quituquina	SC	290	17 39 05	60 42 05	100-	50	Ll	roadside
85	SC14	Quituquina	SC	290	17 39 05	60 42 03	110-	35	Ll	school
86	SC15(4)	Quituquina	SC	290	17 39 15	60 41 41	120-	60	Ll	800m from the school
87	SC16	Quituquina	SC	290	17 38 50	60 42 06	100-	65	Ll	roadside
88	SC17	Quituquina	SC	290	17 39 20	60 42 14	100-	60	Ll	roadside
89	SC18(4)	Candelaria	SC	310	17 38 05	60 35 46	100-	45	Ll	centre of the Community
90	SC19(3)	La Fortuna	SC	350	17 27 11	60 40 44	5-23	23	Ll	in front of the school
91	SC20(4)	Okinawa I	SC	285	17 12 52	62 53 55	70-	40	Ll	behind the Culture Cent.
92	SC21(4)	Abapo	SC	640	18 53 53	63 23 39			Ll	side of the highway
93	SC32(4)	Yapacani	SC	330	17 24 27	63 53 16	50-	60	Ll	behind the square
94	SC33(4)	Curva	SC	280	17 49 30	60 46 05	20-40	44	Ll	roadside
95	CH45	Parque Monumental	CH	2800	19 01 25	65 15 17	20-45, 80-	40	Va	park
96	CH46	Tarabuco	CH	3230	19 09 09	64 53 54	60-	160	Va	farm field
97	CH47	Tarabuco	CH	3200	19 09 42	64 54 10	80-	100	Va	farm field
98	CH48	Lupiara Pampa	CH	3210	19 15 33	64 46 59	60-80	50	Va	behind the school
99	CH49	Lupiara Pampa	CH	3200	19 15 37	64 47 11	60-100	42	Va	other side of the creek
100	CH50	Redencion Pampa	CH	2490	18 49 29	64 36 41			Va	under the watertank
101	CH51	Padilla	CH	2140	19 18 22	64 17 42	100-	50	Va	farm field
102	CH55	Yamparaez	CH	3105	19 10 50	65 07 58	50-70	50	Va	500m W from the Station
103	CH56	Yamparaez	CH	3105	19 10 52	65 07 48			Va	150m SE "
104	CH57	Lavadero	CH	3010	19 10 41	65 02 58			Va	50m N from the well
105	SC22	Sanjon	SC	1415	18 01 52	64 14 58	18-80	38	Va	400m N from the well
106	SC23	Lagunillas	SC	1565	18 16 07	64 09 29			Va	Cemetery
107	SC24	Cochabambita	SC	1505	18 14 25	64 10 07	200-	60	Va	farm filed
108	SC25	Tucumancillo	SC	1580	18 22 20	64 08 54	35-50	35	Va	farm field
109	SC26	El Trigal	SC	1560	18 18 23	64 09 00	120-	35	Va	Plaza
110	SC27	Comarapa	SC	1730	17 55 02	64 31 07	35-	50	Va	near to The Runway
111	SC28	San Isidro	SC	1485	18 02 45	64 25 59	30-50, 100-	50	Va	near to the school
112	SC29	El Tambo	SC	1490	18 01 30	64 26 54	150-	30	Va	peach yard
113	SC30	Pampa Grande	SC	1250	18 04 57	64 06 58	65-	55	Va	500m to the bridge
114	SC31	Samaipata	SC	1610	18 10 33	63 52 56	40-	25	Va	The cemetery
115	TA1	Calamuchita	TA	1690	21 42 05	64 37 17	80-130	40	Va	in the Community
116	TA2	La Choza	TA	1725	21 40 14	64 36 42			Va	along the highway
117	TA3	San Isidro	TA	1750	21 39 45	64 37 28	65-130	40	Va	on the roadside to S. I.
118	TA4	San Isidro	TA	1700	21 39 52	64 37 52	9-40	45	Va	San Isidro
119	TA5	San Isidro	TA	1710	21 40 15	64 37 35	10-18	34	Va	near to the cemetery

Table 4-2-2 Geophysical Station's Data

No.	Station No	Location	Depto	Eleva.	Latitude	Longitude	Depth of Aquifer	Res.	Zone	Note
120	TA6	San Isidro	TA	1710	21 39 40	64 38 08	30-50	30	Va	soccer ground
121	TA7	San Isidro	TA	1710	21 40 10	64 37 08			Va	W of the old mine
122	TA8	San Isidro	TA	1730	21 40 00	64 36 55			Va	entrance to an old mine
123	TA9	San Isidro	TA	1730	21 40 44	64 36 31	30-90	30	Va	along the highway
124	TA10	Col. Linares	TA	400	22 40 17	64 16 16	45-85	43	Va	Col. Linares
125	TA11	Campo Grande	TA	365	22 48 31	64 18 23	40-60, 110-	100	Va	near to Campo Grande
126	TA12	Bermejo	TA	360	22 49 26	64 18 20	60-110, 200-	90	Va	sugar cane field
127	TA13	Bermejo	TA	350	22 49 30	64 19 16	23-40	120	Va	near to Bermejo River
128	TA14	Bermejo	TA	352	22 49 49	64 19 23	70-100, 180-	70	Va	sugar cane field
129	TA15	Bermejo	TA	379	22 46 19	64 18 06	55-	130	Va	Vda. Patrocina's house
130	TA16	Porcelana	TA	379	22 46 16	64 17 25	75-	130	Va	near to the School
131	TA17	Com. Talita	TA	378	22 46 40	64 19 08	45-	140	Va	behind the runway, Berm.
132	TA18	Naranjita	TA	339	22 50 56	64 19 20	150-	80	Va	Bermejo
133	TA19	San Antonio	TA	3440	21 26 30	64 57 59	7-45, 90-	30	Va	Iscayachi
134	TA20	Chorcoya Aviles	TA	3810	21 37 34	65 03 01	6-30	75	Va	Iscayachi
135	TA21	Chorcoya Lago	TA	3710	21 43 02	65 05 13	50-90, 160-	80	Va	Iscayachi
136	TA22	Sama	TA	3465	21 29 09	64 57 27	18-80	90	Va	Iscayachi
137	TA23	Lulcayo	TA	3460	21 29 59	64 57 21	18-30	27	Va	Iscayachi
138	TA24	Pueblo nuevo	TA	3550	21 32 33	64 58 35	2-52	57	Va	Iscayachi
139	TA25	Junacas	TA	2300	21 25 52	64 27 48	20-85	30	Va	school
140	TA26	Junacas Norte	TA	2350	21 24 58	64 26 57	35-	70	Va	behind the school
141	TA27	Polla	TA	2430	21 23 17	64 26 39			Va	farm filed
142	TA28	Polla	TA	2400	21 22 49	64 27 18			Va	near to the school
143	TA29	Naranjos	TA	1230	21 35 21	64 08 57	20-45	25	Va	pasture
144	TA30	Naranjos	TA	1250	21 34 16	64 08 36	8-40, 100-	27	Va	school
145	TA31	El Puesto	TA	1210	21 39 00	64 09 10	8-20	32	Va	pasture
146	TA32	La Cueva	TA	1130	21 40 55	64 12 24	20-38, 52-	35	Va	pasture
147	TA33	Lajitas	TA	990	21 22 32	64 07 28			Va	behind the school
148	TA34	Saladito	TA	890	21 17 04	64 06 19			Va	farm

LP :La Paz OR :Oruro CH :Chuquisaca SC :Santa Cruz TA :Tarija
LP8(2) : two points as LP8
Eleva. : elevation (m)
Depth of Aquifer : -depth of "aquifer-resistivity layer"- depth from the surface of the ground in meter(m)
Al :Altiplano Ch :Chaco Ll :Llano Va :Valle
Res. : resistivity of possible aquifer (Ω-m)

3) Results of Geophysical Prospecting, Test Drilling and Well Logging at Test Wells

Nine geophysical stations were sellected for test drilling on geophysical results on a condition discribed in the 2) of this section.

They are as follows:

Area	Well No.	Geoph. No.	Location
Altiplano	JC1	LP5	Patacamaya-La Paz
	JC2	OR10	Corque-Oruro
	JC3	OR3	Penas-Oruro (substituted OR5)
Valle	JC8	TA9	La Choza-Tarija
	JC9	TA30	Naranjos-Tarija (TA10- TA11-)
Llanura	JC4	SC11	San Carlos-Santa Cruz
	JC5	SC14	Quituquina-Santa Cruz
Chaco	JC6	CH5	Campo Leon-Chuquisaca
	JC7	CH26	El Simbolar-Chuquisaca

The results of geophysical prospecting, test drilling and well logging and each other's relation are as follows.

JC1 : Geophysical station LP5 in Patacamaya- La Paz (Figure 4-2-6 ,4-2-7)

Geophysical results.

9~35m / 230 Ω-m	high resistivity layer consisting of much debris from back mountain range.
30~65m / 60 Ω-m	sandy layer - "aquifer-resistivity layer"
65~95m / 4 Ω-m	muddy layer
95m~ / 30 Ω-m	sandy layer - "aquifer-resistivity layer"

Drilling	support geophysical results.
Well logging	23~65m aquifer
Screen interval	23~65m

JC2 : Geophysical station OR10 in Corque - Oruro (Figure 4-2-8, 4-2-9)

Geophysical results

9~40m / 26 Ω-m	muddy layer
40m~ / 40 Ω-m	sandy layer - "aquifer-resistivity layer"

Drilling	support geophysical results.
Well logging	support geophysical results.
Screen interval	42~66m

JC3 : Geophysical station OR3 in Huacuyo - Oruro (Figure 4-2-10, 4-2-11)

Geophysical results

4~33m / 63 Ω-m	mixed current deposit with gravels, sand, mud
33~117m / 150 Ω-m	consolidated sand stone or conglomerate
117m~ / 47 Ω-m	sandy layer - "aquifer-resistivity layer"
Screen interval	29~60m

JC4 : Geophysical station SC11 in San Carlos - Santa Cruz

(Figure 4-2-12, 4-2-13, 4-2-14)

Geophysical results

65~140m / 7 Ω-m	muddy layer
140~ / 40 Ω-m	sandy layer - "aquifer-resistivity layer"
Results of drilling and well logging	support geophysical results
Screen interval	146~248m

JC5 : Geophysical station SC14 in Quituquina - Santa Cruz

(Figure 4-2-15, 4-2-16, 4-2-17)

Geophysical results

32~110m / 110 Ω-m	shale, slate, sand stone with few cracks
110m~ / 35 Ω-m	shale, slate, sand stone with much cracks - "aquifer-resistivity layer"
Drilling results	
0~40m	mixed layer with grabel, mud
40~110m	shale
110m~	more crack
Well logging	no support geophysical results
Screen interval	117~182m

JC6 : Geophysical station CH5 in Campo Leon - Chuquisaca (Figure 4-2-18, 4-2-19)

Geophysical results

280~350m / 15 Ω-m	muddy layer
350m~ / 60 Ω-m	sandy layer - "aquifer-resistivity layer"
Drilling	
~300m	muddy layer
300m~	sandy layer
Well logging	support geophysical results
Screen interval	306~361m

JC7 : Geophysical station CH26 in El Simbolar - Chuquisaca (Figure 4-2-18, 4-2-20)

Geophysical results

~225m / 6 Ω-m		muddy layer
225~ / 23 Ω-m		muddy + sandy layer - "aquifer-resistivity layer"
Drilling		
	0~240m	muddy layer
	240m~	muddy + sandy layer
Well logging	75~150m	sandy layer
Screen interval	99~159m	

JC8 : Geophysical station TA9 in La Choza - Tarija (Figure 4-2-21, 4-2-22, 4-2-23)

(Drilling point is located on the court of a chapel, 1km west from TA9)

Geophysical results

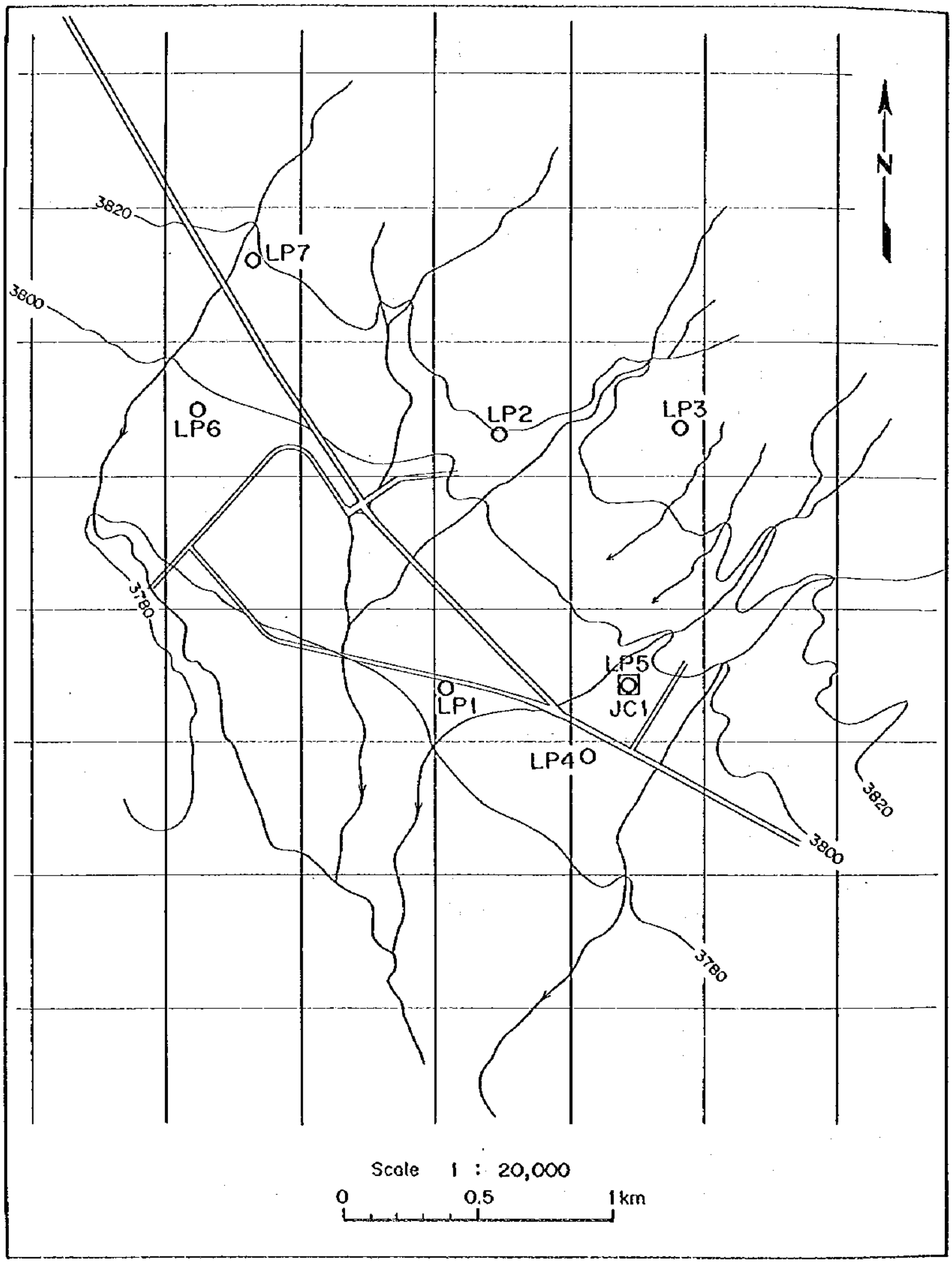
~31 / 12 Ω-m		muddy layer
31~90 / 30 Ω-m		sandy layer - "aquifer-resistivity layer"
90~105 / 2 Ω-m		muddy or silt layer
105m~ / 120 Ω-m		basement
Drilling		support geophysical results.
Well logging		support geophysical results
Screen interval	46~119m	welling out 7 l/s

JC9 : Geophysical station TA30 in Naranjos - Tarija (Figure 4-2-24)

Geophysical results

8~40m / 31 Ω-m		sansy layer - "aquifer-resistivity layer"
40~100m/ 16 Ω-m		muddy layer
100m~/ 27 Ω-m		sandy layer - "aquifer-resistivity layer"
Drilling	muddy layer	dry well

Figure 4-2-6 Location of Geophysical Points in Patacamaya, La Paz



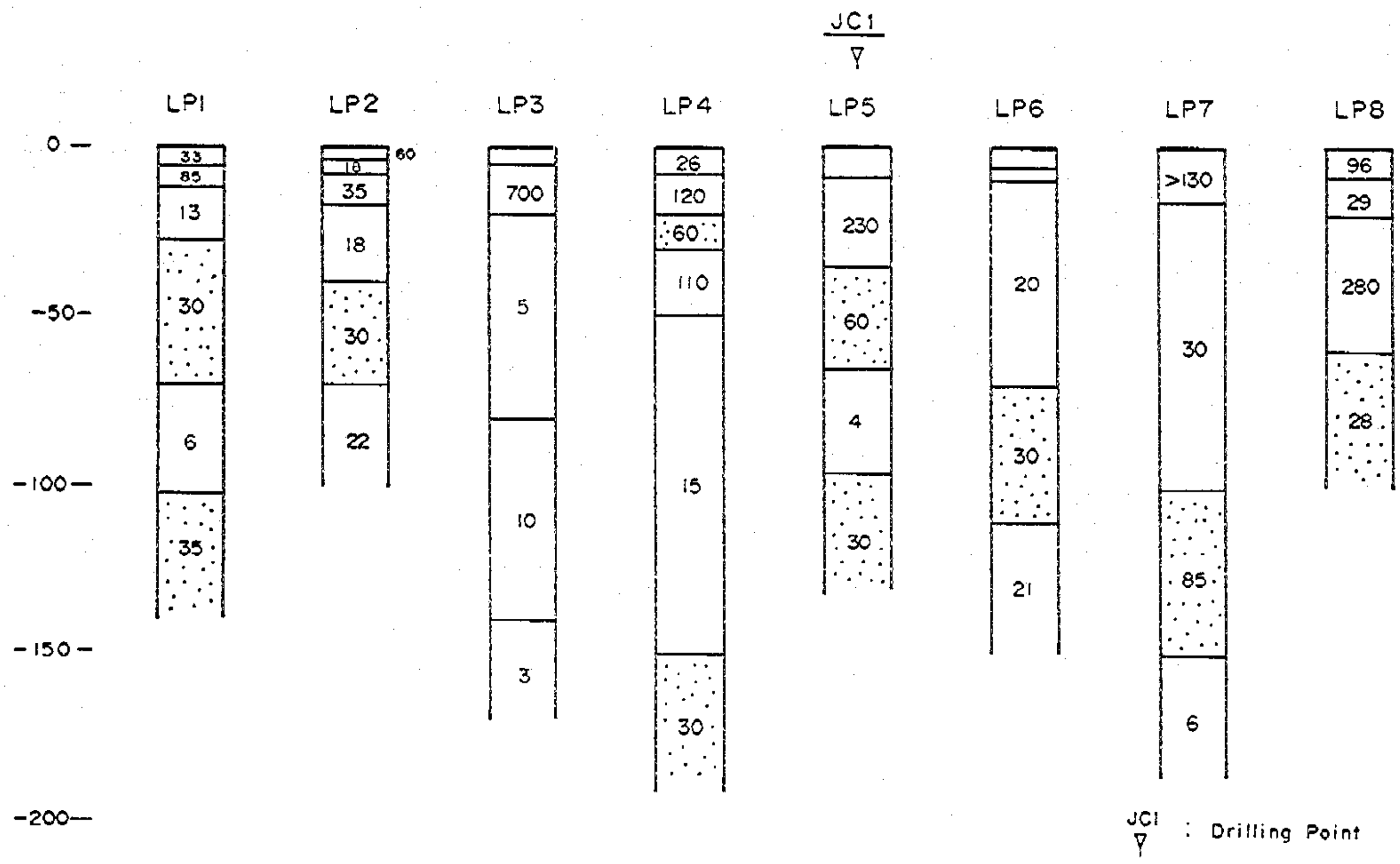


Figure 4-2-7 Resistivity Profile of Patacamaya, La Paz

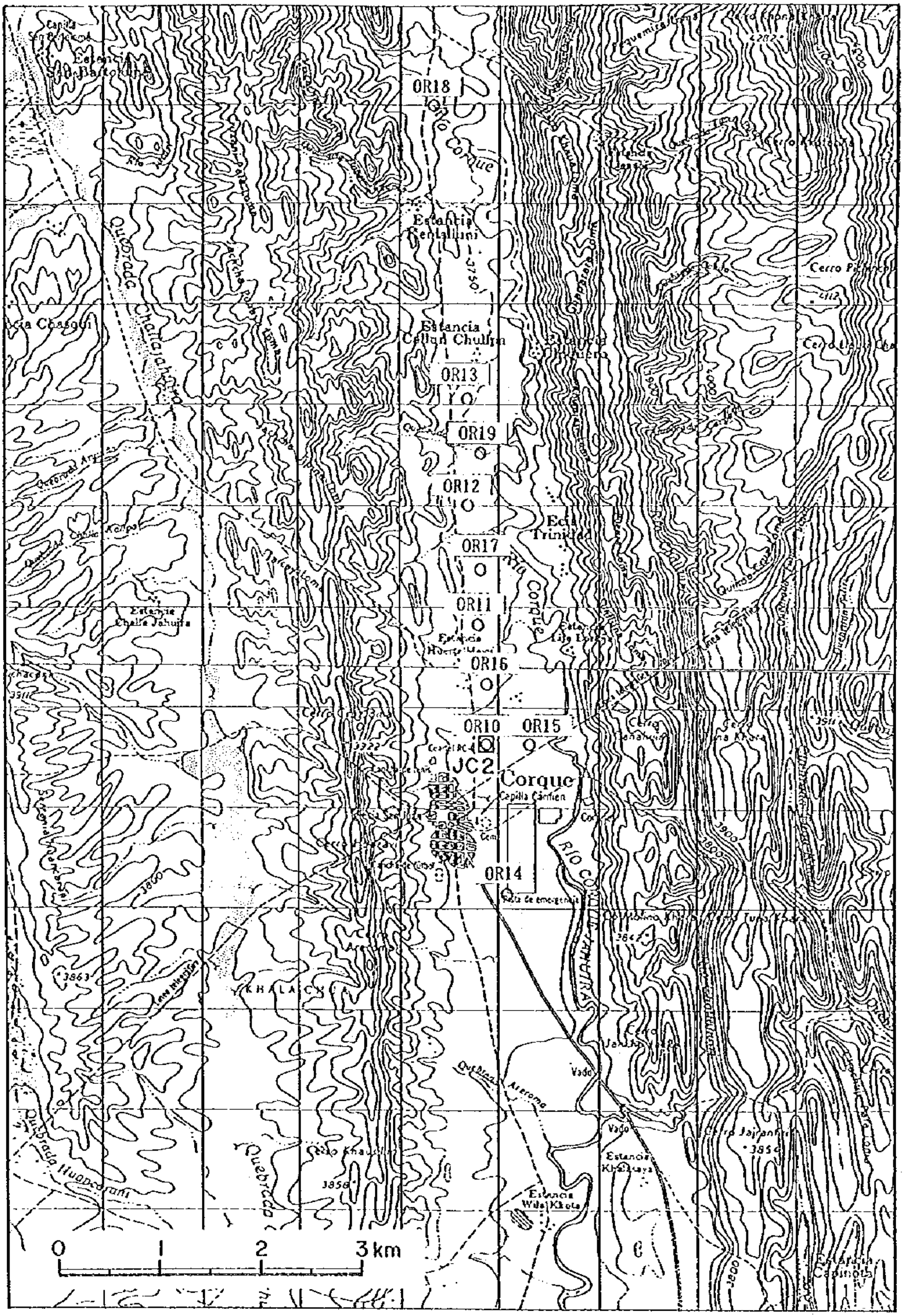


Figure 4-2-8 Location of Geophysical Points in Corque, Oruro

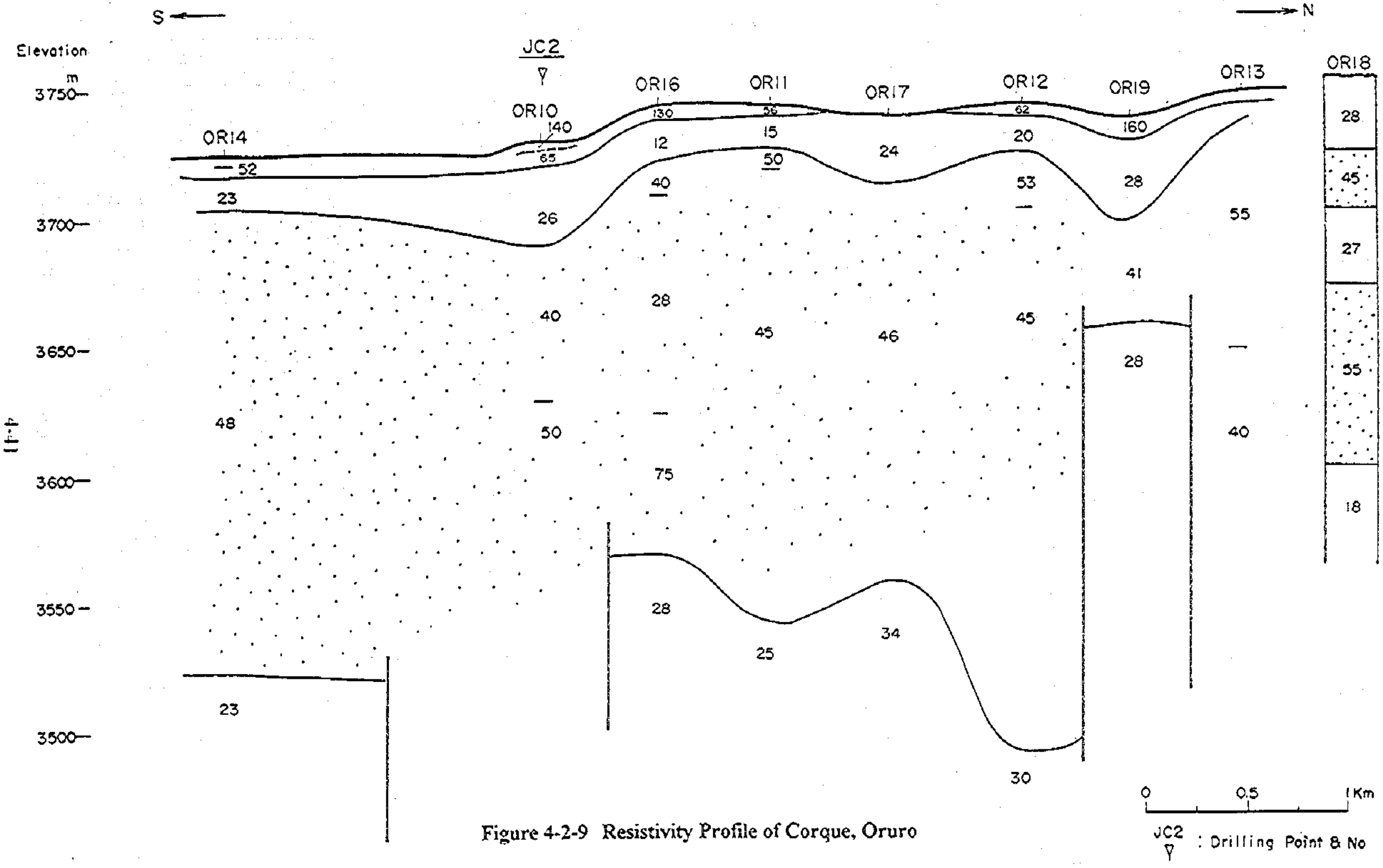


Figure 4-2-9 Resistivity Profile of Corque, Oruro

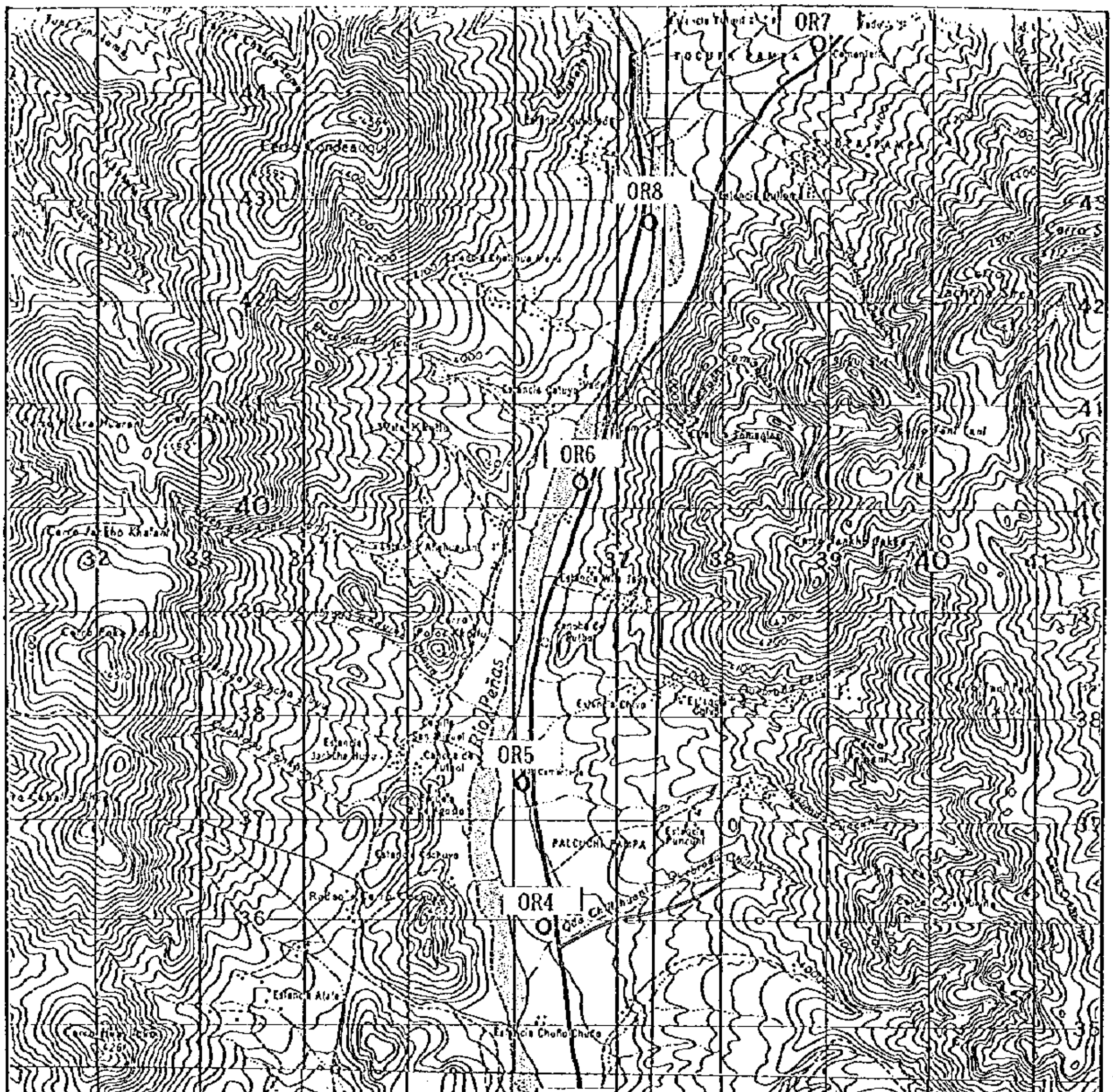


Figure 4-2-10 Location of Geophysical Points in Penas, Oruro

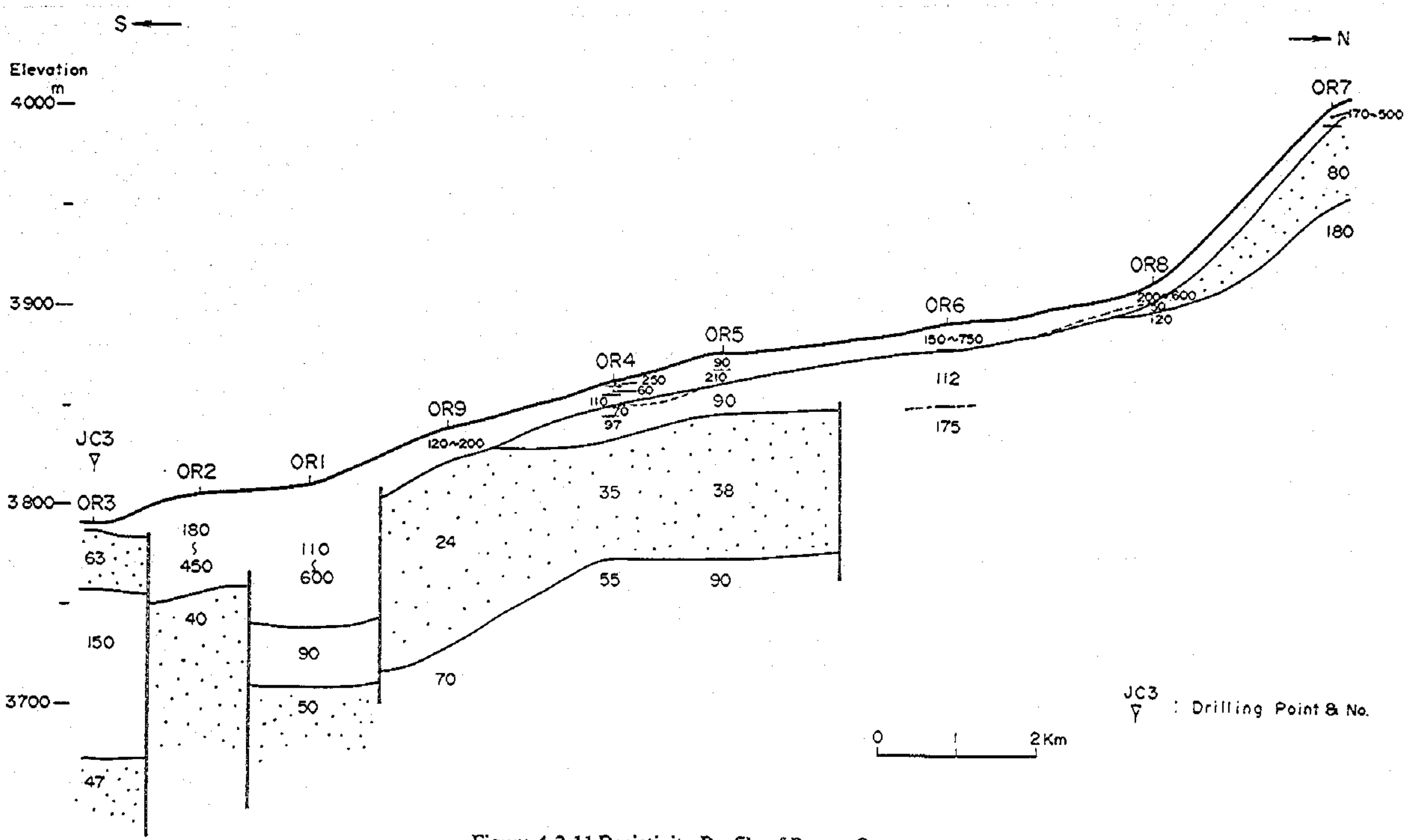


Figure 4-2-11 Resistivity Profile of Penas, Oruro

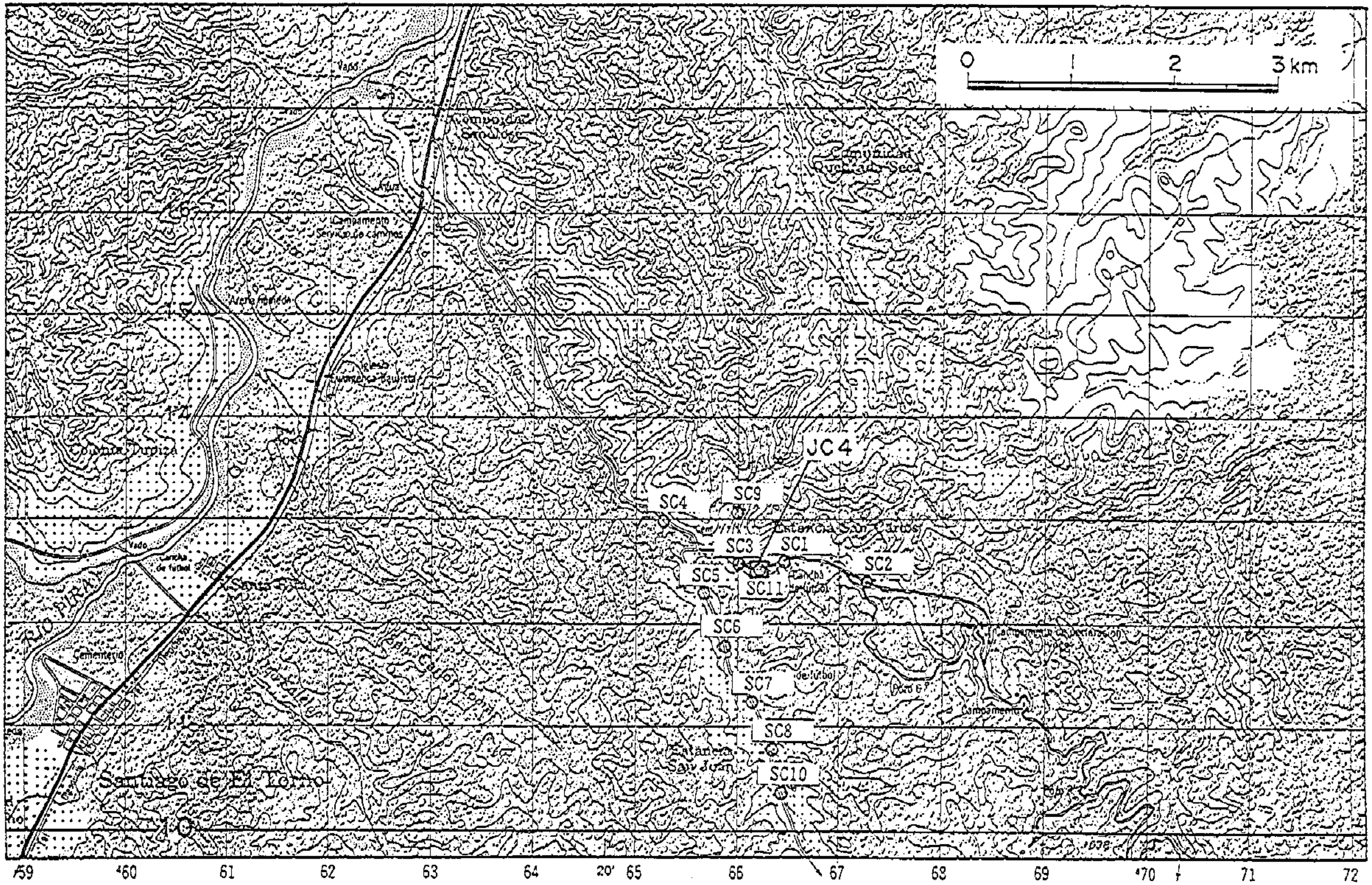


Figure 4-2-12 Location of Geophysical Points in San Carlos, Santa Cruz

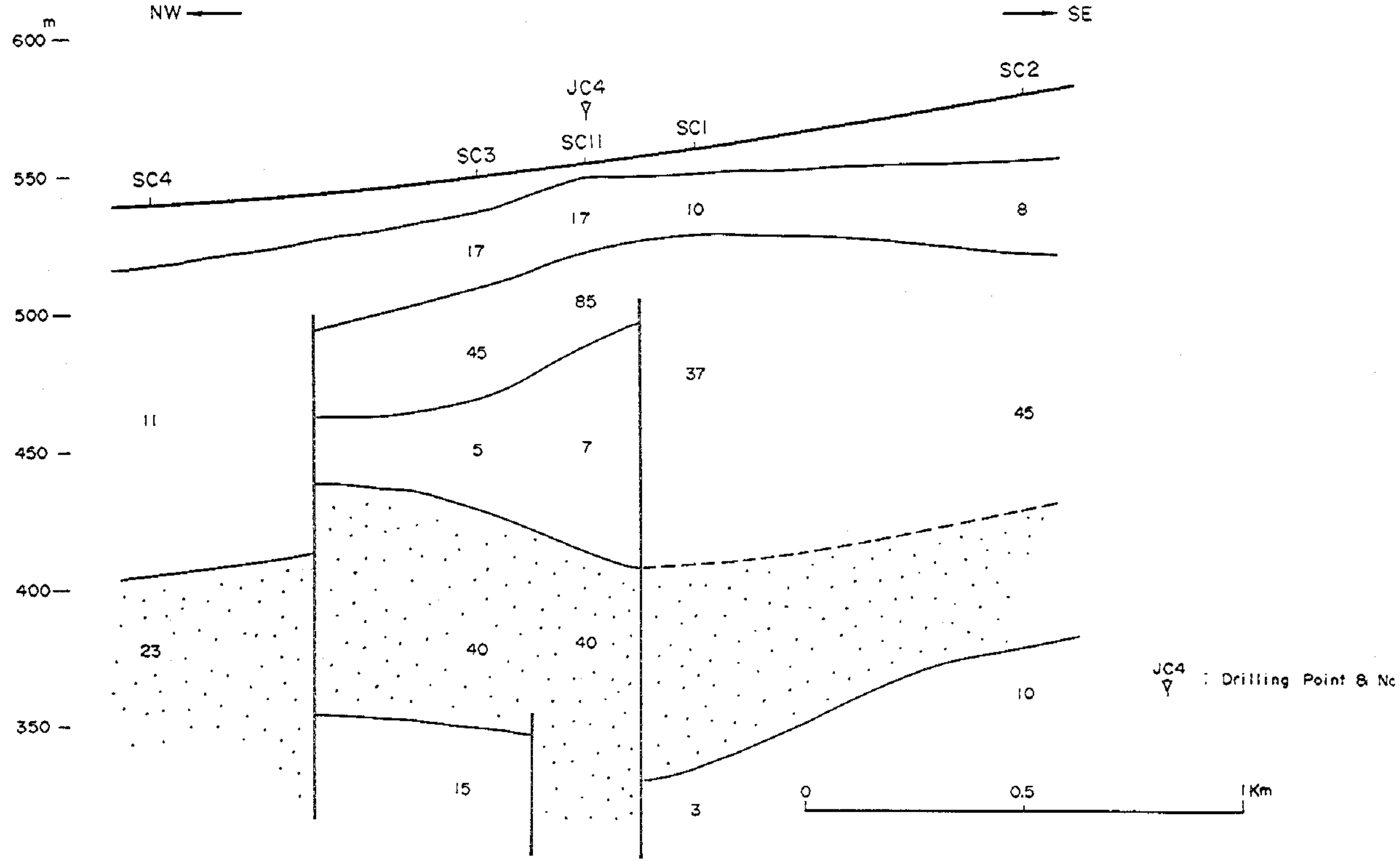


Figure 4-2-13 Resistivity Profile of San Carlos(1), Santa Cruz

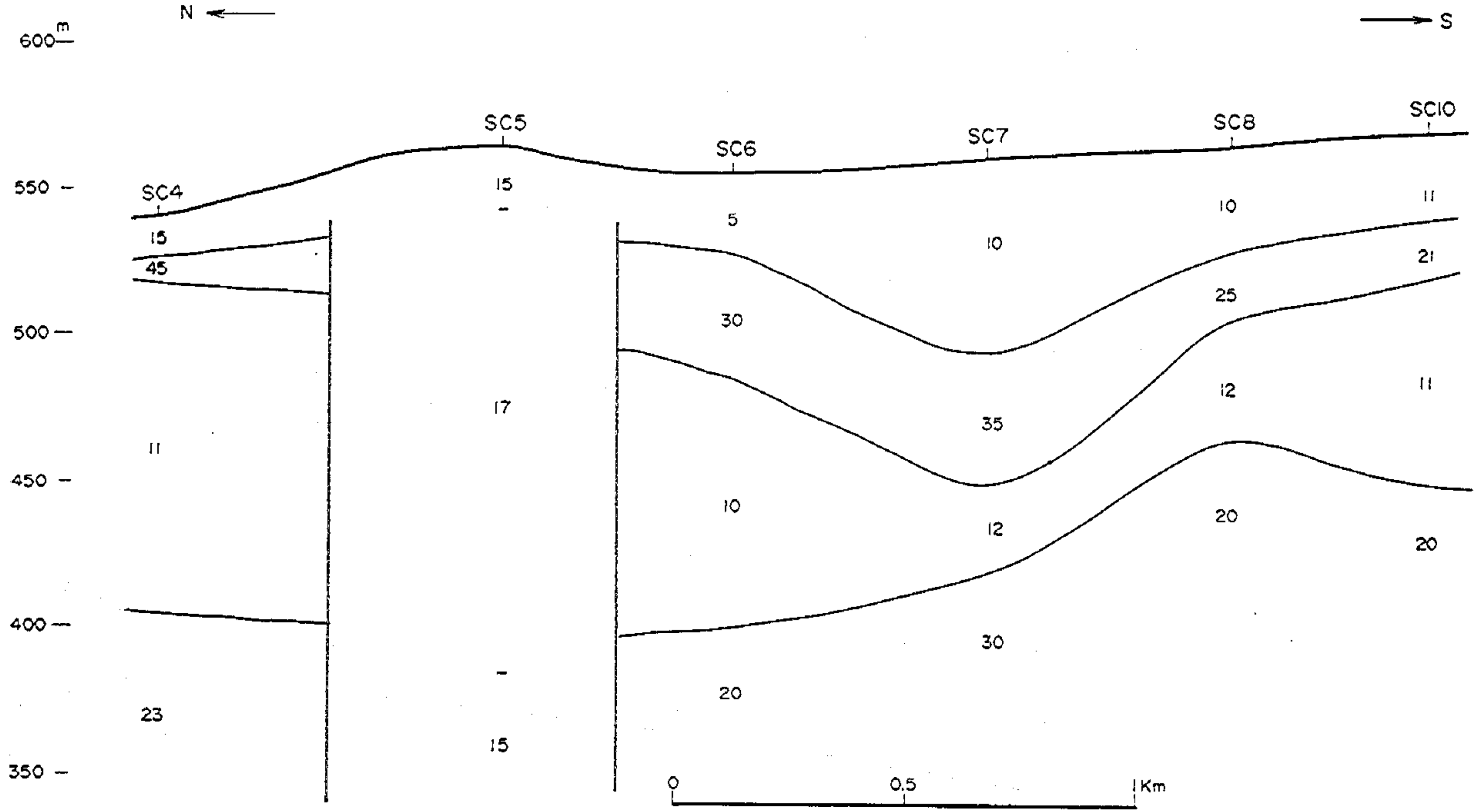


Figure 4-2-14 Resistivity Profile of San Carlos(2), Santa Cruz

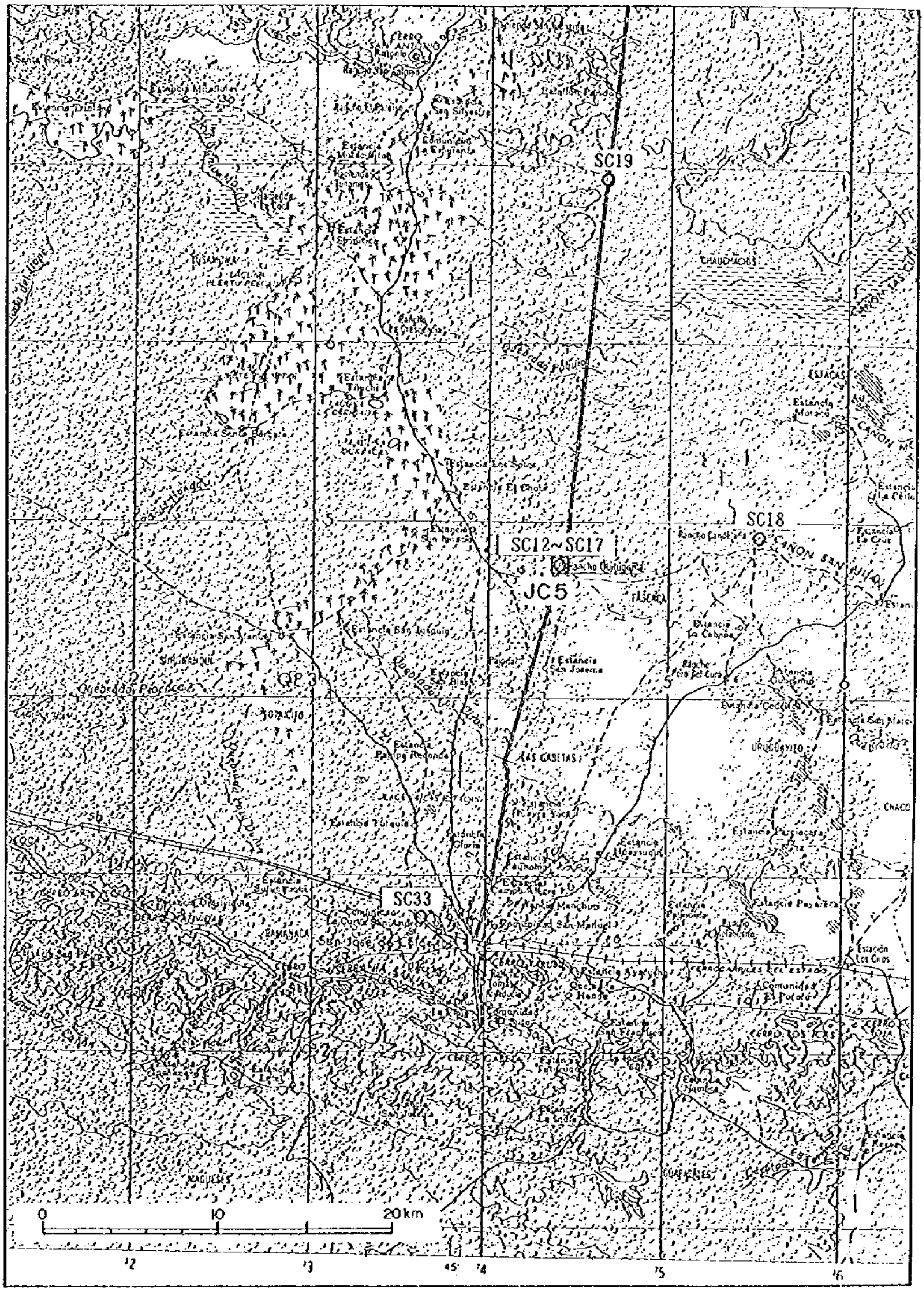


Figure 4-2-15 Location of Geophysical Points in Quituquina, Santa Cruz

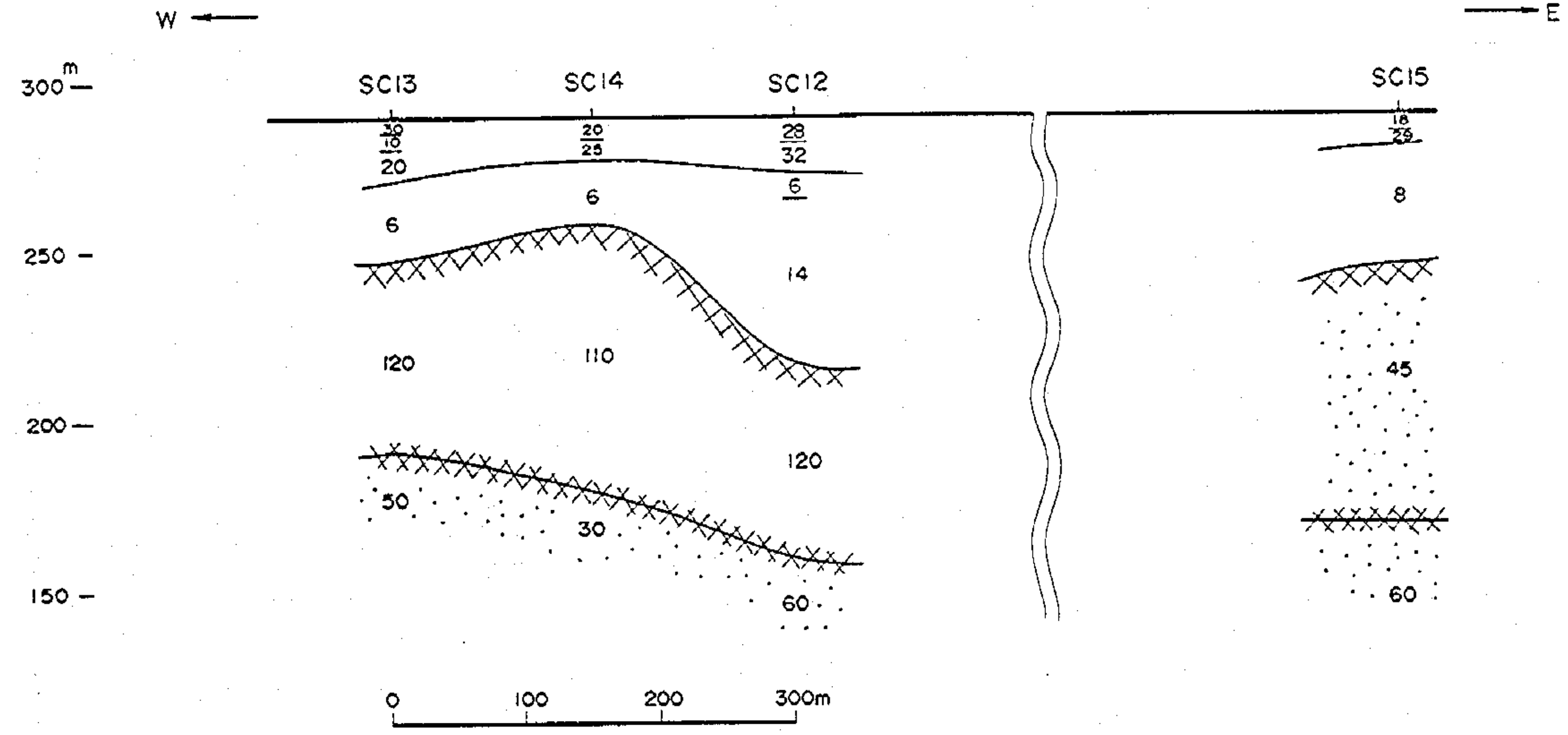


Figure 4-2-16 Resistivity Profile of Quituquina(1), Santa Cruz

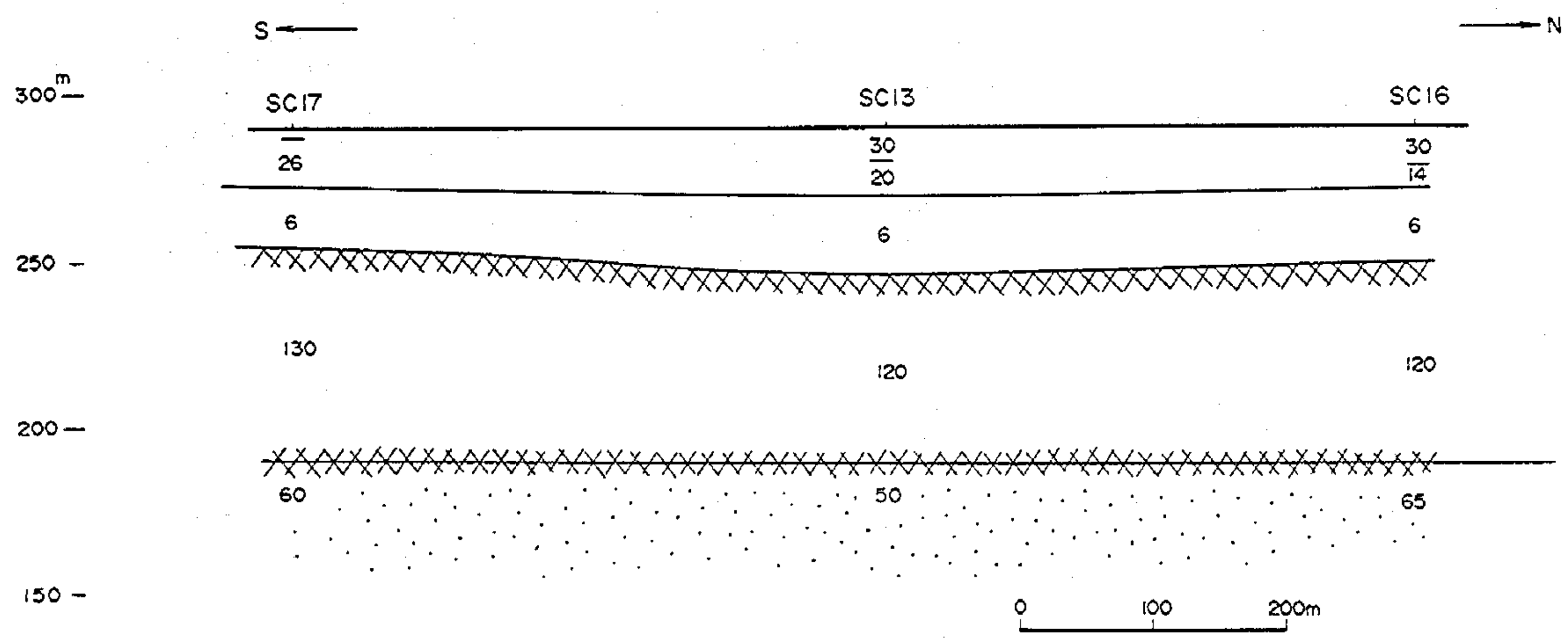


Figure 4-2-17 Resistivity Profile of Quituquina(2), Santa Cruz

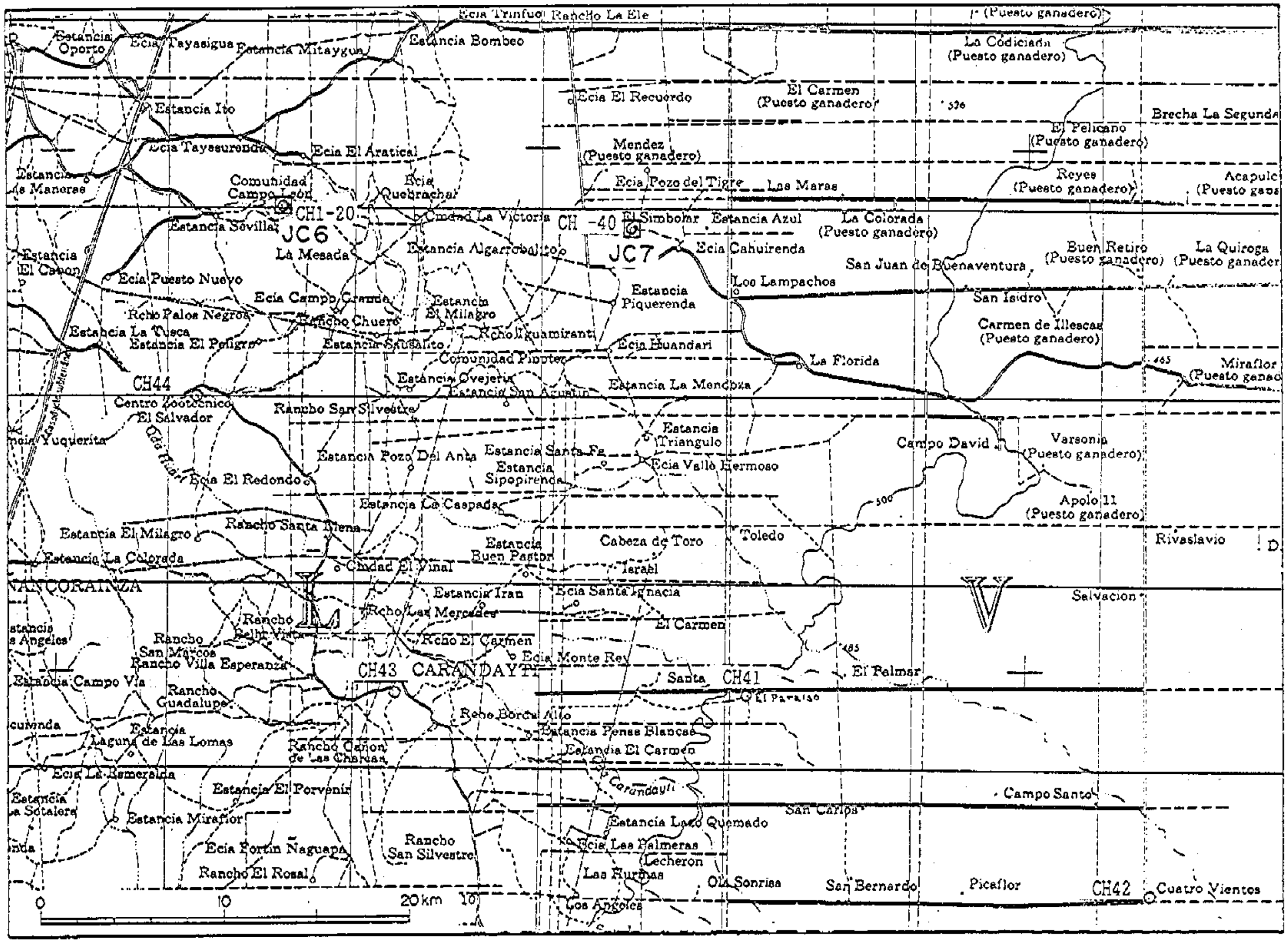


Figure 4-2-18 Location of Geophysical Points in Chaco, Chuquisaca

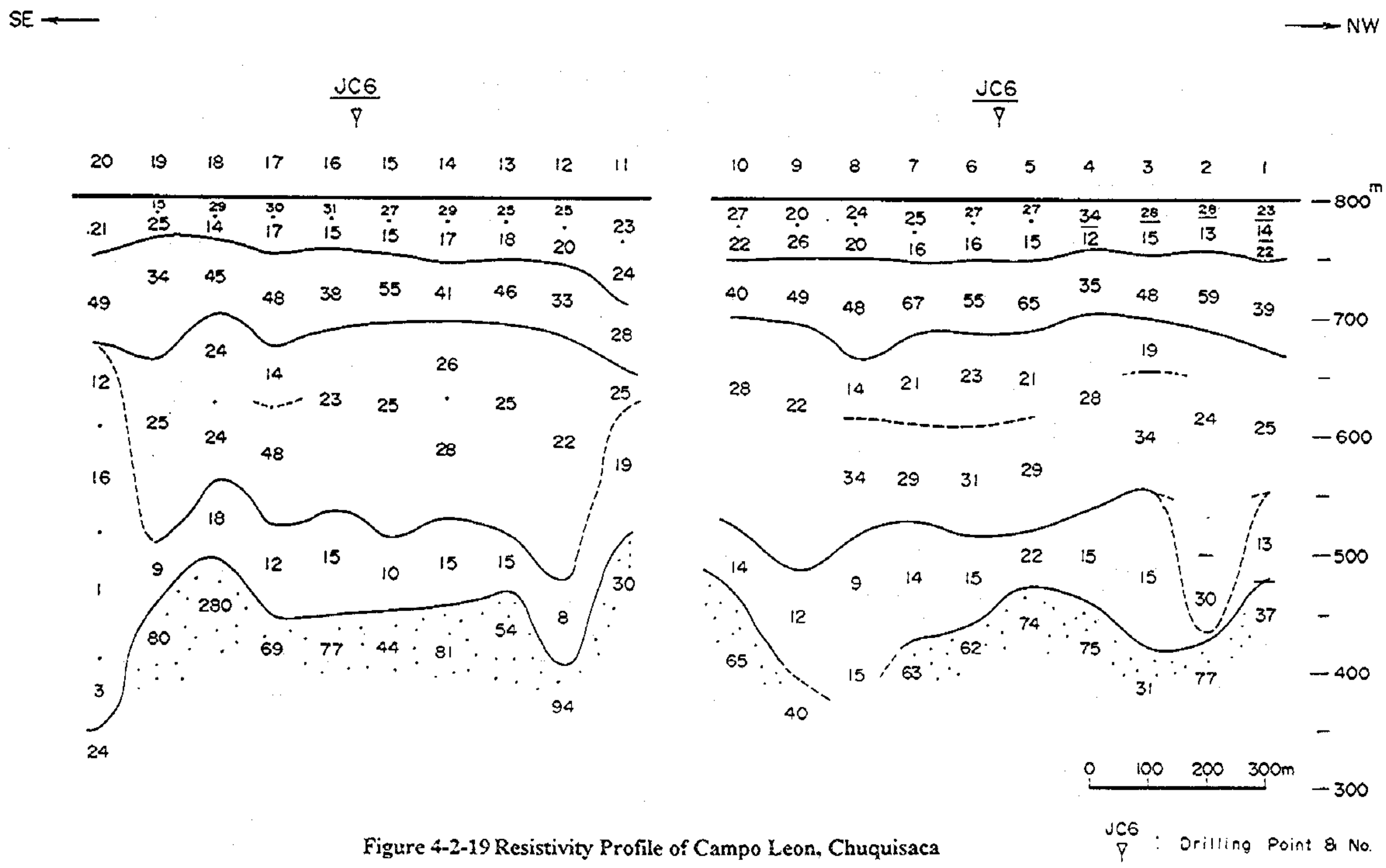


Figure 4-2-19 Resistivity Profile of Campo Leon, Chuquisaca

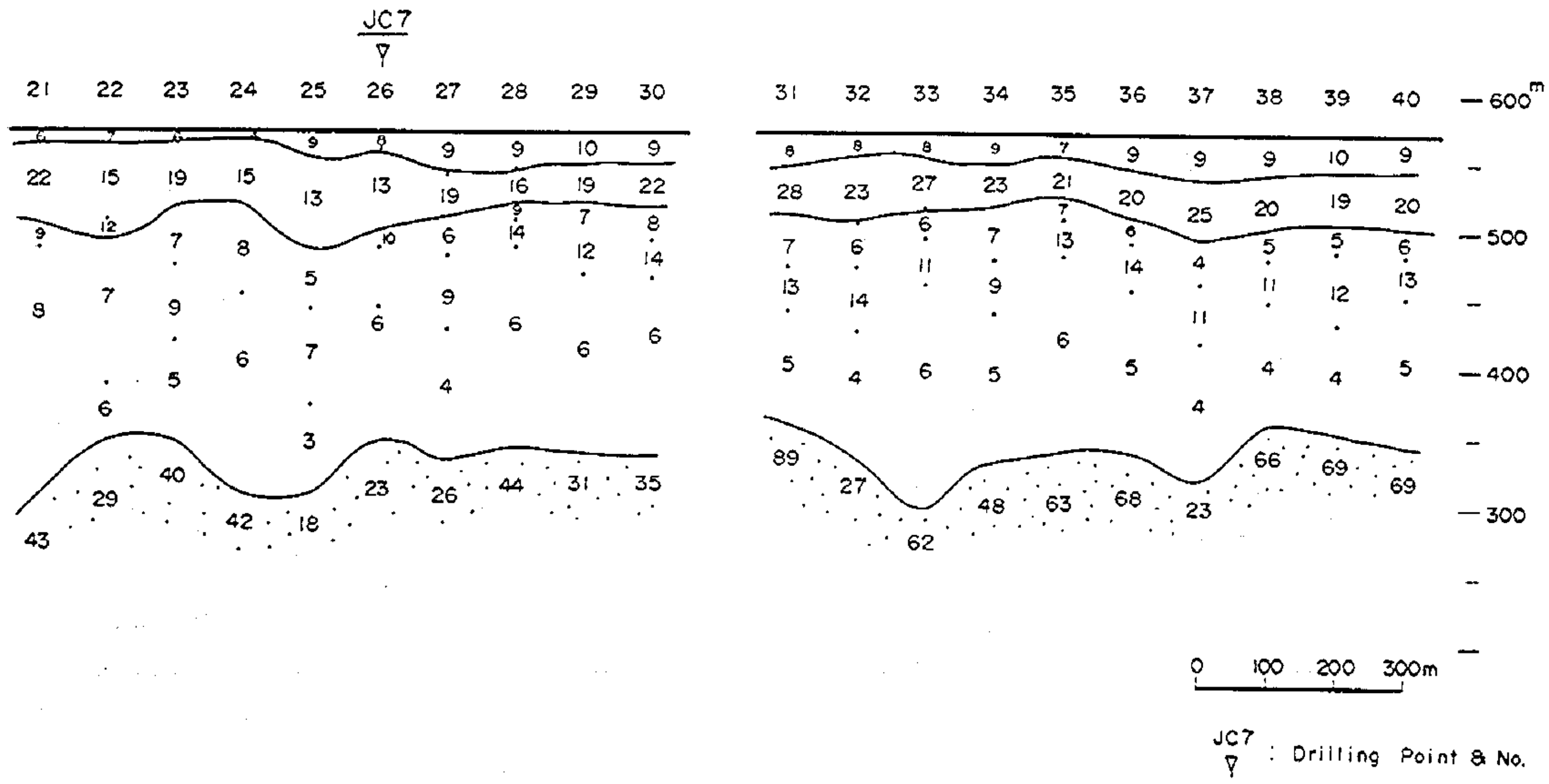


Figure 4-2-20 Resistivity Profile of Simbolar, Chuquisaca

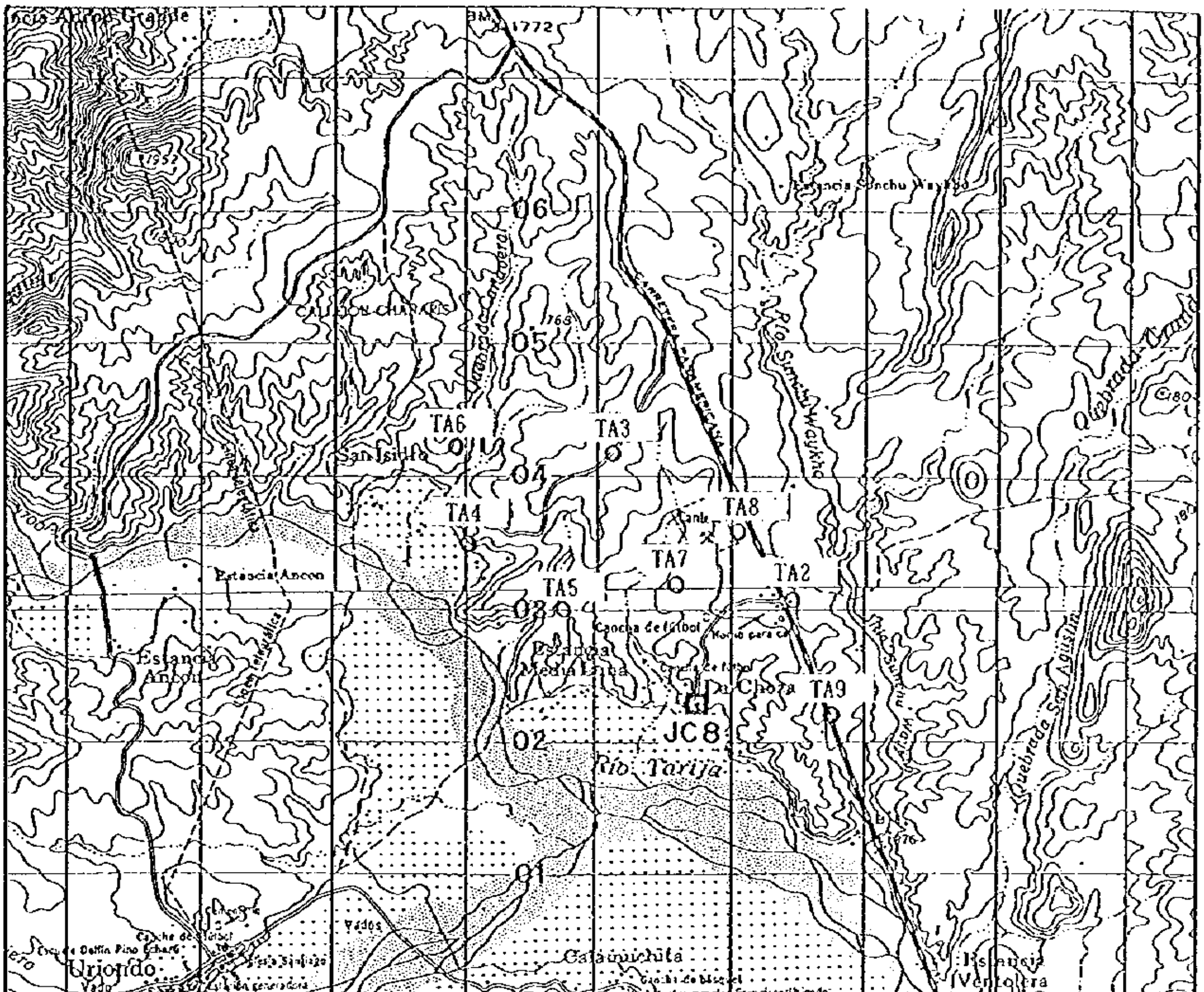


Figure 4-2-21 Location of Geophysical Points in La Chosa, Tarija

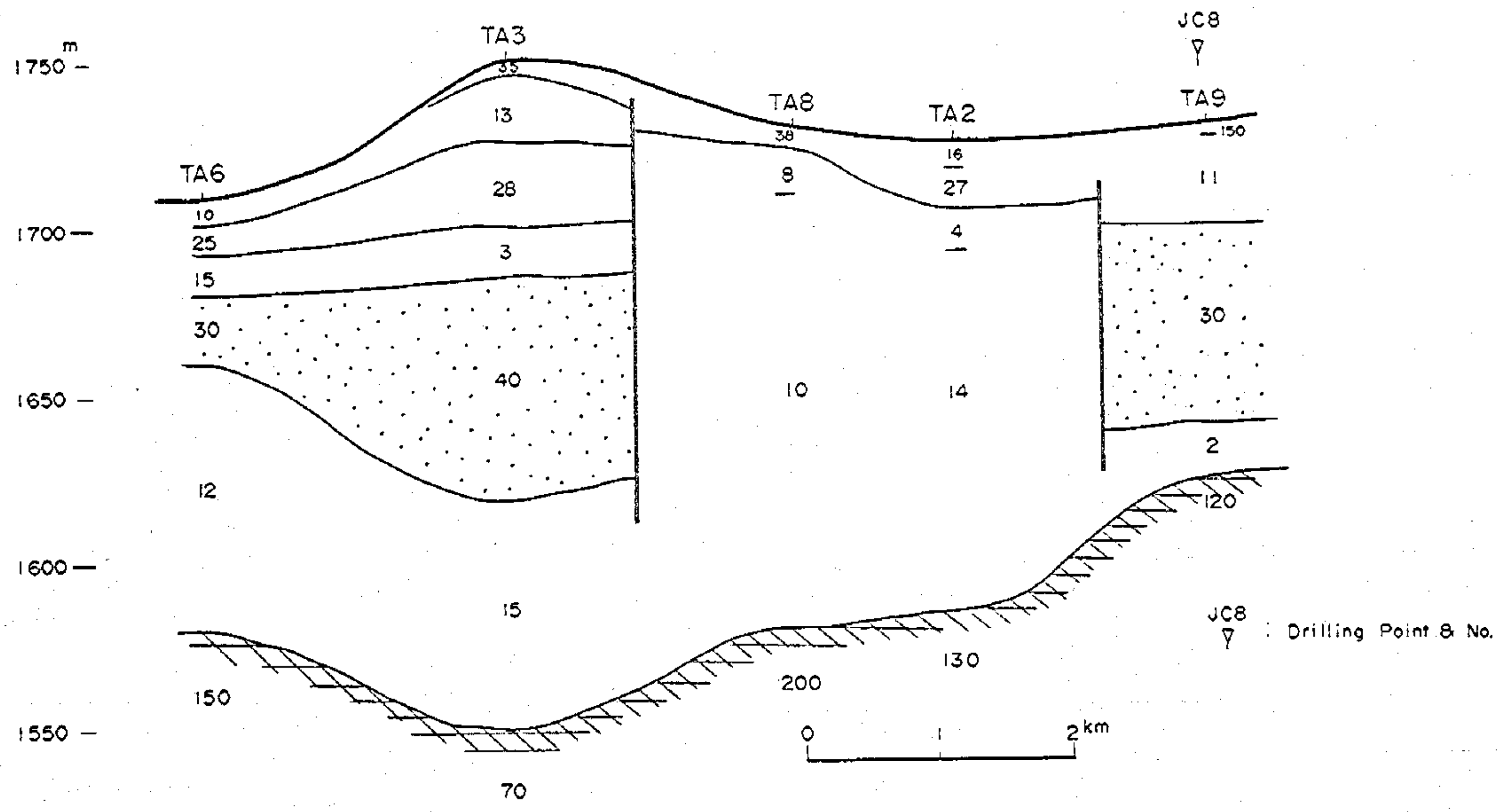


Figure 4-2-22 Resistivity Profile of La Chosa(1), Tarija

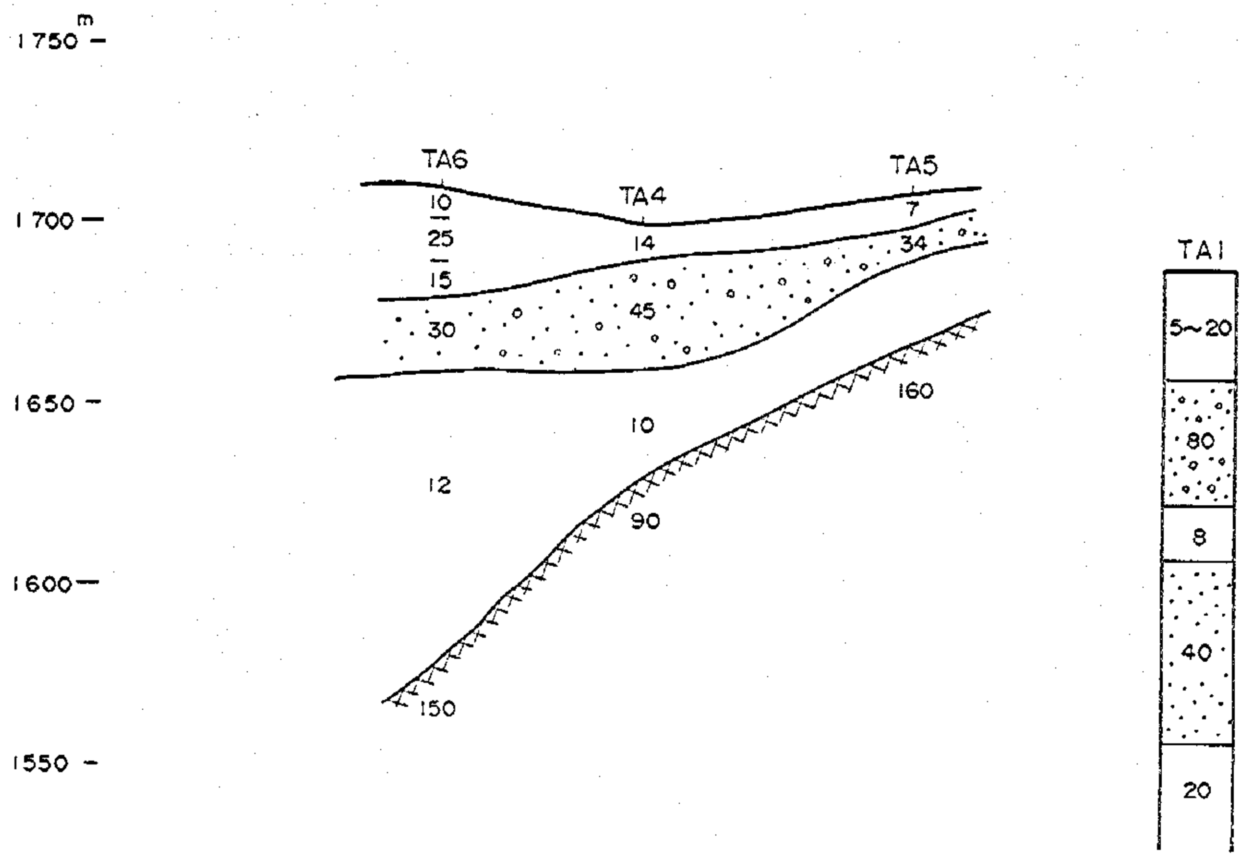


Figure 4-2-23 Resistivity Profile of La Chosa(2), Tarija

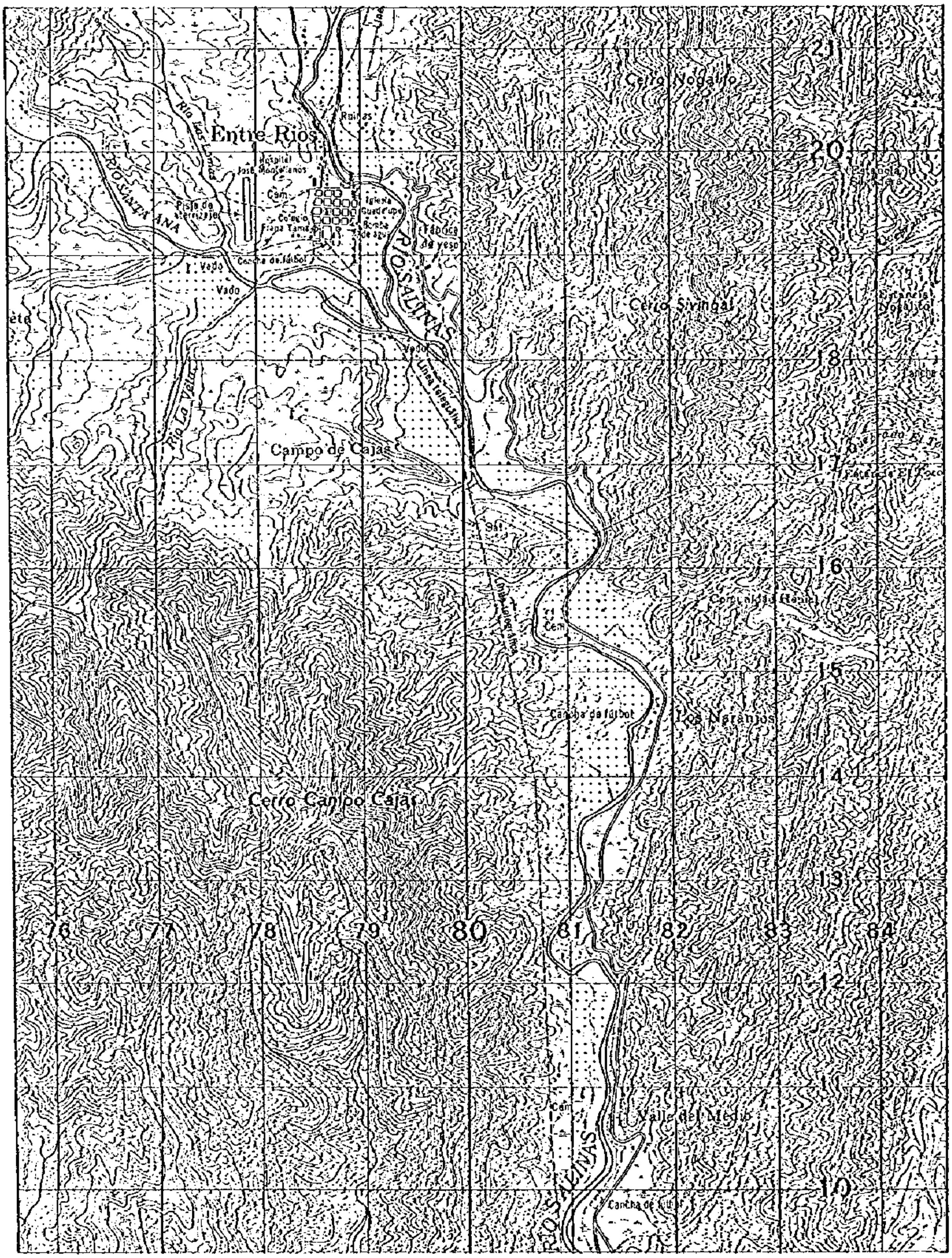


Figure 4-2-24 Location of Geophysical Points in Naranjos, Tarija

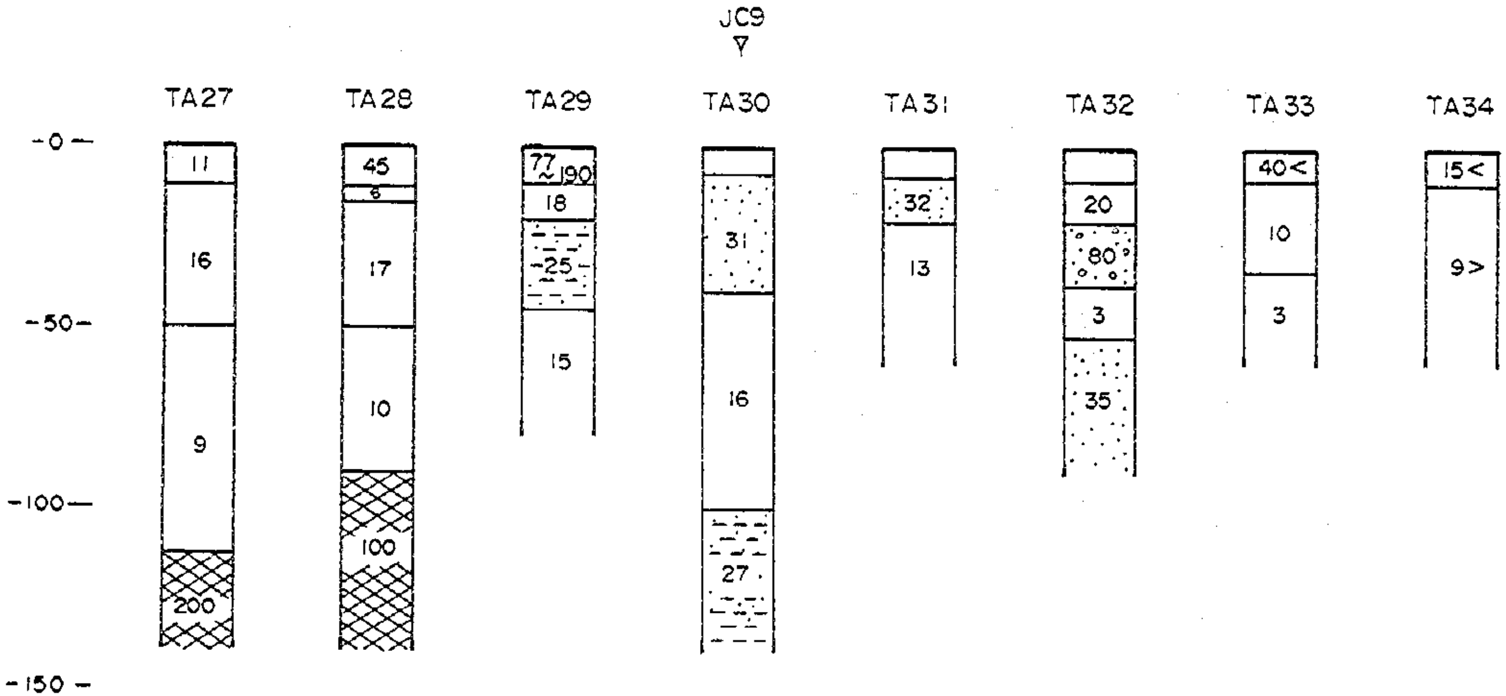


Figure 4-2-25 Resistivity Profile OF Naranjos, Tarija

4.2.2 Test Well Drilling

1) Outline of the Survey

In order to check the geological structure and groundwater properties in the Study Areas, test boring surveys were carried out at the 9 locations shown in Figure 4-2-25. Tables 4-2-3~4 show the survey points and an outline of the drilling work. The surveys were carried out by commissioning the work to local drilling firms. After drilling the pilot hole, electrical logging was performed to determine the screen insertion positions. The main hole was then drilled, screens and casings were inserted, and gravel was filled between the casings and the well wall of the borehole. Thereafter, washing of the borehole, stepwise pumping tests, continuous pumping tests, and recovery tests were performed and hydraulic constants were calculated.

Although Campo Grande was initially planned for JC-9, the point was moved to Naranjos because of difficulties in drilling due to the abundance of cobble. Also, although drilling to 150m was scheduled for JC-8 and JC-9, drilling was interrupted at 127m at both sites, the reason being the spontaneous flowing out of groundwater in the case of JC-8 and the accidental collapsing of the bit in the case of JC-9.

Table 4-2-3 Location of Test Wells

	Block No.	Department	Province	Block	Coodination		Altitude
					Latitude	Longitude	(m)
JC-1	213003401	La Paz	Aroma	Patacamaya	17 14 38 S	67 54 00 W	3,800
JC-2	403000101	Oruro	Carangas	Corque	18 20 35 S	67 40 42 W	3,730
JC-3	406000701	Oruro	Poopo	Huacuyo(Penas)	18 41 59 S	66 44 26 W	3,790
JC-4	701030130	Santa Cruz	Andres Ibanes	San Carlos	17 58 33 S	63 19 02 W	555
JC-5	705010104	Santa Cruz	Chiquitos	Quituquina	17 39 05 S	60 42 03 W	290
JC-6	110030309	Chuquisaca	Luis Calvo	Campo Leon	20 31 39 S	63 08 35 W	800
JC-7	110030307	Chuquisaca	Luis Calvo	Simbolar	20 31 19 S	62 56 48 W	570
JC-8	604010707	Tarija	Avilez	La Choza	21 40 45 S	64 36 59 W	1,685
JC-9	606011601	Tarija	Burnet O'connor	Naranjos	21 34 16 S	64 3 36 W	1,250

Table 4-2-4 Outline of the Test Boring Surveys

Point No.	Department	Community	Term of Drilling	Drilling Firm	Rig Model
JC-1	S. La Paz	Patacamaya	08.11.95~23.11.95	GEOBOL	TH-60 USA
JC-2	Oruro	Corque	21.09.95~03.11.95	GEOBOL	R-36 USA
JC-3	Oruro	Penas	25.11.95~20.12.95	GEOBOL	TH-60 USA
JC-4	Santa Cruz	San Carlos	23.08.95~01.10.95	HIDROSUR	LEE MOORE USA85
JC-5	Santa Cruz	Quituquina	18.10.95~17.12.95	HIDROSUR	LEE MOORE USA85
JC-6	Chuquisaca	Campo Leon	24.08.95~26.10.95	HIDROSUR	WILSON USA 79
JC-7	Chuquisaca	Simbolar	03.11.95~24.11.95	HIDROSUR	WILSON USA 79
JC-8	Tarija	La Chosa	15.09.95~12.10.95	HIDROSUR	FAILING USA75
JC-9	Tarija	Naranjos	12.12.95~04.02.96	HIDROSUR	FAILING USA75

These comunidads have a characteristics as mentioned below:

Patacamaya is a town located at the eastern edge of the Altiplano and built on a fan comprised of Quatenary gravel supplied from "Cordillera Oriental."

Corque is a town situated between the two mountain ranges which rise from the central part of the vast plain of the Altiplano. The mountain ranges extend continuously in the north-south direction and a flat, sandy formation is deposited between the mountain ranges. The "stratum water" at the lower limit of the sandy formation and the "fissure water" in the Tertiary system beneath the sand layer may be anticipated as potential groundwater sources. Data can be obtained to confirm whether or not the development of the "fissure water" in the bedrock is possible in the plain area of the Altiplano, where the groundwater in shallow underground locations is extremely high in salinity.

Penas is located on a river terrace at the foot of a mountain at the eastern edge of the Altiplano. Bedrock, comprised of the Silurian system, exists below the river terrace and the "stratum" water at the bottom of the river terrace and the "fissure water" in the Silurian system can be anticipated as potential groundwater sources. Whether or not development aiming at the "fissure water" in the bedrock of the Altiplano is possible can be confirmed here also.

La Chosa is located in a basin in "Cordillera Oriental." Areas of similar topgraphy dot "Cordillera Oriental" and these are areas where lake water flowed out from the bottom of a lake in ancient times. The geology of the surface at La Chosa consists of lake bottom sediments of an ancient lake. The fine-grain geology at shallow underground locations does not accompany an aquifer and the salinity of the groundwater is high. However, the existence of a gravel layer at the lower limit of the lake bottom sediments can be anticipated from the geological structure of neighboring areas and groundwater of good quality can be expected from this gravel layer. The base rock structure around La Chosa is favorable for the formation of a gravel layer at the lower limit of the lake bottom sediments and is advantageous in terms of groundwater flow mechanisms as well.

Naranjos is located in "Seranias Sub-Andinas" and is a district that is shifted slightly toward the Bermejo river system side from the watershed of the Bermejo river system and the Pilcomayo river system. Since the areas where a community can be formed are restricted due to the continuation of extremely steep landforms in "Seranias Sub-Andinas," communities are not necessarily formed at a location where surface water or groundwater can be obtained easily. Naranjos has been selected as a district favorable for the development of the "fissure water" in the bedrock in "Seranias Sub-Andinas," where there are restrictions in the locations where communities are formed.

San Carlos is located at the western edge of the plain zone. The geology of the surface consists of fine-grain sand with Quaternary silt. In this district, the groundwater either does not exist at depths of 130 m and shallower or accompanies offensive odors. However in terms of geological structure, the area around San Carlos is one in which the base of the Quaternary system accompanies rough-grain sand or gravel and is favorable in terms of groundwater recharge and advantageous for development aiming at the "fissure water" in the base rock. The "stratum water" at the base of the Quaternary system and the "fissure water" in the Tertiary base rock can thus be anticipated as potential groundwater sources.

Quituquina is located at the eastern edge of "Llanura Chaco-Beniana" and between "Escudo Central" and "Las Sernias Chiquitanas." Since the groundwater from shallow, hand-dug wells in this area accompanies metallic elements, the purpose of a test well here would be to check the conditions of the groundwater in the Ordovician system that comprises the bedrock.

Campo Leon is located in the western part of "Llanura Chaco" called the "costa." This is a district where the aquifer depth and the static water level of groundwater are both extremely low. In the dry season, domestic water can be obtained only from ponds called "atajado" and even these dry up in the last few months of the dry season.

Simbolar is located east of Campo Leon, at the western part of "Llanura Chaco" called the "llano." Although the domestic conditions here are similar to those of Campo Leon, the aquifer depth and the static water level of groundwater are somewhat shallower than those at Campo Leon.

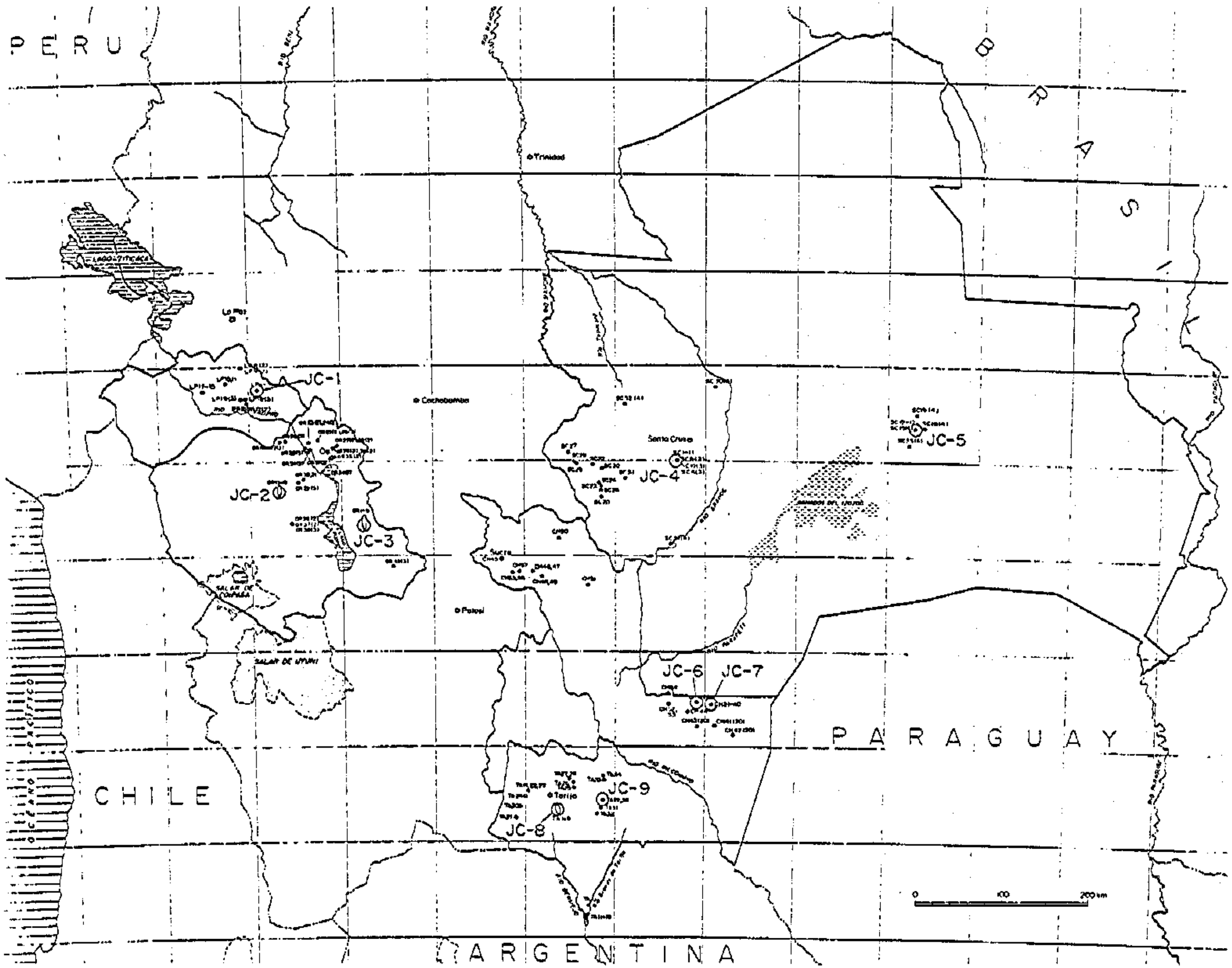


Figure 4-2-26 Location of Test Well Sites

2) Results of the Test Wells

The results of test well drillings are shown in Tables 4-2-5.

Whereas the per-second-yield obtained was 4.0 liters for JC-1, 2.0 liters for JC-2, 2.0 liters for JC-3, 10 liters for JC-4, 0.7 liters for JC-5, 2.25 liters for JC-6, and 7.55 liters for JC-8. Water was not obtained from JC-7 and JC-9. The geology at JC-5 was mudstone and a satisfactory aquifer could not be found up to the drilling depth. The hydraulic constants calculated from the results of the pumping tests are as shown in Table 4-2-6. Periods of drilling works in each site are shown in Table 4-2-7.

The surveys required a term of 16 to 65 days from the arrival of equipment at the site to completion, and the drilling rate per month was 70 to 200m (overall average: 123 m).

The geology and the aquifer depths which were clarified by the test boring surveys were highly consistent with the results of geophysical prospecting, thus demonstrating the effectiveness of geophysical prospecting.

Table 4-2-5 Test Well Data

	Block No.	a:Diameter of Drl. of Drl.(mm)	b:Depth of Drl.H Drl.(mm)	C:Diame.of S/C S/C (mm)	d:Depth of S/C S/C (m)	Aquifer e(m) -	f(m)	Screen g(m) -	h(m)	i%,(g-f)/b	j:Geology	k:Static W.L. (m)	l:Yield (m^3/hr)	m:Dynamic W.L. (m)	n: Draw Down (m)sw	o:Elect. Con. micro-s/cm
JC-1	213003401	216.0	100.0	152.4	62.5	23.0 -	56.0	23.0 -	32.0	9.0%	sand, gravel,	13.4	14.4	27.2	13.8	
		-	-	-	-	-		36.0 -	42.0	6.0%	sandstone,	-	-	-	-	
		-	-	-	-	-		44.0 -	47.0	3.0%	conglomerate,	-	-	-	-	
		-	-	-	-	-		50.0 -	56.0	6.0%	mudstone	-	-	-	-	
Total						33.0		24.0		24.0%	-					
											sand, gravel,					
JC-2	403000101	216.0	100.0	152.4	87.0	42.0 -	66.0	42.0 -	45.0	3.0%	sandstone, mudstone,	6.5	7.2	26.1	19.6	
		-	-	-	-	-		57.0 -	66.0	9.0%	conglomerate	-	-	-	-	
Total						24.0		12.0		12.0%	-					
											sand, gravel,					
JC-3	406000701	216.0	100.0	152.4	66.5	25.0 -	51.0	29.0 -	50.0	21.0%	conglomerate,	7.2	7.2	29.0	21.8	
		-	-	-	-	-		54.0 -	60.0	6.0%	mudstone	-	-	-	-	
Total						26.0		27.0		27.0%	-					
JC-4	701030130	311.2	260.0	203.2	254.6	146.0 -	248.0	146.0 -	152.0	2.3%		57.5	36.0	93.0	35.5	655
		-	-	-	-	-		164.0 -	170.0	2.3%	sand/mud, sandstone,	-	-	-	-	
		-	-	-	-	-		191.0 -	197.0	2.3%	conglomerate,	-	-	-	-	
		-	-	-	-	-		213.0 -	219.0	2.3%	mudstone	-	-	-	-	
		-	-	-	-	-		242.0 -	248.0	2.3%		-	-	-	-	
Total						102.0		30.0		11.5%	-					

Table 4-2-5 Test Well Data

	Block No.	a:Diameter of Drl. (mm)	b:Depth of Drl.H Drl.(mm)	C:Diame.of S/C S/C (mm)	d:Depth of S/C S/C (m)	Aquifer e(m) - f(m)	Aquifer Screen g(m) - h(m)	Aquifer i %(g-f)/h	j:Geology	k:Static W.L. (m)	l:Yield (m^3/hr)	m:Dynamic W.L. (m)	n: Draw Down (m/sw)	o:Elect. Con. micro-s/cm
JC-5	705010104	311.2	200.0	203.2	197.6	95.0 - 195.0	117.0 - 123.0	3.0%	sand/mud, limestone,	32.5	2.5	122.5	90.0	5,320
		-	-	-	-	-	132.0 - 135.0	1.5%	sandstone,	-	-	-	-	
		-	-	-	-	-	142.0 - 145.0	1.5%	conglomerate,	-	-	-	-	
		-	-	-	-	-	149.0 - 155.0	3.0%	graywacke, dorelite,	-	-	-	-	
		-	-	-	-	-	162.0 - 165.0	1.5%	shale, mudstone	-	-	-	-	
		-	-	-	-	-	173.0 - 182.0	4.5%		-	-	-	-	
	Total					100.0	30.0	15.0%	-					
JC-6	110030309	311.2	411.0	203.2	405.6	306.0 - 361.0	306.0 - 312.0	1.5%		190.0	8.1	282.9	92.9	719
		-	-	-	-	-	319.0 - 328.0	2.2%		-	-	-	-	
		-	-	-	-	-	338.0 - 344.0	1.5%	sand/mud, sandstone,	-	-	-	-	
		-	-	-	-	-	352.0 - 361.0	2.2%	conglomerate,	-	-	-	-	
		-	-	-	-	-	365.0 - 368.0	0.7%	mudstone	-	-	-	-	
		-	-	-	-	-	383.0 - 386.0	0.7%		-	-	-	-	
		-	-	-	-	-	394.0 - 397.0	0.7%		-	-	-	-	
	Total					55.0	39.0	9.5%	-					
JC-7	110030307	311.2	258.0	203.2	171.6	40.0 155.0	99.0 102.0	1.2%		139.0	-	-	-	-
		-	-	-	-	-	112.0 - 121.0	3.5%		-	-	-	-	
		-	-	-	-	-	125.0 - 128.0	1.2%	sand/mud, sandstone,	-	-	-	-	
		-	-	-	-	-	138.0 - 141.0	1.2%	conglomerate,	-	-	-	-	
		-	-	-	-	-	156.0 - 159.0	1.2%	mudstone	-	-	-	-	
	Total					115.0	21.0	8.1%	-					

Table 4-2-5 Test Well Data

	Block No.	a:Diameter of Drl.	b:Depth of Drl.H	C:Diame.of S/C	d:Depth of S/C	Aquifer				k:Static	l:Yield	m:Dynamic	n: Draw	o:Elect.
							Screen			W.L.		W.L.	Down	Con.
		of Drl.(mm)	Drl.(mm)	S/C (mm)	S/C (m)	e(m) - f(m)	g(m) - h(m)	i:%,(g-f)/b	j:Geology	(m)	(m^3/hr)	(m)	(m)sw	micro-s/cm
JC-8	604010707	215.9	127.4	152.4	120.4	46.0 - 118.7	46.0 - 49.0	2.4%	sand, gravel,	+6.0	27.2	-	-	500
		-	-	-	-	-	51.0 - 54.0	2.4%	sandstone,	-	-	-	-	
		-	-	-	-	-	75.0 - 84.0	7.1%	orthquartzite, shale,	-	-	-	-	
		-	-	-	-	-	91.0 - 100.0	7.1%	mudstone, limestone	-	-	-	-	
		-	-	-	-	-	112.7 - 118.7	4.7%		-	-	-	-	
Total						72.7	30.0	23.6%	-					
JC-9	606011601	311.2	127.0	152.4	127.0	91.0 - 121.0	91.0 - 121.0	23.6%	-	-	-	-	-	
Total						30.0	60.0	23.6%	-					

Table 4-2-6 Hydrogeological Constants

	Block No.	a:Diameter of Dri of Drl.(mm)	b:Depth of Drl.(m)	k:Static (m)	l:Yield (m3/hr)	n: Draw (m)sw	p:Specific Cap. (m^3/day)	q:Transmissivity <T>	r:Hydraulic Cond. <K>	s:Storativity <S>
JC-1	213003401	216.0	100.0	13.4	14.4	13.8	1.04	0.463 x 10-3 m2/sec	0.0193 x 10-3 m/sec	-
JC-2	403000101	216.0	100.0	6.5	7.2	19.6	0.37	0.521 x 10-3 m2/sec	0.0434 x 10-3 m/sec	-
JC-3	406000701	216.0	100.0	7.2	7.2	21.8	0.33	0.069 x 10-3 m2/sec	0.0026 x 10-3 m/sec	-
JC-4	701030130	311.2	260.0	57.5	36.0	35.5	1.02	0.613 x 10-3 m2/sec	0.0204 x 10-3 m/sec	-
JC-5	705010104	311.2	200.0	32.5	2.5	90.0	0.03	0.002 x 10-3 m2/sec	0.0001 x 10-3 m/sec	-
JC-6	110030309	311.2	411.0	190.0	8.1	92.9	0.09	0.104 x 10-3 m2/sec	0.0027 x 10-3 m/sec	-
JC-7	110030307	311.2	258.0	139.0	-	-	-	-	-	-
JC-8	604010707	215.9	127.4	+6.0	27.2	-	-	-	-	-
JC-9	606011601	311.2	127.0	-	-	-	-	-	-	-

p:Specific Cap. = Specific Capacity
r:Hydraulic Cond. = Hydraulic Conductivity

3) Groundwater Quality

The water quality test results for the groundwater obtained at the test boring survey points are shown in Table 4-2-8. The groundwater at JC-5 was high in turbidity and concentration of soluble matter and was thus unsuitable as drinking water. Although the groundwater at JC-1 and JC-2 were somewhat high in iron concentration, the water quality items satisfied the drinking water quality standards of the Republic of Bolivia. The water quality of groundwater from other survey points also satisfied the drinking water quality standards and were low in turbidity and organic pollutants. Also, the concentrations of soluble matter were not particularly high in comparison to water from shallow wells. With the exception of JC-5, the conductivity was in the range, 380~830 $\mu\Omega$/cm, and the total hardness was in the range, 139~237 mg/l.

Table 4-2-7 Periods of Drilling Works

	Block No.	Department	Province	Block	a:Drill Method Method	b:Mobilization (days)	c:Drilling (days)	d:Logging (days)	e:Reaming (days)	een/Casing Install (days)	g:Developing (days)	h:Pumping Test (days)	i:Site Restoration (days)	j:Demobilization (days)	k:Working Term (days)	l:Machine G/H
JC-1	213003401	La Paz	Aroma	Patacamaya	R	2	7	1	-	1	1	3	1	-	16	G1
JC-2	403000101	Oruro	Carangas	Corque	R	2	35	1	-	1	1	3	1	-	44	G2
JC-3	406000701	Oruro	Poopo	Huacuyo(Penas)	R	10	7	1	-	1	1	3	1	2	26	G2
JC-4	701030130	Santa Cruz	Andres Ibanez	San Carlos	R	9	40	1	5	2	4	3	1	-	65	H1
JC-5	705010104	Santa Cruz	Chiquitos	Quituquina	R	6	39	1	5	1	4	2	1	2	61	H1
JC-6	110030309	Chuquisaca	Luis Calvo	Campo Leon	R	8	20	1	19	1	11	2	2	-	64	H2
JC-7	110030307	Chuquisaca	Luis Calvo	Simbolar	R	5	6	1	4	1	7	2	1	5	32	H2
JC-8	604010707	Tarija	Avilez	La Choza	R	8	12	1	10	1	-	-	1	15	48	H3
JC-9	606011601	Tarija	Burnet O'connor	Naranjos	R	10	20	1	14	1	1	2	1	5	55	H3

a:Drill Method = Rotary Method (R) or Percussion Method (P)
G1/H3 = "GEOBOL" or "HIDROSUR" & Machine No.

Table 4-2-8 Quality of Groundwater of Test Wells

項 目	JC－1 Patacamaya	JC－2 Corque	JC－3 Penas	JC－4 San Carlos	JC－5 Quituquina	JC－6 Campo Leon	JC－8 La Choza
Water temperature (°C)	16.00	–	13.00	27.7	24.9	30.3	20.5
pH	6.75	8.10	8.35	6.96	7.62	7.44	8.0
Color	–	–	–	3.0	98.0	12.0	5.0
Turbidity	clear	crystalline	clear	1.0	11.0	5.0	0.40
Total hardness (mg/l-$CaCO_3$)	138.4	236.17	119.18	363	217	137	271.4
Conductivity ($\mu\Omega$/cm)	386.2	831.81	415.9	733	5,350	719	500
Soluble matter (mg/l)	–	–	–	513	3.745	503	–
Alkalinity (mg/l-$CaCO_3$)	113.30	177.54	121.47	425	722	160	376
E. coli colonies (MNP/100ml)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ca (mg/ℓ)	32.4	63.44	30.75	105.0	43.4	46.0	–
Mg (mg/ℓ)	13.93	18.85	10.26	24.5	26.4	5.3	–
K+Na (mg/ℓ)	54.2	60.9	111.7	–	–	–	–
Fe (mg/ℓ)	3.19	2.30	0.32	0.04	2.85	0.08	ND
Mn (mg/ℓ)	–	–	–	0.00	0.00	0.00	–
Cl (mg/ℓ)	17.3	63.45	32.69	8.5	50.50	78.0	31.1
SO_4 (mg/ℓ)	51.08	63.27	44.82	13.9	1.524.2	124.0	175.0
HCO_3 (mg/ℓ)	113.30	177.54	102.79	88.3	34.2	11.5	412.0
NO_3 (mg/ℓ)	–	–	–	4.5	0.0	22.3	–
NO_2 (mg/ℓ)	ND	–	ND	0.01	0.00	0.17	ND