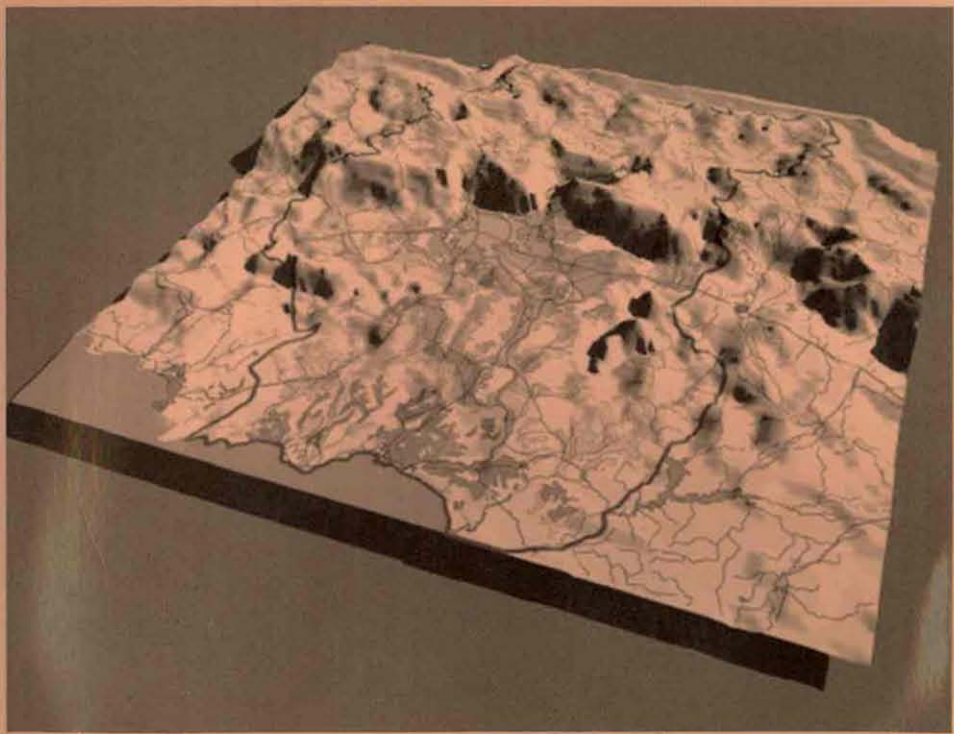


JAPAN INTERNATIONAL  
COOPERATION AGENCY  
(JICA)

THE STUDY  
ON  
AGRICULTURAL DEVELOPMENT AND WATER MANAGEMENT  
IN METROPOLITAN AREA

MAIN REPORT

August, 1999



NAIGAI ENGINEERING CO., LTD.  
ASIA AIR SURVEY CO., LTD.

R E P U B L I C O F C H I L E  
NATIONAL IRRIGATION COMMISSION  
(CNR)

JAPAN INTERNATIONAL  
COOPERATION AGENCY  
(JICA)

THE STUDY  
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AGRICULTURAL DEVELOPMENT AND WATER MANAGEMENT  
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**MAIN REPORT**

August, 1999

NAIGAI ENGINEERING CO., LTD  
ASIA AIR SURVEY CO., LTD

REPUBLIC OF CHILE

THE STUDY ON AGRICULTURAL DEVELOPMENT AND  
WATER MANAGEMENT IN METROPOLITAN AREA, CHILE

COMPOSITION OF FINAL REPORT

1. EXECUTIVE SUMMARY

2. MAIN REPORT

(Volume I)

PICTURES  
ABBREVIATIONS  
SUMMARY  
MAIN REPORT  
- PART I MASTER PLAN  
- PART II FEASIBILITY STUDY  
ATTACHMENT

3. ANNEXES

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ANNEX B SOIL AND LAND USE  
ANNEX C METEO-HYDROLOGY  
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ANNEX J AGRICULTURAL ECONOMICS  
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ANNEX N SCOPE OF WORKS

Exchange Rate

The exchange rate is as follows:

1.00 \$ = 0.002083US\$ = 0.2352Yen

August 1998

## P R E F A C E

In response to a request from the Government of Republic of Chile, the Government of Japan decided to conduct the study on Agricultural Development and Water Management in Metropolitan Area and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Chile a study team headed by Mr. Hisashi Terakado, Naigai Engineering Co., Ltd., three times between June 1998 and June 1999.

The team held discussions with the officials concerned of the Government of Chile, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Chile for their close cooperation extended to the team.

August 1999



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Kimio Fujita  
President

Japan International Cooperation Agency



▲ Large scale vineyard (Pirque)



▲ Cultivation of avocado (Mar a Pinto)



▲ Cultivation of *chirimoya* (Mallaraucé)



▲ Collecting and shipping center of strawberry (San Pedro)



▲ Direct sale shop by farmers (Talagante)



▲ Raising seedling facility managed by a production enterprise of small and medium scale farmers (El Monte)



▲ Milk collection facility of small scale dairy farmers (Maria Pinto)



▲ Raising seedling facility managed by a production enterprise of small and medium scale farmers (Isla de Maipo)



▲ Grassland irrigation by center pivot system



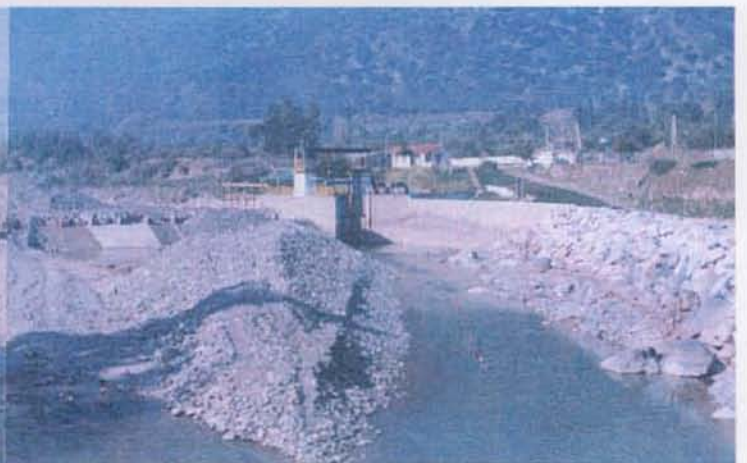
▲ Newly developed vineyard by a major winemaker (Casa Blanca)



▲ Setting nursery stocks of grape and prevention nets against small animals with tube irrigation



▲ Midstream of the Mapocho River where urban sewage is flew into



▲ Intake facilities of the first section of the Maipo River (Obra head works)  
Left; San Carlos canal for agricultural use, Right; intake canal for water supply managed by EMOS



▲ Traditional intake facilities (Downstream of the Mapocho River)



Traditional slit division works; the width of the slit is determined by the number of *acción*



▲ Intake facilities in the midstream of the Mapocho River (Mallarauco canal)



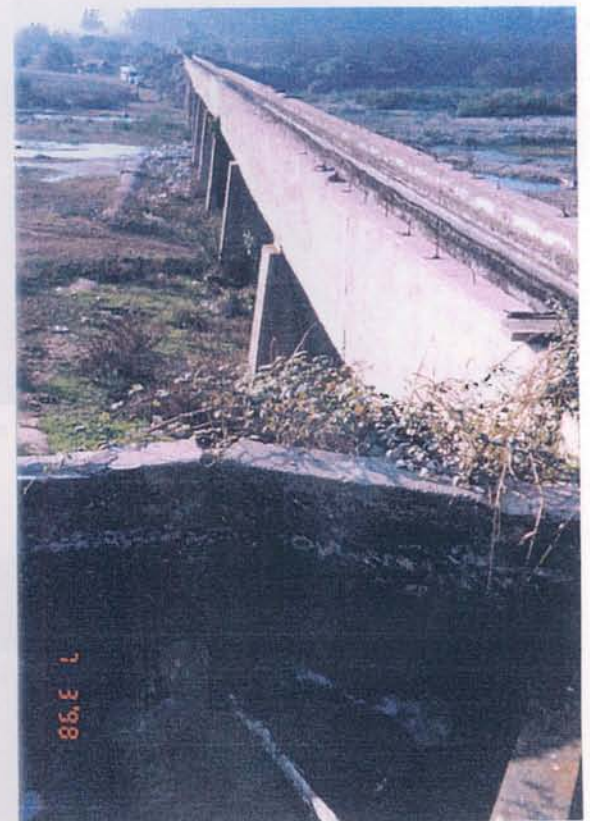
▲ Energy dissipator in the midstream of Mercedes canal



▲ Division works after the exit of the tunnel of Mallarauco canal



▲ Secondary canal and division works



▲ Aqueduct across the river



▲ Tertiary canal without lining



▲Proposed site for integrated intake weir in the upper stream (The third section of the Maipo River)



▲Proposed site for integrated intake weir in the lower stream (The third section of the Maipo River)



▲Proposed site for middle scale dam in Culipran area

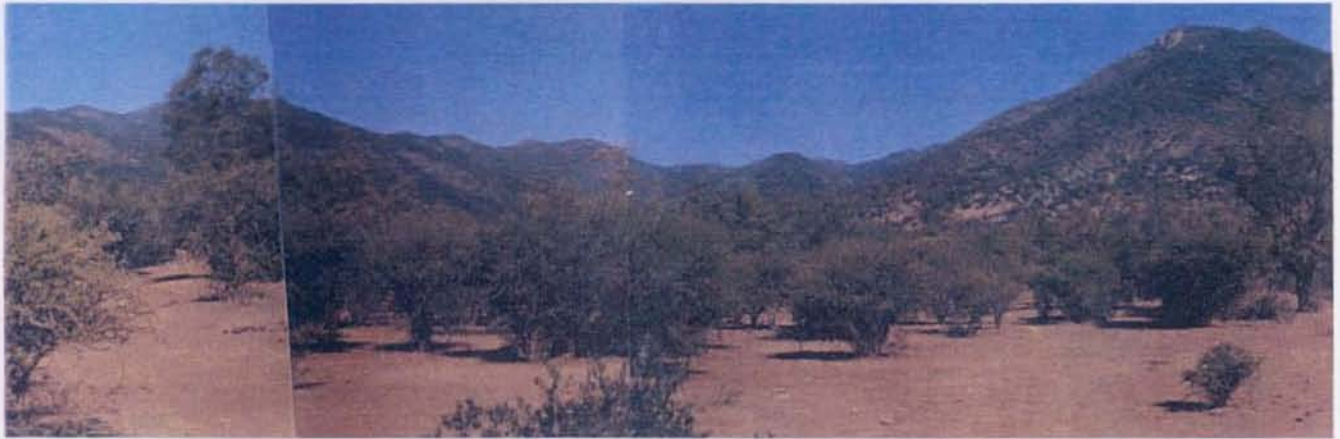


▲Proposed site for new irrigation area in Culipran area





▲Proposed site for new irrigation area in Popeta area



▲Proposed site for new irrigation area in Popeta area



▲Proposed site for new irrigation area in Alhué area



▲Existing large scale grape cultivation area in Yali area



▲Water contamination in the terminal part of Mallarauco canal



▲Water contamination in the terminal part of Mallarauco canal



▲Water contamination in the terminal part of Mallarauco canal



▲Farm pond for drip irrigation in Mallarauco area



▲Complete view of Mallarauco - Manzano area



▲Proposed site for a sewage treatment plant in Mallarauco - Reforma area



▲South main canal in Mallarauco - Las Carrera area



▲Proposed site for a sewage treatment plant in Mallarauco - Las Carrera area



▲Explanation and discussion on Inception Report



▲Signing for M/M on Ic/R



▲Explanation and discussion on Progress Report 1



▲Signing for M/M on Progress 1



▲Explanation and discussion on Interim Report



▲Signing for M/M on Interim Report



▲Explanation and discussion on Progress Report 2



▲Signing for M/M on Progress 2

## **ABBREVIATION**

### **Institutions and Organizations**

- AGCI Agency for International Cooperation of Chile
- BCC Central Bank of Chile
- CASEN Survey of Socioeconomic Characterization (Ministry of Planning)
- CEPAL Economic Commission for Latin America and the Caribbean
- CIREN Center of Natural Resources Information
- CNR National Irrigation Commission
- CONAF National Forest Corporation
- CONAMA National Environmental Commission
- COREMA Regional Environmental Commission
- CORFO Production Development Corporation
- DGA General Department of Waters
- DOH Department of Hydraulic Works (Former Department of Irrigation)
- DR Department of Irrigation
- EMOS Metropolitan Company of Sanitary Works
- ESSEL El Libertador Company of Sanitary Services
- ESVAL Valparaiso Company of Sanitary Works
- FAO Food and Agriculture Organization of the United Nations
- FOSIS Solidarity and Social Investment Fund
- FUCOA Foundation of Communications, Training and Farming Culture
- IDIEM Institute of Materials Testing Research
- IGM Military Geographic Institute
- INDAP Agricultural Development Institute
- INE National Statistics Institute
- INIA National Institute of Agricultural Research
- INN National Standards Institute
- IRM Intendency of the Metropolitan Region
- MINAGRI Ministry of Agriculture
- MI Ministry of the Interior
- MIDEPLAN Ministry of Planning and Coordination
- MINVU Ministry of Housing and Urbanism
- MOP Ministry of Public Works
- ODEPA Office of Studies and Agricultural Policy
- SAG Agriculture and Livestock Service
- SMAPA Municipal Service of Drinking Water and Sewer System
- PROMM Program of Medium and Small Irrigation Works
- SECPLAC Communal Secretariat of Planning and Coordination
- SEREMI Ministerial Regional Secretariat
- SERNAGEOMIN National Service of Geology and Mining
- UFOCO Union for the Development of Competitiveness
- MEFR Ministry of Economy, Development and Reconstruction

### **Others**

- \$ Chilean Peso
- US\$ United States Dollar

• B/C	Benefit Cost Ratio
• IRR	Internal Rate of Return
• SDR	Social Discount Rate
• NPV	Net Present Value
• EC	Electric Conductivity
• BOD	Biochemical Oxygen Demand
• DO	Dissolved Oxygen
• pH	Hydrogen Ion Concentration
• S.S.	Suspended Sediment
• mm	Millimeter
• cm	Centimeter
• m	Meter
• km	Kilometer
• g	Gram
• kg	Kilogram
• t	Ton
• m <sup>2</sup>	Square Meter
• km <sup>2</sup>	Square Kilometer
• ha	Hectare
• HRB	Hectáreas de Riego Básico ( = Basic Irrigation Area)
• m <sup>3</sup>	Cubic Meter
• MCM	Million Cubic Meter
• l	Litter
• l/s	Litter per Second
• m/s	Meter per Second
• m <sup>3</sup> /s	Cubic Meter per Second
• t/ha	Ton per Hectare
• %	Percentage
• °C	Degree Centigrade
• MSL	Mean Sea Level

Republic of Chile  
The Study on Agricultural Development  
and  
Water Management in Metropolitan Area, Chile  
Main Report

**S U M M A R Y**

**I MASTER PLAN STUDY**

**1 Introduction**

(1) Authority

The Government of Chile requested the Government of Japan to undertake a study on "Agricultural Development and Water Management in Metropolitan Area, Chile" in July 1996. The study aims mainly to formulate a master plan for agricultural development and water management reflecting upon environmental conditions in metropolitan area, Chile and to conduct a feasibility study for the agricultural development plan(s) in the priority project area(s). The study covers 3,200 km<sup>2</sup> of farm land located in outskirts of Santiago metropolitan area. In response to the request, the Government of Japan dispatched the Preparatory Study Team from November 3, 1997 to November 21, 1997 through JICA, and agreed on the Scope of Work for the Study. The study was conducted in two steps; Phase I and Phase II from June, 1998 to March 1999. During the Phase I study, master plan on the agricultural development in the whole study area was formulated. In the Phase II study, feasibility study on priority areas selected among the master plan was carried out. This report describes results of field study and detailed development plans derived from the analysis of present situation of the study area.

(2) Background

The Republic of Chile faces the Pacific Ocean of the South American continent and stretches about 4,300 km from south to north. Andian mountains are the east frontier by Argentine, the north is bordered by Peru and Bolivia, and the south reaches to the Antarctic Ocean. Total population is 15 million and GDP per capita is US\$ 5,000 in 1998. The secondary industry is mainstay of economical activities in Chile.

In the beginning of 1970s, economic policy of Chile advanced to the market oriented and open economy. Continuous economic growth is lasting at 6.4 % of average economic growth rate after overcoming the debt crisis in the beginning of 1980s. Recent national economy is also stabilized as shown in the economic parameters such as 8.2 % of inflation rate and 5.5% of unemployment rate. Agriculture and fisheries sector occupies around 7 % of GDP, 14% of employment and 10% of exports, and takes position which next to mining industry in the national economy. Agricultural development policy of the government toward 2000 puts stress on increase of agricultural production and export. And policy also aims at the balanced development of agriculture through supporting and strengthening of small scale farmers.

Agriculture in Chile has large varieties depending on the land condition derived from a long and narrow shape stretching from south to north. Metropolitan region having capital city of Santiago is the important areas of agriculture in the nation because of irrigation facilities provided for a long time, fertile soils and abundant variable climatic condition that is cultivable from sub-tropical till temperate crops. Since the late 1970s, metropolitan area has been expanded drastically with population growth and industrial development in the capital city of Santiago. This phenomena

causes urban sprawl and tightness of water utilization due to increase of demand such industrial water use as water works, hydraulic generation and mining industries.. Moreover, agriculture in the metropolitan area suffers on negative effects by contaminated irrigation water because kinds of crop cultivation are limited. Various water demand in the metropolitan area depends on surface water and groundwater in the Maipo river basin originated in the Andes mountains. According to the situation mentioned above, the evaluation of available water resources, optimum allocation of water, and the conservation of the basin environment have been recognized their necessities.

Reflecting these situations, the government of Chile has been started the study on "Maipo Project" in 1979 by the National Irrigation Commission as the competent authorities. Major objectives of the project were the water source development for the new irrigation scheme, the overall basin irrigation study contributing to the coordination and the management of the present water utilization on the Maipo river basin. The study consisted of four stages; to grasp the natural condition of the basin, to grasp the water demand of the basin, to establish the water utilization plan of the basin and evaluate the project. The first stage had been completed, however, the study had been suspended by the domestic affairs. Review of the first stage study results and the execution of the further stages are the urgent issues

### (3) Objectives of the Study

The objectives of the study are; to formulate a master plan for agricultural development and water management reflecting upon environmental conditions in metropolitan area, Chile, to conduct a feasibility study for the agricultural development plan(s) in the priority project area(s) and to carry out technology transfer to the Chilean counterpart personnel through on-the-job training in the course of the study.

### (4) Study Area

The study covers the Metropolitan Region and the part of V and VI Regions. Total area for the master plan is about 3,200 square kilometers, which consists of actual and potential irrigated areas.

## 2 The Present Situation of the Study Area

### (1) Rural society

Rural society in Chile was drastically changed from the simple structure, which there are the owners of large plantations and their labor farmers, by Agrarian Reform in 1962. The present rural society is a newly created society which consists of new and old landholders. Therefore, establishing communal society as an unity of inhabitants has been not matured, yet.

The names of administrative division; *Ciudad* (city), *Pueblo* (town), and *Aldea* (village) do not represent the community as a social unit but are just classifications by geographical location.

The unit of the most fundamental organization in rural society is Community Council (*Juntas de Vecinos* - JJVV) which is the divided organization of *Comuna* or the terminal organization of national administration. JJVV consists of those who have settled down there and are older than 18 years old. The unity of JJVV is called *Unidad Vecinal* (UV). The self-government right of both JJVV and UV is established, legally. JJVV is formed by territorially related connection and can be regarded as the community unit. Thus, hereafter, when the report says "community," it refers to JJVV. The communities in the study area are extended into main roads and shape row

communities.

Under JJVV which plays a main role as an organization, various activity groups such as improvement of education groups, volunteer activity groups and clubs are working. Moreover, there are canal associations and producers' organizations as farmers' organizations. These are not limited by UV but established as regional wide organizations by their purposes and functions.

(2) Administrative division and sub-basin division in the study area

According to the Census in 1992, the population in the study area was about 546,000 persons. While 96% of the total population concentrates in urban areas, 4% of those lives in rural areas. Administrative divisions are Region, Province, and *Comuna*. To grasp the basins' characteristics in the study, the study area is divided into 12 sub-basins by *Comuna* based on natural and agricultural conditions.

(3) Geology

Chile locates the part of volcanic and seismic zones in the Pacific Rim. The downgoing plate from the Pacific Ocean forms the upheaval of the Andes mountains and volcanic and seismic zones exist in the country. Geology in the study area consists of sedimentary and volcanic rocks which deposited from the Mesozoic Jurassic period to the Mesozoic Cretaceous period.

(4) Climate

The climate in the study area is the Mediterranean climate. Annual average temperature is 16°C and annual rainfall is 438mm. The rainy season is from April to September (fall / winter) and the dry season is from October to March (spring / summer). About 90% of total rainfall is concentrated in the rainy season.

(4) Land use

The study area is highly irrigated area and total area of its agricultural and livestock farming development is about 1,465,000ha. 68% of this is utilized for cultivation. The metropolitan area of Santiago in 1992 is about four times as much as that in 1940. The progress of this has been accelerated and the metropolitan area of Santiago has sprawled out, rapidly. So as to regulate this disordered expansion and sprawling, "The Metropolitan Area of Santiago Regulation Plan (*Plan Regulador Metropolitano de Santiago-SEREMI-MINVU 1994*)" was established. On the other hand, there is the system which enables to sell farmland as 0.5ha sub-divided housing lot. This strengthens the sprawling.

(5) Water resource

1) Surface runoff

The major rivers in the study area are the main and branch streams of the Maipo river. Relevant to water use in the area, the surface runoff from each sub-basin under the condition of average year and 85% probability of exceedance is calculated as the table below.

Item	Annual Average year (MMC)	85% Probability of Exceedance (MMC)
Total annual runoff	5,822.1	3,396.6
Oct. to Mar.	2,989.6	1,756.0
Apr. to Sep.	2,832.5	1,640.6



Item	Annual Average year (MMC)	85% Probability of Exceedence (MMC)
Runoff from the Andean Mountains	4,060.2	2,448.5
Oct. to Mar.	2,867.7	1,689.1
Apr. to Sep.	1,192.5	759.4
Runoff from areas except the Andean Mountains	1,761.9	948.1
Oct, a Mar,	121.9	66.9
Apr. to Sep.	1,640.0	881.2

Surface runoff in the study area can be estimated around 58 MCM in the average year. 70% of total surface runoff is supplied by thaw in the Andes Mountains, furthermore, 70% of runoff from the Andes Mountains concentrates upon summer, from October to March. Runoff from areas except the Andes Mountains is estimated around 17.6 MCM and 90% of total runoff generates by precipitation falling in winter from April to September.

## 2) Groundwater

As the results of calculation by obtaining from the executed survey on aquifer distribution, depth of aquifer and effective porosity, the potential yield of groundwater in the study area is estimated at about 26,000 MCM. Among this, Maipo-Mapocho groundwater unit occupies more than half of it, 22,000 MCM.

## (6) The present situation of water use

Water utilization in the study area is broadly divided into three categories, irrigation water use for about 180,000ha of farmland, drinking water supply for 5.5 million residents including Santiago city and the other industrial water utilization. This depends mostly on discharge from the upstream basin of the Maipo river.

Based on the required water for crops, the required irrigation water amount in the study area counts 4,370 MCM (surface runoff; 4,130 MCM, groundwater; 240 MCM). Including the return flow, about 2,460 MCM and about 2,240 MCM of surface runoff are used for irrigation in average year and 85% probability of exceedance. The water use for domestic water supply, and mining and the other industries is about 910 MCM. Among it, about 450 MCM of domestic use depends on the surface runoff of the Maipo river. On the other hand, during irrigation period, from October to March, the discharge from the upstream reach of the Maipo river is about 2,870 MCM and about 1,690 MCM in average year and 85 % probability of exceedance, respectively. The present utilization of surface runoff of the Maipo river has reached to its limit. Moreover, the tightness of water use leads to speculative acquisition of water right which focuses on the free trade of water right under the Law.

## (7) Water balance

So as to clarify the present water use, water balance study of each sub-basin is carried out under the condition of average year and 85% probability of exceedance on rainfall and surface runoff. Present water utilization in each basin is presented in the table below.

Sub-basin	Demand (a) (MCM)		Average		85% probability of exceedance	
	Irrigation	Others	Deficit (b) (MCM)	Ratio (b/a) %	Deficit (b) (MCM)	Ratio (b/a) %
1. Río Maipo Alt	65.798	3.190	0.000	0.00	0.000	0.00
2. Río Clarillo	140.478	0.620	0.000	0.00	3.048	0.02
3. Río Mapocho Alt	242.758	804.310	0.000	0.00	0.000	0.00
4. Estero Lampa	392.614	38.470	158.857	0.37	194.815	0.45
5. Río Mapocho Bajo	725.123	28.085	0.000	0.00	62.610	0.08
6. Río Angostura	1204.022	9.726	508.621	0.42	594.097	0.49

Sub-basin	Demand (a)		Average		85% probability of exceedance	
	(MCM)		Deficit (b)	Ratio (b/a)	Deficit (b)	Ratio (b/a)
	Irrigation	Others	(MCM)	%	(MCM)	%
7. Estero Albué	259.128	0.580	199.570	0.77	214.339	0.83
8. Melipilla	796.971	5.168	549.590	0.69	564.292	0.70
9. Estero Puangue	360.834	1.350	126.089	0.35	131.278	0.36
10. Estero Yali	39.495	0.690	5.746	0.14	7.315	0.18
11. San Antonio	13.625	7.010	7.855	0.38	8.774	0.43
12. Estero Casablanca	125.595	8.939	48.650	0.36	54.470	0.40
Total	4366.440	908.138	1604.978		1835.038	

### (8) General situation of agriculture

In the study area, various types of agriculture by irrigation is carried out. Especially, large amount of grapes for wine production, table grapes and deciduous fruit trees are cultivated. Moreover, cultivation of semi-tropical fruit trees (avocado, citrus) has been increased in the hillside of hilly area, recently. Main cultivation crops and livestock raising situation are shown in the table below.

Crops	'75-'76 Census (ha)	'97 Census (ha)
Cereals, Processing crops	67,391	31,748
Vegetable, Flower	23,686	25,885
Fruits	28,411	43,506
Vineyard	2,985	6,703
Seeds and seedlings	N.A.	5,898
Forage	28,979	30,619
Total	151,452	144,359

Source: Domestic agriculture and livestock, Recent trend and forecast, , CORFO, 1998

Animals	Head		%
	Metropolitan Region	National	
Cow	229,531	4,141,545	5.5
Sheep	60,544	3,710,549	1.6
Swine	643,066	1,722,403	37.3
Horse	40,016	415,184	9.6
Goat	21,005	738,183	2.8

Source: 1997 Census

### (9) Farmers and their agriculture

In the study, farmers are classified according to the landholding area as follows.

Landholding area (ha)	Name	Share in the study area (%)
0.5~15	Small scale farmers	74.7
15~100	Medium scale farmers	19.2
100 以上	Large scale farmers	6.1

Through the 12 sub-basins, farming in the study area can be summarized as following. In case of medium and large scale farmers, fruits growing or forage crop dominates their cultivation. While in case of small scale farmers, forage crop dominates their cultivation, then, vegetable and flower cultivation occupies the share in their cultivation.

### (10) Agricultural infrastructure

#### 1) Facilities

Irrigation system starts from the intake facilities in rivers or reservoirs. Then, the irrigation water flows through the settling basin, main canals, branch canals, and then to fields. Structures of existing intake facilities vary from concrete to gabion

and/or rock-fill. Its structural level differs from each other. Both main and branch canals in the study area are generally unlined. Even though lining entire canals might be effective against the leakage from canals, it is hard to be facilitated because beneficiaries have to bear the cost for the rehabilitation works and it affects the downstream areas where return flow is used as the irrigation water. The incentive to rehabilitate the facilities is low because water balance is considered in the area as a whole. The irrigation method in the fields is furrow irrigation generally, but the areas where suffers from shortage of water adopt water saving irrigation methods (Californian method, drip irrigation). Most of the areas, where groundwater is used for irrigation, adopt pumping irrigation.

## 2) Operation and maintenance of irrigation facilities

O & M of irrigation facilities is handed by canal associations (*Asociación de Canalistas*) which are established by farmers and approved legally. The associations manage canal facilities including intake structures. O & M cost is paid by the burden charge according to the number of water right, or *Accións* which hold the water users.

## (11) Market / Marketing

The Metropolitan Region is the central market of agricultural products domestically and also the consumption area. There can be seen economic activities of various industries concerned such as wholesalers, large scale retailers, exporters, processors and so on. The market which holds long history and traditional system has come not to adopt to the demand of the age, gradually. The market which has a new system such as wholesale market in Santiago city and a model market is planned. Generally, main buyers of agricultural products of small scale farmers in rural areas are middlemen, traditional wholesale markets and livestock markets. Selling to middlemen on the fields is one method, but its price is low. Direct sale along with roads is also often seen. Moreover, there is another selling method that farmers pay from 2 to 7% commission to intermediaries or traders with special contracts.

## (12) Agricultural support

Government agencies concerned with agricultural support are MOP (Ministry of Public Works), MINAGRI (Ministry of Agriculture), and MEFR (Ministry of Economic Promotion and Reconstruction). Main support programs are providing information, establishment of organizations, technology transfer, providing credit and so on. The objects of the programs are farmers of all classes, but especially small scale farmers are put stress on. Nevertheless, the support system by public institutions is not enough from the aspect of personnel and budget. The fundamental condition to be provided the support from these institutions is holding water right. The applicants of the INDAP projects which is the support institution of small scale farmers have following limitations; they must be farmers who hold water right of 0.5 ~ 12ha irrigate area, the beneficiaries should be organized, and the project plan has already formulated and so on. The financial support for small scale farmers whose access to general financial institutions such as city banks is weak is executed by government agencies concerned such as INDAP and PROMM. INDAP provides long term credit for investment in facilities and short term credit for cropping budget. PROMM provides financial and technical support for irrigation at the same time.

## (13) NGOs

From the point of agricultural support, there are about 800 active NGOs (Non Governmental Organizations). In the study area, there are 450 organizations, and two of them are working on the field of agriculture concerned.

#### (14) Farmers' organizations

As farmers' organizations, there are canal associations, their upper organizations, farmers' association, producers' organizations and so on. However, there is not a cooperative including functions such as selling and purchasing, and providing credit. The farmers' association is the organization for protecting farmers' right but its activities are stopped at present. Producers' organizations are established by small scale farmers who hold less than 15ha land according to the purpose of production. They are working as *Asociación Gremial de Pequeños Agricultores* (small scale farmers production organization) and organizations provided the support from government agencies concerned.

#### (15) Rural infrastructure

On the whole, installation ratio of basic infrastructure is high. Nevertheless, installation of water supply facilities and sewerage system are behind in regional rural areas, especially mountainous areas.

#### (16) Environment

##### 1) Environmental administration

The national steps to solve environmental problems are carried out by the Fundamental Law of Environment, systematically and CONAMA (National Environment Committee), institutionally.

##### 2) Designated area for protection

In the study area, there are four conservation areas, one natural monument, four protection areas, and three sanctuaries. Among them, Estero el Yali, which belongs to conservation areas, was registered as the marsh of the Ramsar Convention.

##### 3) Environmental pollution

The metropolitan area has took pride in its traditional characteristics of the particular scenery which urban areas and farmland are closely located. Transformation of farmland into housing lots or industrial areas with urban population growth impacts on not only change of the scenery but also on regional environment, ecologically. Furthermore, lack of proper sewage treatment system in Santiago city leads to contamination of irrigation water by urban sewage. This results in prohibition of some kind of vegetable cultivation by using surface flow of water entire part of the study area. According to this situation, sewage treatment plan in Santiago city which targets at 2024 has been established by EMOS. In the plan, Santiago city is divided into three treatment plant sections and three improvement stages (starting from 2001, 2004, and 2009). Treatment of sewage starts to implement, gradually. The third stage will be terminated in 2024.

### 3 Constraints and Development Potentials on Agricultural Development

According to the results of the study on the present condition, the problems on the agriculture in the study area can be summarized in following four points.

#### (1) Disparity caused by landholding scale

- The landholding structure in the study area is distorted. 6% of landowners who hold more than 100ha farmland occupy 86% of total farm land in the study area and more than 80% of landowners who hold less than 15ha

- occupy only 5% of that.
- Large and medium scale farmers have established their bases for farming and management. On the other hand, small scale farmers have not established stable farming and management. Thus, extended reproduction of agriculture is difficult for them.
- Migration of the small scale farmers from rural to urban areas has been increased.

According to the present problems, following points will be cared in the future.

- Quitting agriculture by small scale farmers and concentration of farmland to large and medium scale farmers
- Collapse of rural society and deterioration of rural ecosystem by quitting agriculture of small scale farmers
- Causing social problems in urban areas

#### (2) Tightness and competition of water use

- Increase of water use other than agriculture with urban expanding
- Available capacity of both surface runoff and groundwater reaches to their limits under the present water right.

According to the present situation, following points are given as direction of the future water use.

- It is hard to settle new water right through the easy method such as use of surface runoff.
- New water utilization will be promoted through the use of small scale groundwater development, obtaining the established water right in the water market, utilization of unused water right, storage of runoff of flood, rationalization of water use so far, and so on.

#### (3) Contamination of agricultural water

- Utilization of contaminated water by sewage from the metropolitan area irrigation water
- Prohibiting cultivation of designated vegetables by contaminated irrigation water
- It will take about 25 years to improve the present situation of contamination

In case that improvement of the present situation is not considered, following points are given.

- Lowering the credibility against the safety of Chilean perishable food in the world market
- Deteriorating health and sanitary environment of farmers

#### (4) Decrease of farmland

- Transformation of superior farmland into urban land use
- Existence of the system which approves the transformation of farmland

According to the trend of the present situation, following points are given on the future land use in the study area.

- Change of land use will be limited by establishment of urban planning
- Decreased farmland by urbanization will be developed for fruits growing

through utilizing micro climate condition in regional rural areas.

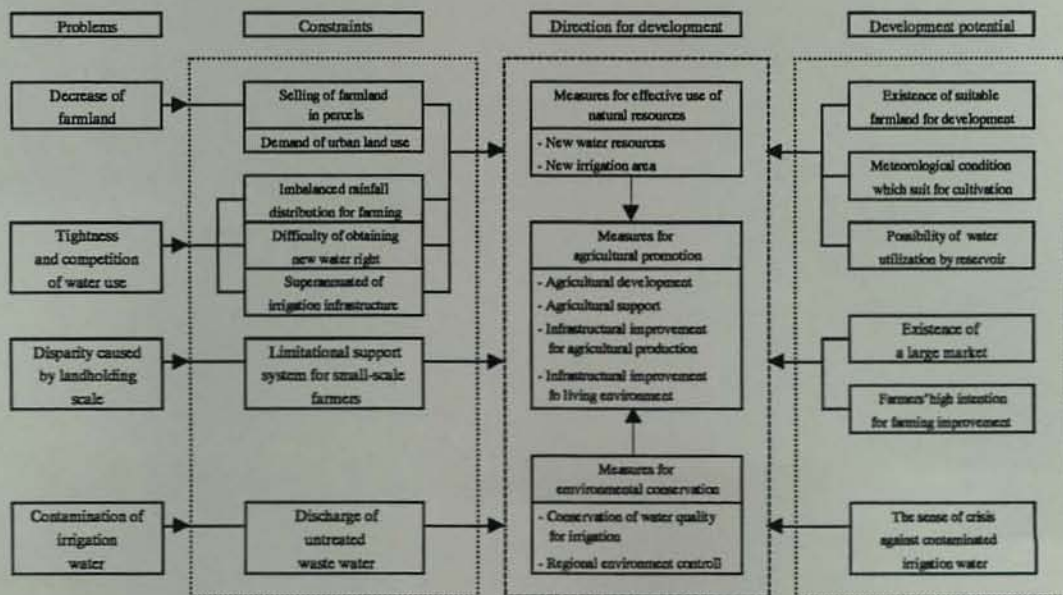
From the problems of the present situation and their future prospects as mentioned above, constraints and development potentials to examine the methods for solving the problems in the area are regarded as follows.

Constraints	Development Potentials
<ul style="list-style-type: none"> <li>• Limited support system for small scale farmers</li> <li>• Decrepit infrastructure and facilities' environment</li> <li>• Little amount of rainfall and imbalanced rainfall distribution</li> <li>• Difficulty of obtaining new water right</li> <li>• Discharge of untreated waste water</li> <li>• Demand of urban land use</li> </ul>	<ul style="list-style-type: none"> <li>• Existence of a large market</li> <li>• Farmers' high intention for improvement of farming</li> <li>• Meteorological and topographical conditions which suit for cultivation</li> <li>• Possibility of utilizing impounded water</li> <li>• The sense of crisis of farmers against contaminated agricultural water</li> <li>• Existence of suitable farmland for development</li> </ul>

As mentioned above, the problems of agriculture in the metropolitan area are

- Existence of disparity among farmers by landholding scale,
- Competition of land and water resources between agricultural and urban uses,
- Deterioration of regional producing and living environment that represents discharge of untreated sewage water into rivers.

The countermeasures to solve these problems are summarized in the following figure based on the future prospects of each problem, constraints on agricultural development, and development potentials mentioned before.



#### 4 Basic Concept and Approach of Development Plan

From the recognition of present situation in the study area, agriculture in the metropolitan area is affected by sprawled expansion and contaminated irrigation water due to sewage by population growth. The development plan is envisaged to promote

socio-economically well-balanced agriculture for the harmonized progress by effective use of limited sources of water and land considering environmental conservation

The plan should be accorded with "Strategic Agenda 1998/2000 Agricultural Development Targets" which is the national agricultural policy. The direction of the plan aims at alleviating disparity between urban and rural areas, coexistence of these areas, and harmonizing with environment. The target year in the plan is set up in 2010.

Based on the concept of development, the framework of the development plan is as follows.

- Agricultural promotion in the metropolitan area
- Effective utilization of potential land and water resources in the study area
- Environmental conservation in the entire basin

## 5 Agricultural Development and Water Management in Metropolitan Area

### (1) Water resource development plan

#### 1) Water source development plan

According to development constraints and potentials, the development constraints in the plan are the limited natural resources. Among them, the key resource is water. Considering that water is necessary for agricultural production and tightened at present, development of new water sources should be examined in the study area. Five methods can be given; a) reservoir facilities (large scale, medium and small scale reservoirs, b) new water creation by saving irrigation water, c) groundwater, d) water use by utilizing unused water right effectively, and e) treated sewage water. Among these, b) can be returned only to the farmers who save water under the present water use system. Groundwater is regarded as small scale supplementary water source, considering that new development of it is regulated by government agencies concerned. Accordingly, both of them are not included in the plan.

According to the topography, geography, scale of the reservoirs, and scale of the basins in the area, possibility of constructing reservoirs is examined in 14 sites, 6 rivers. Considering social, economic, and environmental conditions of each reservoir site, total four sites; one site for large scale and three sites for medium and small scale are selected. New water source amount by construction of reservoirs is estimated at 398.6MCM as presented in the table below.

River	Site	Area of basin (km <sup>2</sup> )	River bed elevation (m)	Dam height (m)	Dam crest-length (m)	Storage capacity (MCM)
Maiipo	El Ingenio	2,785	1,159	161	800	360
Colina	El Cepo	208	970	45	630	4.6
RosaRío	Patagua Chica	184	120	37	350	29.3
Curacavi	El Flamenco	244	331	27	250	4.7

It is also possible to construct small reservoirs in streams in the area beside the dams mentioned above. The small reservoirs can be used as storage of surplus water from irrigation canals and discharge of its basin by rainfall, and can be used as supplementary water source during irrigation period.

DOH has an undistributed but available water right of 25.0m<sup>3</sup>/s (*Decreto No.1039*) for the irrigation project in the second section. In the development plan, the irrigation utilization plan is formulated through utilization of this water right held by DOH from the view of effective utilization of unused water right.

EMOS has the plan of using treated water of 3.5m<sup>3</sup>/s as irrigation water because an urban sewage treatment plant, the first stage, in South Santiago will start the operation from 2001. Utilization of the treated water has some problems to be solved in near future, such as decreasing return flow in the downstream basin and water right on the treated water. Nevertheless, the development plan assumes the problems would be solved. Thus, this is included into the development plan.

## 2) Water resources distribution

Among new water source development plans, the water source which is available for domestic water is only the large scale dam plan. Therefore, concerning both irrigation and domestic water uses, expansion of domestic water use in 2010 will be 40 MCM among 360 MCM of newly developed water amount. Thus, the rest of it, 320 MCM is new irrigation water source. The irrigation area is expected to be about 18,500ha. On the other hand, available supply of middle and small-scaled dams, 39 MCM is regarded as new irrigation or supplementary water sources around reservoir sites. The water with unused water right in the downstream basin of the Maipo river is distributed only for irrigation use, and new irrigation area will be 21,000ha. Treated sewage by EMOS can irrigate about 3,000ha.

The water distribution mentioned above, the alternatives to newly developed water amount are summarized as follows;

Item	The alternatives of water source development plan			
	Without dams	With dams		
	A-1	A-2 (middle and small scale dams)	A-3 (Large scale dam)	A-4 (A-2+A-3)
Large dam	—	—	360 MCM	360 MCM
Middle and small dam	—	39MCM	—	39MCM
Water right of the 2 <sup>nd</sup> section	25.0 m <sup>3</sup> /s	25.0 m <sup>3</sup> /s	25.0 m <sup>3</sup> /s	25.0 m <sup>3</sup> /s
Treated sewerage use	(3.5 m <sup>3</sup> /s)	(3.5 m <sup>3</sup> /s)	(3.5 m <sup>3</sup> /s)	(3.5 m <sup>3</sup> /s)
Water supply	—	—	40 MCM	40 MCM
Irrigation development (With existing water right)	21,000 ha	21,000 ha	21,000 ha	21,000 ha
Treated sewerage use	(3,000 ha)	(3,000 ha)	(3,000 ha)	(3,000 ha)
Total (1)	21,000 ha	23,300 ha	39,500 ha	41,800 ha
Total (2)	(24,000 ha)	(26,300 ha)	(42,500 ha)	(44,800 ha)

## (2) Land resource development plan

In this plan, urbanization areas are to be established in accordance with "The Metropolitan Area of Santiago Regulation Plan (*Plan Regulador Metropolitano de Santiago - SEREMI-MINVU 1994*)" which is the regulation for controlling disordered expansion of Santiago city and sprawling. Except urbanization areas, the present land use will remain. As new irrigated farmland, about 112,000ha land is regarded in the northern, western, and southwestern parts of the area based on land productivity classification shown in the table below. The reclamation of these farmlands is limited by the location of water source and available water amount.

Division of basin	Land productivity potential	
	I-IV	
Est. Yali	26,002	*
Est. Casablanca	25,779	**
Est. Alhué	19,184	*
Est. Lampa	20,688	**
Est. Puangue (Curacavi, Maria Pinto)	9,634	*
Cuc. Melipilla	10,383	*
	111,670	

Source : \* CIREN, \*\* REA



### (3) Agricultural promotion plan

Basic concept of agricultural promotion in the plan is social balance by economic development and coexistence of urban and rural areas as described in "Development concept and approach." From this meaning, plans of production infrastructure improvement for increasing agricultural productivity, both technological and financial supports required for production activities with this infrastructure, and alleviating disparity between urban and rural areas on living environment are to be established.

- 1) Agricultural production plan
  - a) New irrigation area

The agricultural production plan established in the study is backed up basically by the condition of new irrigation areas selected through the study. The production plan which is implemented at present is conditioned by economically successful export. Nevertheless, the basic approaches of the plan are supplementing insufficiency of small scale farmers' production opportunities and increasing their productivity because their productivity is low in agricultural production structure and modernization of agriculture burdens them. So as to promote agriculture in the metropolitan area, which is the target of the study plan, selection of new irrigation areas is required to deal with decreasing farmland. In the master plan, 6 areas (Popeta, Yali, Alhué, Puangue, Casablanca, and Lampa) will be new irrigation areas. These areas are selected based on examination of land and water resources from the view point of agricultural development.

The preconditions of the established crop cultivation plan are as follows;

- The farmland which plans to be newly irrigated is unirrigated land at present.
- The crop cultivation plan includes estimation of unused land area for production such as follow land, staircase land and meadow on both small scale farmers and large and medium scale farmers. Under the present condition, the area is estimated at from 27 to 69% with small scale farmers' and from 15 to 20% with large and middle scale farmers. In the plan, it is estimated at from 22 to 33% with small scale farmers and from 9 to 20% with large and medium scale farmers. The average percentage in the new irrigation areas is 12.7%.
- On the other hand, from the point of land use in the crop cultivation plan, one of the standards is not beyond largely the portion of intensive cultivation (fruits, vegetables, grapes for wine and table grapes, seed production, and seed) in Lampa, Mapocho Bajo, and Angostura where intensive cultivation has been already operated. In case of subjecting average regions, the degree of intensity in these three basins is realistic, feasible and best level for reaching under the present market condition and the framework of economic policy.
- In crop selection, available crops in basins of the Maipo river and crops whose planting and cultivation area is large in the project area and its suburb are selected.

The present cultivated crops and proposed crop cultivation plan are presented below based on geographical location in the study area.

#### - Popeta area

The cultivation plan is mainly relevant to the present crop cultivation in present irrigated areas, Melipilla and Popeta. In irrigated areas in Popeta

(including Cholqui, Carmen Alto, Culiprán, Tantehue, and Los Guindos), a lot of grapes, vegetables and fruits are cultivated due to its climatic condition. Many private investors promote cultivation by groundwater and rainfall in unirrigated area here.

- Alhué area

It is planned that the present level of Alhué area, where large unirrigated land exists even it is blessed with fertile soil and fine climatic condition, alters to the level of Melipilla basin and irrigated areas in Cabras where a lot of fruit trees and grapes for wine are cultivated. This area is provided very appropriate climatic condition for grape cultivation as well as Casablanca area. High potentials of this area are supported by keen interest of many vineyards and investors on the expanding cultivation plan in this area. On the other hand, there is possibility of cultivation crop diversification on vegetables, flowers, crop cultivation for seed production because of advantage on the aspect from producing environment, which is isolated condition due to natural condition, the neighboring of markets, and blessed climatic condition.

- Yali area

San Pedro area where much fruit trees, grapes, and crop cultivation for seed production have been cultivated in these years is provided with blessed climatic condition. Nevertheless, there is large area of unirrigated land. Because of this, the crop cultivation plan for fruit trees, grapes, seed production is planned.

- Puangue area (Curacaví, Maria Pinto, and Ibacache)

The idea of the crop cultivation plan in this area mainly connects with the crop cultivation system of present irrigated area in Puangue and Melipilla basin. In the plan, mainly fruit tree growing and secondly grape cultivation for wine will be major cultivation crops. Besides them, vegetable and flower cultivation will occupy some portion because this area is the suburb of Santiago.

- Casablanca area

The idea of crop cultivation plan mainly connects with present irrigated area in Casablanca basin and rapid growth of grapes for wine cultivation in these years. Therefore, grapes and fruit tree growing is planned as main crops in this area. The portion of forage crop cultivation will decrease compared to the present level, but it will remain an important crop especially in the area where irrigation water is not distributed. Furthermore, vegetable cultivation also has a certain level of possibility because main road to the central coast is passed through in this area.

- Lampa area (Colina and Polpaico)

Crop cultivation relates to crop cultivation system of the present irrigated area in Lampara basin where a lot of vegetables, fruit trees, and crop cultivation for seed production are cultivated. At present, cultivation of vegetables, fruit trees, and crops for seed production occupy 69% of farmland. Yet, cultivation of vegetables and crops for seed production which need small investment will be stressed.

b) Area for rehabilitation of existing irrigation facilities

The farming in the areas for rehabilitation of existing irrigation facilities will remain the present farming type but fruit tree growing will increase at hilly and sloping areas. Accordingly, based on the present cultivation crops, proposed main cultivation

crops in each area are presented in the table below.

Farmers' scale	Small scale farmers				Medium and large scale farmers			
Farming area	24,562.9 ha				105,165.7 ha			
Sub-basin	Decreased crops		Increased crops		Decreased crops		Increased crops	
Clarillo	Cereals	17.1ha	Fruit tree	24.2ha	Cereals	120.7ha	Fruit tree	63.3ha
	Fallow land	21.4ha	Forage crop	14.3ha	Forestation	65.5ha	Forage crop	60.5ha
Lampa	Cereals	65.2ha	Fruit tree	65.2ha	Forestation	155.2ha	Seed	62.4ha
	Fallow land	97.9ha	Forage crop	97.9ha			Fruit tree	155.2ha
Angostura	Cereals	69.2ha	Fruit tree	34.6ha	Cereals	442.1ha	Fruit tree	443.7ha
			Vegetable / Flower	34.6ha	Forestation	492.2ha	Forage crop	490.6ha
Melipilla	Cereals	82.2ha	Fruit tree	106.8ha	Cereals	259.4ha	Fruit tree	257.8ha
	Fallow land	106.8ha	Forage crop	82.2ha	Forestation	265.2ha	Vegetable	266.8ha
Puange	Cereals	49.4ha	Fruit tree	64.2ha	Cereals	105.9ha	Fruit tree	88.8ha
	Fallow land	64.2ha	Forage crop	49.4ha	Traditional crops	102.4ha	Forage crop	119.5ha
Total		573.4ha		573.4ha		2,008.6ha		2,008.6ha
Crop transformation ratio		2.3 %			1.9 %			

### c) Area for the water quality improvement

Crop cultivation plan in the improvement area of irrigation water quality, cropping ratio of vegetables will be increased in case of small scale farmers by introducing the chard, cabbage, cauliflower, and so on which prohibited the cultivation at present. Even the quality of irrigation water is improved, utilization of irrigation water will be made mainly on prevailing fruit cultivation in case of large and medium scale farmers. Quality of fruits cultivated by the improved irrigation water has high marketability. Accordingly, the present cultivation of fruits will be followed on the crop production plan for the large and medium scale farmers.

#### 2) Agricultural support plan

More than 80% of small scale farmers among those who engage in agriculture live in rural areas, and they are in charge of main role in rural and regional society in fact. Therefore, it is important for vital and stable development of rural areas to make the small scale farmers vital and settled down. The support institutions for changing the present situation of small scale farmers and supportive methods for implementing the plan are ordered by support institutions such as SECPLAC, INDAP and FOSIS or as support programs of each institutions.

In order to be provided financial and technical supports from the support institutions, the basic condition is establishment of small scale farmers' organizations. Based on the present situation of the existing support system, in the support plan, establishing organization of unorganized small scale farmers is mainly promoted. Advancing the functions of the existing producers' organizations and construction of the base facilities for various activities to develop regional agriculture which each organization can use are also proposed.

#### 3) Rural infrastructure improvement plan

The infrastructure relevant to living is relatively highly installed in rural areas, the study area. The disparity between rural and urban areas has been shrunk in the points of living environment. Therefore, in the plan, improvement of roads in mountainous areas, drinking water supply facilities, and sewage treatment plants in regional urban areas are proposed. Proposed amount of installation is as follows;

Basin	Installation of rural water supply	Sewage treatment plants	Local road installation
	Unit	Unit	Km
1.Río Maipo Alto	-	2	-
2.Río Clarillo	4	1	-
3.Río Mapocho	-	6	-
4.Est. Lampa	3	3	-
5.Río Mapocho	-	6	-
6.Río Angostura	4	6	15
7.Est. Alhué	8	2	35
8.Melipilla	5	1	20
9.Est. Puangue	9	2	12
10.Est. Yali	8	3	55
11.San Antonio	3	3	28
12.Est. Casablanca	8	4	26
Total	52	39	191

#### 4) Agricultural infrastructure improvement plan

The agricultural infrastructure improvement plan in the objective area is irrigation facility improvement. The irrigation facility improvement consists of rehabilitation in the existing irrigated areas and construction of facilities in new irrigation areas.

Irrigation facilities rehabilitation plan in the existing irrigation area, Clarillo, Angostura, Puangue, Lampa and Melipilla in which indicate significant shortage of irrigation water are selected as the objective areas. Reduction of O & M cost of irrigation facilities and alleviation of water shortage at the field level are intended. Moreover, regarding the rehabilitation of the existing intake structures in the second and third sections in the Maipo river, those structures are to be integrated into the proposed intake weirs of new irrigation areas. In accordance with establishment of *Junta de Vigilancia* which manages water utilization among water users, water management is handed by and supported from the structural aspects. Summary of the improvement plan by area is presented in the table below.

Sub-basin	Area (ha)	Main improvement structures		
		Intake structures (unit)	Diversion works (unit)	Canals (km)
Río Clarillo	2,500	-	12	16
Río Angostura	45,105	22	47	235
Est. Puangue	13,412	6	17	98
Est. Lampa	13,381	-	14	63
Melipilla	28,690	5	34	211
Total	103,088	33	127	623

New irrigation plan is proposed based on the water amount created by unused water right, large scale dam, and medium and small scale dams in accordance with a plan for water source development described in the water resource development plan. Irrigation by unused water right uses DOH's water right of 25m<sup>3</sup>/s in the second section of the Maipo river. The objective areas are sub-areas of Yali, Alhué, and Popeta (21,000ha). Expected available supply of 320 MCM by construction of a large scale dam distributes to sub-areas of Lampa and Curacavi (18,500ha) relevant to location of a constructed dam. Expected available water of 39 MCM by construction of middle and small dams is distributed as new irrigation water around the dam sites and supplementary water source for areas of Colina and Curacavi (550ha). The objective area of irrigation plan by using treated sewage is Curacavi area (3,000ha).

#### (4) Environmental conservation plan

##### 1) Irrigation water conservation plan

As the countermeasure against the problem of contaminated irrigation water in Santiago city, there is a sewage treatment plant construction plan by EMOS. In this plan, the treatment plants are to be constructed in three sites step by step in Santiago city. The plants will start to operate from 2001 to 2009. Nevertheless, it takes about 25 years to obtain adequate irrigation water from the rivers sanitarily after completing the plants.

The present situation which Chilean agricultural products gains good reputation in the international market should not be lost and be sustained for long time from now on. Taking a long time to solve a problem of the contaminated irrigation water should be considered as anxiety relevant to sustainability of good reputation in the international market. Thus, the countermeasures should be prepared as soon as possible. In the plan, the countermeasures for water quality improvement from agricultural side are proposed in order to accelerate recovering the function of the suburban agricultural area as a perishable food supply center for consumers in the metropolitan area and to protect the inflow of unexpected negative information into the international agricultural product market where competition is very severe before it happens.

The objective areas do not include the proposed areas by EMOS in the plan. On changing water source, there is the only possibility to avoid contamination by groundwater after the confluence of the Maipo and Mapocho rivers as adopted methods for countermeasures. Two methods; avoiding the source of contamination by bypass and water quality improvement are practicable. The sewage treatment is planned by the method of Standard Activated Sludge as well as the treatment method planned by EMOS. The targets for improving water quality are less than 23/100ml groups of colitis germ, BOD of 20mg/l, and SS of 30mg/l.

The measures for improvement of water quality with canals are summarized as follows;

Measures for improving water quality	The objective canals	Intake amount (m <sup>3</sup> /sec)
Avoiding contamination sources (through bypass)	Canal La Polvora	0.5
	Canal La Punta	5.8
	Canal Casas de Pudahuel	0.8
	Total	7.1 m <sup>3</sup> /sec (3 canals)
Improving water quality	Canal Las Mercedes	10.5
	Canal Esperanza Alto	0.7
	Canal Esperanza Bajo	1.7
	Canal Romero	1.0
	Canal Castillo	2.0
	Canal Domingano	0.8
	Canal Mallarauco	8.5
	Canal El Paico	2.5
	Canal San Miguel	4.2
	Canal Lo Aguirre	3.6
	Canal Lo Chacon	3.6
	Canal La Manresa	1.2
Total	40.3 m <sup>3</sup> /sec (12 canals)	

##### 2) Promotion of environmental education

Urban areas in the study area have the problems of illegal disposal of wastes and untreated discharge of contaminated water, while rural areas have the problems of the canal contamination by domestic wastes, miscellaneous sewage and waste of

















































































































































































































































































































































































































































































































































































































































































































































































































