社会開発協力部報告書

No. 7

THE REPUBLIC OF PERU

FINAL REPORT
FOR
THE MASTER PLAN STUDY
ON
THE [illegible] PREVENTION PROJECTS
IN
[illegible]MAC R[illegible] BASIN

MAIN REPORT

MARCH 19[illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO, JAPAN

THE REPUBLIC OF PERU

FINAL REPORT
FOR
THE MASTER PLAN STUDY
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CONSTITUTION OF REPORT

PREFACE

In response to the request of the Government of the Republic of Peru, the Government of Japan has decided to conduct a master plan study on the disaster prevention project in the Rimac river basin and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Peru a survey team headed by Mr.Ryuzou Nishikawa of NIPPON KOEI CO.,LTD, comprising other members of that company from February to March 1987, from June to July 1987, from September to October 1987, and in January 1988.

The team had discussions on the Project with the officials concerned of the Government of Peru and conducted a field survey in the whole Rimac river basin. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the basin and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Peru for their close cooperation extended to the team.

March, 1988

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

MASTER PLAN STUDY
ON THE DISASTER PREVENTION PROJECT
IN THE RIMAC RIVER BASIN

Date : March 31, 1988

Mr. Kensuke Yanagiya
President
Japan International
Cooperation Agency
Tokyo

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit herewith the Final Report on the Master Plan Study on the Disaster Prevention Project in the Rimac River Basin. This report presents the result of the study performed on the basis of the Minutes of Meeting agreed between INDC and JICA.

The report presents the problems for the disaster prevention in the basin, possible measures to cope with the problems, and the master plan for the disaster prevention in the basin.

The report consists of the summary report, main report and its supporting report. The summary report summarizes major results of the Master Plan Study. The main report presents master plan including its background, conditions and assumptions. The supporting report describes the details of the conditions, methodology, etc. for planning. Besides, the data book for the master plan study is also prepared and submitted herewith.

All members of the Study Team wish to express grateful acknowledgement to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction, Japanese Embassy at Peru, and the officials concerned of the Government of the Republic of Peru for their close cooperation extended to the Study Team.

The Study Team sincerely hopes that the study results would contribute to socio-economic development and well-being in the Rimac river basin.

Yours sincerely,

Ryuzou Nishikawa
Team Leader

ABBREVIATION

1. Abbreviation of Peruvian Offices

CENTROMIN S.A.	Empresa Minera del Centro del Perú Center Perú Mining Company)
CAPECO +	Cámara Peruana de la Constructión (Peruvian Chamber of Construction
CONCITEC	Consejo Nacional de Ciencia y Tecnología (National Council of Science and Technology)
COOPOP	Cooperación Popular (Popular Cooperation)
CORDE CALLAO	Corporación de Desarrollo del Calao (Development Corporation of Callao)
CORDE LIMA	Corporación de Desarrollo de Lima (Development Corporation of Lima)
CORPAC	Corporación Peruana de Aviachión Comercial (Peruvian Corporation of Commercial Air Travel)
C.P.L.	Concejo Provincial de Lima (Provincial Council of Lima)
DGAF	Dirección General de Aerofotografia (Department of Aerophotographs)
DGASI	Directión General de Aguas, suelos e irrigaciones (General Direction of Water, Soil and Irrigations)
DHNM	Direcciónddе Hidrología y Navegación de la marina (Navigations and Hydrographic Direction of the Peruvian Navy)
ELECTRO LIMA	Empresa de Electricidad de Lima (Electric Company of Lima)
ELECTRO PERU	Empresa de Electicidad del Perú S.A. (Electric Company of Perú)
ENACE	Empresa Nacional de Edificaciones (National Enterprise for Building)
ENAFER S.A.	Empresa Nacional de Ferrocarriles del Perú

	(Railroad National Company of Perú)
IGN	Instituto Geofísico Nacional (Geophysics Institute of Perú)
IMARPE	Instituto del Mar del Perú (Oceanic Institute of Perú)
INADE	Instituto Nacional de Desarrollo (Development National Institute)
INAF	Instituto Nacional de Ampliación de la Frontera Agrícola (National Institute for the Widening of Agriculture Lands Frontier)
INE	Instituto Nacional de Estadísticas (Statistics National Institute)
INP	Instituto Nacional de Planificación (Planning National Institute)
INFOR	Instituto Nacional Forestal y de Fauna (Forest, Fauna National Institute)
ING	Instituto Nacional Geográfico (National Geographic Institute)
INGEMMET	Instituto Geológico Minero y Metalúrgico (Metallurgy, Mining and Geologic Institute)
INVERMET	Inversiones Metropolitanas (Metropolitan Inversions)
MINIS. AERON.	Ministerio de Aeronáutica (Aeronautic Ministry)
MINIS. AGRIC.	Ministerio de Agricultura (Agriculture Ministry)
MINIS. ECON.	Ministerio de Economía y Finanzas (Economics and Finance Ministry)
MINIS. EDUCA.	Ministerio de Educación (Education Ministry)
MINIS. ENERG.	Ministerio de Energía y Minas (Energy and Mining Ministry)
MINIS. GUERRA	Ministerio de Guerra (War Ministry)
MINIS. INDUS.	Ministerio de Industria, Turismo e Integración

	(Industry, Tourism and Trade Ministry)
MINIS. INTER.	Ministerio del Interior (Interior Ministry)
MINIS. PESQ.	Ministerio de Pesquería (Fishing Ministry)
MINIS. PRESD.	Ministerio de la Presidencia (Presidency Ministry)
MINIS. PREE	Ministerio de Relaciones Exteriores (Foreign Relations Ministry)
MINIS. SALUD	Ministerio de Salud (Health Ministry)
MINIS. TRABJ.	Ministerio de Trabajo (Labour Ministry)
MINIS. TRANSP.	Ministerio de Transportes y Comunicaciones (Transports and Communications Ministry)
MINIS. VIVIE.	Ministerio de Vivienda y Construcción (Housing and Construction Ministry)
MUN. DIS. LIMA	Municipalidad Distrital de Lima (District Council of Lima)
MUN. DIS CALLAO	Municipalidad Distrital del Callao (District Council of Callao)
MUN. DIS. ATE	Municipalidad Distrital de Ate (District Council of Ate)
MUN. DIS. CHACL.	Municipalidad Distrital de Chaclacayo (District Council of Chaclacayo)
MUN. DIS. CHOS.	Municipalidad Distrital de Chosica (District Council of Chosica)
MUN. DIS. MATUc	Municipalidad Distrital de Matucana (District Council of Matucana)
MUN. DIS. SANMAT	Municipalidad Distrital de San Mateo (District Council of San Mateo)
NCTL +	Naturaleza, Ciencia y Tecnología Local (Nature, Science and Local Technology Organization)
ONERN	Oficina Nacional de Evaluación de Recursos Naturales

	(National Evaluation Office of Natural Resources)
PREDES +	Centro de Estudios y Prevencio de Desastres (Prevention Disasters and Studies Center)
PRES. CO. MI.	Presidencia del Consejo de Ministros (Presidency of the Ministries Cabinet)
SAN	Servicio AerofotogrMinisterio de Economía y Finanzas (Economics and Finance Ministry)
MINIS. EDUCA.	Ministerio de Educación (Education Ministry)
MINIS. ENERG.	Ministerio de Energía y Minas (Energy and Mining Ministry)
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PRES. CO. MI.	Presidencia del Consejo de Ministros (Presidency of the Ministries Cabinet)
SAN	Servicio Aerofotográfico Nacional (National Aerophotographics Service)
SE/CNDC	Secretaría Ejective/Comité Nacional de Defensa Civil (Executive Secretary/Civil Defense National Committee)
SEDAPAL	Servicio de Agua Potable y Alcantarillado de Lima (Drinkable Water and Sewering Service of Lima)
SENAPA	Servicio Nacional de Agua Potable y Alcantarillado (National Drinkable Water and Sewering Service)
SENAMHI	Servicio National de Meteorología e Hidrología

	(Meteorologic and Hydrologic National Service)
SNI	Sociedad Nacional de Industrias (National Industry Society)
UNFV	Universidad Nacional Federico Villarreal (Federico Villarreal National University)
UNMSM	Universidad Nacional Mayor de San Marcos (San Marcos University)
UNA	Universidad Nacional Agraria (Agriculture University)
UNI	Universidad Nacional de Ingeniería (Engineering National University)

+ Private Offices

2. Abbreviation of Measurement

Length

mm	Millimeter
cm	centimeter
m	mete
Km	kilometer

Time

S or sec	second
min	minute
h or hr	hour
d	day
y or yr	year

Area

cm^2	square centimeter
m^2	square meter
ha	hectare
Km^2	square kilometer

Volume

cm^3	cubic centimeter
m^3	cubic meter
l	liter

Weight

g	gram
kg	kilogram
ton	metric ton

Other Measures

%	percent
°	degree
°C	degree centigrade
103	thousand
106	million
109	billion

Derived Measures

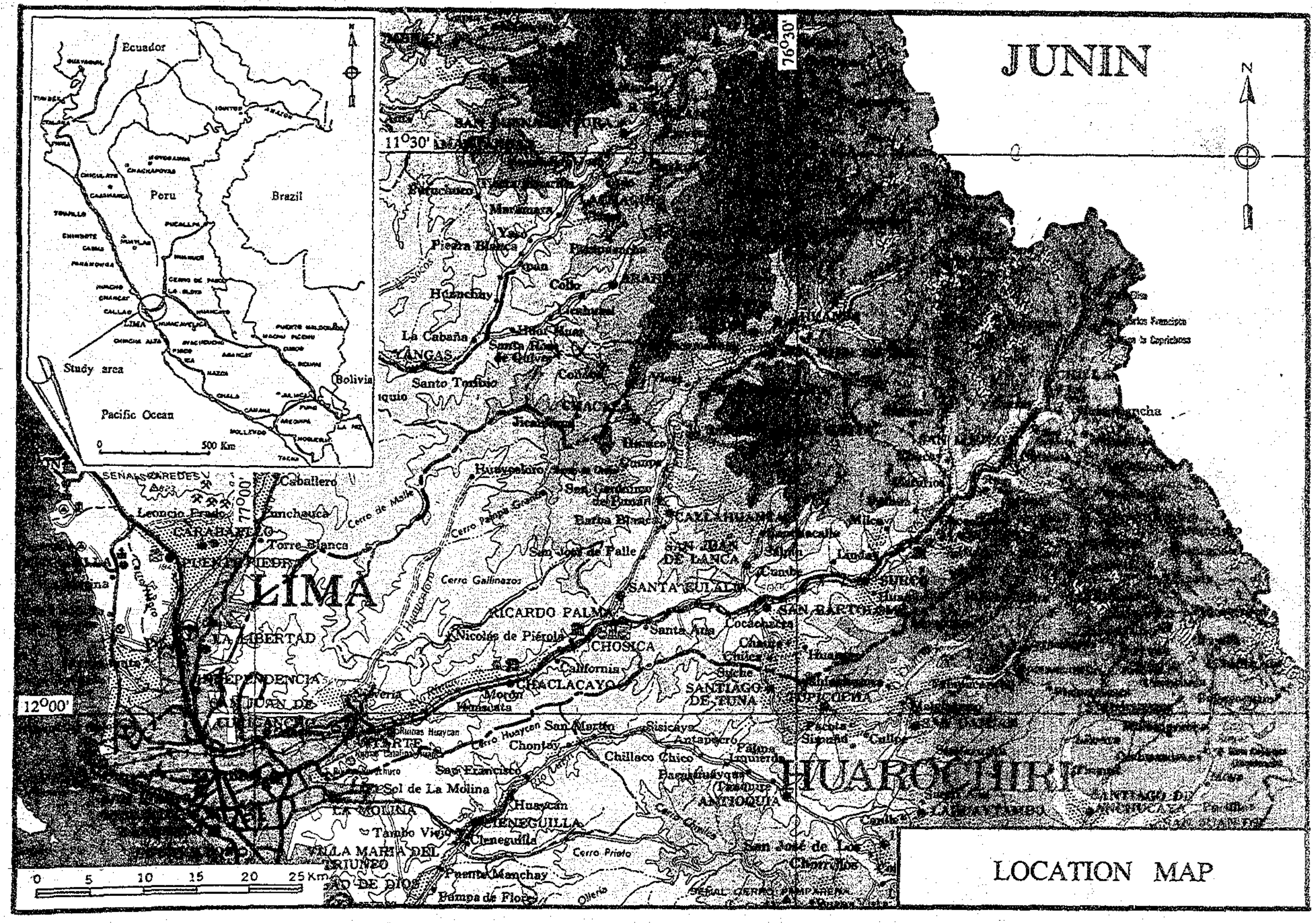
m^3/s	cubic meter per second
KWH	kilowatt hour
MWH	megawatt hour

Currency

US$	U S Dollar
I/.	Perú Inti
¥	Japanese Yen

3. Abbreviation of others

JICA	Japan International Cooperation Agency
GDP	Gross Domestic Product
GRODP	Gross Regional Domestic Product
GNP	Gross National Product
Ref.	Reference
O&M	Operation and Maintenance
El.	Elevation
WL	Water Level
HWL	High Water Level
FWL	Flood Water Level
LWL	Low Water Level
Fig.	Figure
Qda/Q	Quebrada (Small Tributary)
Spe	Slope



LOCATION MAP

SUMMARY

THE MASTER PLAN STUDY ON THE DISASTER PREVENTION PROJECT IN RIMAC RIVER BASIN

SUMMARY

BACKGROUND

1. The Rimac River, passing through the metropolitan area of Lima-Callao in the Republic of Peru, plays a paramount role as water resources for the municipal and industrial water supply, irrigation and electric power.

On the other hand, the basin area suffers remarkable damages caused by the flood inundation and debris flow. The disaster occurs almost every year, resulting in serious damages such as the traffic blockade, loss of human life and destruction of structures, etc. In view that an extraordinary weather called "El Nino" has recently caused remarkable disasters in the basin including the Lima region, the development of disaster prevention measure comes to the most urgent subject.

2. Such being the situation, the Government of the Republic of Peru requested to the Government of Japan in January 1985 an extensive assistance in regard to the preparation of a master plan for the disaster prevention in the Rimac River basin.

In response to the request from the Government of the Republic of Peru, the Government of Japan decided to conduct the master plan study on disaster prevention project in the Rimac River basin (the Study) in accordance with the Agreement on Technical Cooperation between the Government of the Republic of Peru and the Government of Japan.

Then, the Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of the technical cooperation programmes of the Government of Japan, undertook the Study in close cooperation with the authorities concerned with the Government of the Republic of Peru. Comite Nacional de Defensa Civil (CNDC) acted as the counterpart agency and also as a coordinating body of the Government of the Republic of Peru. (It is noted the name of CNDC was changed to INDC (Institute Nacional de Defensa Civil) during the study period.) Besides, an Advisory Committee was organized by the Government of Japan. The Advisory Committee properly reviewed and advised on the Study, joining the discussions on the major reports prepared by the Study Team.

3. JICA despatched the preliminary survey team to the Republic of Peru in August and November, 1986. Then, the scope of work was determined in detail through the discussion between the Japanese side and the Peruvian side.

The activity of the JICA Study Team commenced from the beginning of February, 1987 in accordance with the Agreement and the scope of work. Since then, through two times of field investigation, detailed analysis in Japan, and discussions on the Interim Report and Draft Final Report, the Final Report on the master plan of the disaster prevention in the Rimac river basin was submitted on March 1988.

4. The report consists of the summary report, main report and its supporting report. The summary report summarizes major results of the master plan study. The main report presents the master plan including its background, conditions and assumptions. The supporting report describes details of the conditions, methodology, etc. for planning. Besides, the data book for the master plan study is also prepared.

PROJECT AREA

5. The Rimac river basin with its catchment area of about 3,500 km^2 is featured by the costa covering Callao and Lima city, and the sierra covering the rest of basin area which corresponds to the northern part of Huarochiri.

The metropolitan area of Callao and Lima forms a striking contrast to the province of Huarochiri. A great difference of population density between the metropolitan area and Huarochiri is observable. The former is more than 1,000 per km^2, in contrast to only 14 per km^2 in the latter. Since social movements of population into the metropolitan area are so conspicuous that about 60% of the population increase during the last decade can be attributed to the migrants.

A major social concern is the improvement of social environment which focuses on the housing problem, poor settlement, and adverse effect of disasters on residents in the basin. Those social problems are, to some extent, interrelated such that the poor settlement is mostly formed in the illegally occupied area which is susceptible to disasters due to debris flow or flooding. In this respect, the housing scheme for relocation is urgently required for the residents who are in danger of disasters. However, the lack of public budget has been the major constraint of promoting the housing scheme.

The economy of basin is, in a way, explained by the interdependence between the metropolitan area and the sierra. The Carretera Central and railway play an important role in keeping this interdependence as transportation infrastructure. Since the topographic conditions surrounding these principal trunk lines are unstable, the traffic tends to be easily blocked off due to the debris flow or slope failure. Under such circumstance, economic losses or damages to the social and economic infrastructure would be enormous if no disaster prevention works are implemented. Consequently the economic importance of the disaster prevention works is clearly recognized.

6. The basin is composed of igneous rocks of the Jurassic or Tertiary period, intrusive rocks of the Cretaceous or Tertiary period, and deposit of the Quaternary period.

In the upper-middle reaches, layers of the Tertiary period are widely distributed. The layer is divided into the upper and lower layers. The lower layer has andesitic facies composed of lava, breccia and tuff. The upper layer has the tuff created by volcanic activity and rhyolitic facies composed of volcanic sands & gravels like mudstone. In the middle-lower reaches, various facies of intrusive rocks are seen. These intrusive rocks are composed of the granite, granocliorite and andesite of the Cretaceous or Tertiary period. In addition, the plutonic rocks form the base layer on a large scale. In the lower reaches, the deposit layer of the Quarternary period is extended on a layer in a large scale and forms the tableland of Lima city.

The basin belongs to the arid or semi-arid zone and the natural vegetation is hardly seen due to scarce rainfalls. Consequently, the weathering of rocks is remarkable. Especially in the middle-lower reaches, unconsolidated deposits of the weathered granite are produced extremely.

7. In the Rimac river basin, the ground elevation is ranged from the sea water level of zero meter to 5,650 m of the Nude Sulkon and the middle-upper area of the basin is surrounded by the Andes mountains more than 4,000 m. Therefore, the basin's topography is extremely steep and consequently becomes one of main causes which induce the various natural disasters.

8. The basin lies in the narrow strip zone in the west coast of the South American Continent held between the Andes and the Pacific Ocean. The general characteristics of climatic feature in the basin are complex due to the steep topography and the El Nino which is a phenomenon of tropical sea water shift to southward along the coast of Ecuador and Peru.

The annual total rainfall is ranged from 10 mm/year in the coastal area to around 1,000 mm/year in the mountainous area. In the coastal area, the rainfall amount is very little throughout a year because the cold sea water of the Humboldt current makes cool air mass near sea surface and it prevents to produce an ascending air current. Thus, the closer to the coastal line of inland, the rainfall amount is less. On the contrary, the mountainous area of the Andes has relatively much rainfall since the influence of air current from the cold sea is weakened.

The runoff of the Rimac river is mainly dominated by the rainfall pattern in the upstream area. The annual average runoff at Chosica where the catchment area is nearly 70% of total area is 32 m^3/sec according to the record in the period of 1969-1987. During four months from January to April, around 65% of annual runoff volume is discharged into the Pacific Ocean. The maximum value ever recorded is 500 m^3/sec on Mar.19,1925 at Chosica.

In the flood runoff analysis of hydrological study, the probable flood discharge was estimated by means of a conventional unit hydrograph method. The result estimated at Chosica is as follows.

Return Period (Year)	Flood Peak Discharge (m^3/sec)
2	150
5	290
10	380
25	490
50	580
100	660
200	740
500	820
1,000	920

9. The area ratio of each land use category in the Rimac river basin is approximately measured as follows:

(a)	Town/Village	4.6%
(b)	Farm (flat land)	1.7%
(c)	Farm (mountain slope)	7.1%
(d)	Mountain (without vegetation)	30.0%
(e)	Mountain (with vegetation)	34.6%
(f)	Swamp	0.8%
(g)	Glacier/Perpetual snow	0.9%
(h)	Lake	0.3%

As seen in the above table, about 70% of the basin is mountain area. The flat plain is developed only in the lower reaches which include the Lima-Callao metropolitan district and in a part of the middle reaches which is located along the Rimac and Santa Eulalia rivers.

In the mountain area, most parts are bare lands without vegetation or with very limited vegetation of some grasses, scattered cactuses, some low trees. The vegetation is seen on the mountain slopes and wide U-shape valleys of the upper reaches where the land is used for the vegetable cultivation or pasturage. Many small mines with its villages are located in the mountain of middle-upper reaches. In the area along the main streams, some towns such as Chosica, San Mateo, Surco, and Matucana are located and farm lands are developed. The main national roads and national railway are also running along this valley of the main stream.

In the flat plain located in the lower reaches, various kinds of buildings, facilities, and structures are seen. The area is developed as the metropolitan district with a high degree of land use. Farm lands and resort areas are also seen in the suburb zone.

BASIC PRINCIPLE FOR FORMULATION OF MASTER PLAN

10. The master plan study on the disaster prevention in the Rimac river basin is formulated in accordance with the following basic guidelines:

(1) The primal concept for preventing disasters or alleviating damages puts its basis on the overall watershed management of the Rimac river basin.

(2) Then, the master plan study on disaster prevention works is examined from both aspects of structural and non-structural measures.

(3) The structural plan is examined and established by dividing into the debris flow/slope failure and flood prevention measures in consideration of the difference in patterns of disaster and necessary countermeasures. Those are finally formulated into the overall planning for the disaster prevention works together with the non-structural plan.

STRUCTURAL PLAN FOR DISASTER PREVENTION DUE TO DEBRIS FLOW/SLOPE FAILURE

11. The structural plan against the debris flow and slope failure in the Rimac river basin is formulated according to the following procedures:

(1) Division and classification of the study area

The study area to which engineering studies for structural measures are to be applied is divided into 75 Quebrada areas and 71 slope areas as shown in Fig. IV-2-1.

Levels of damageability and danger are largely different among the areas, and therefore, the classification for the divided areas is made for effectively formulating the master plan in accordance with the levels of damageability and danger.

The study area is classified into three groups in the following way:

Group A : Areas categorized as Group A are supposed to have a high degree of danger and protective object, and historical experiences of disaster. Countermeasures for debris flow disaster are examined in detail for each area.

Group B : Areas of Group B have relatively less degree of danger and damageability. The countermeasures examined in Group A are applied to the area of Group B according to the area characteristics, and formulated at the preliminary level.

Group C : Damageability and danger are considered to be little. So no specific countermeasures against disaster are examined.

The classification of the study area into the three groups is made by comprehensive judgements of area characteristics by the Quebrada and slope areas based on the levels of danger and damageability as below:

Level of danger

Level A : Probability of disaster occurrence is high.

Level B : Probability of disaster occurrence is comparatively high.

Level C : Probability of disaster occurrence is low.

Level of damageable amount

Level A : Damageable amounts susceptible to disaster are large.

Level B : Damageable amounts are not so large as the level A.

Level C : Damageable amounts are small or not identified.

Classification

Group A : Level of danger and damageability is level A.

Group B : Level of danger and damageability is not level C except areas classified into Group A.

Group C : Level of danger or damageability is level C.

The result of classification is listed as follows:

Group A

(a) Quebrada areas : 7 areas

R-6 Qda. Quirio
R-7 Qda. Pedregal
R-8 Qda. Carosio
R-9 Qda. Corrales
R-19 Qda. Rio Seco
R-32 Qda. Paihua
S-1 Qda. Cashahuacra

(b) Slope areas : None

Group B

(a) Quebrada areas : 23 areas

(b) Slope areas : 25 areas

Group C

(a) Quebrada areas : 45 areas

(b) Slope areas : 46 areas

(2) Structural Plan

(a) Long-term discharge volume of debris flow

The structural plan for debris flow is formulated based on the discharge volume of debris flow corresponding to 100 year scale of return period. The volume of debris flow in long-term scale is estimated on the basis of the discharge volume of debris flow occurred in Qda. Pedregal on March 1987 (157,200 m^3), the catchment area of Quebrada, the safety factor in due consideration of the accuracy of measuring discharge volume (1.2), the mitigation coefficient of each Quebrada according to the condition of vegetation. The discharge volume estimated in each Quebrada is listed in Table IV-7-1.

(b) Structural measures

The structural measures for debris flow are broadly classified into three types, based on the features or conditions of each Quebrada.

<u>Type A</u>

The case that check dams for restraining the debris flow and channel works for handling the mud flow safely are planned. The settlement of residential houses is so dense.

<u>Type B</u>

The case that necessity of restraining the debris flow is not so urgent since the settlement area to be protected is small. A safety method of protecting the damageable properties is considered for the case.

<u>Type C</u>

The case that the structural measures of reducing the debris flow and channelling the debris or mud flow into the river safely are required since the debris flow into the river dams up river stream, resulting in the disaster due to over-flow of the river water. A check dam for reducing the production of sediments as well as checking the debris flow is required. Works for changing the direction of debris flow at its outlet are also necessary.

Type A and B are further classified into two sub-categories as follows:

<u>Type A</u>

Type A1 : In case that appropriate sites or places for constructing the check dams are available, the proper structural measures are planned.

Type A2 : In case that appropriate sites for the check dams are not identifiable, the channel works as well as small scale of dams for diverting the debris flow into the channel works are planned.

Type B

Type B1 : Protection of the railway and road is the primal objective in this case since no settlements are found. The structural measure for fulfilling this purpose is the construction of training dykes to control the direction of debris flow.

Type B2 : Since small settlement areas are identifiable, two ways of structural measures are provided. One is the training dykes for protecting the settlement areas. The other is the sand arresting dam which forms a retarding place for regulating the outflow of sediments or controlling the direction of debris flow at the top of alluvial fan.

The structural plan for each Quebrada area is selected out of the mentioned types according to the characteristics of each Quebrada area. This means that there is no other alternative plan for examination.

(2) Structural measures for slope failure

The disasters caused by the slope failure are broadly classified into the debris flow from the small Quebrada and land slide on the slopes. The effective measures for the disaster due to the debris flow or land slide which tend to cause the blockade of traffic in the road or railway are introduced as follows;

(a) Bridges are the conceivable candidate for preventing the disasters to transportation infrastructure.

(b) Rock-shed tunnel is conceivable for protecting of the road and railway.

(c) Retaining walls are recommended for blocking the landslide.

(3) Structural plan and economic evaluation

The structural plan for each Quebrada and slope area is formulated according to the conditions and countermeasures explained above. The proposed structural measures, structures, their total construction cost, and the economic internal rate of return (EIRR) are shown in the following tables. The EIRR is analysed assuming (1) the project life of 50 years, (2) operation and maintenance cost of 0.5% of the direct construction cost, and increase rate of 3% in the enhancement of basin's economy.

Quebrada area		Type of Stru.Plan	Dam (No.)	Channel Works (km)	Dike (km)	Bridge (No.)	Tunnel (No.)	Project Cost (x 10^3US$)	EIRR (%)
			Proposed Main Structures						
(A) Group A									
R-6	Q. Quirio	A1	2	1.8	-	2	-	8,623.4	5.25
R-7	Q. Pedregal	A1	3	1.9	-	2	-	11,649.4	5.65
R-8	Q. Carosio	A2	1	0.3	-	1	-	1,432.7	9.85
R-9	Q. Corrales	A2	2	0.2	-	-	1	3,054.5	6.02
R-19	Q. Rio Seco	B1	-	-	1.5	2	2	3,145.9	10.12
R-32	Q. Paihua	C	2	-	0.5	-	-	6,442.1	5.09
S-1	Q. Cashahuacra	B2	1	0.4	12.5	1	-	3,057.4	4.15
(B) Group B									
R-1	Q. Chacracayo	A1	3	3.3	-	-	-	9,448.2	8.99
R-2	Q. Chacrasana	A1	1	1.1	-	-	-	4,534.0	3.19
R-3	Q. California	A1	1	1.3	-	-	-	8,101.6	4.79
R-4	Q. Santa Maria	A1	1	1.0	-	-	-	4,436.3	3.39
R-5	Q. La Cantuta	A1	3	1.2	-	-	-	14,465.5	-0.24
R-10	Q. La Ronda	A1	4	1.3	-	-	-	8,677.1	2.31
R-11	Q. Santa Ana	B1	-	0.4	0.6	1	-	2,071.4	11.54
R-13	Q. Cupiche	B1	-	0.4	0.5	1	-	1,427.8	12.79
R-15	Q. Canchacalla	C	5	0.5	0.5	-	-	27,160.9	-2.09
R-16	Q. Guayabo	B2	2	0.4	-	1	-	1,101.2	14.94
R-17	Q. Agua Salada	B1	-	0.5	0.5	1	-	1,760.4	10.90
R-18	Q. Esperanza	B1	-	-	0.4	1	-	1,184.8	14.30
R-23	Q. Huacre	B1	-	0.5	0.5	-	-	575.6	3.75
R-24	Q. Matata	B1	-	0.5	0.5	1	-	1,135.1	3.71
R-25	Q. Cuchimachay	A1	2	1.1	-	1	-	2,946.7	2.90
R-31	Q. Chucumayo	B2	1	0.7	1.6	1	-	2,818.1	8.45
R-33	Q. Chacahuaro	B2	1	0.3	-	-	-	428.6	17.90
R-34	Q. Pancha	C	3	0.5	-	-	-	7,976.9	-1.07
R-35	Q. Viso	C	2	0.5	-	-	-	2,404.1	3.96
R-37	Q. Parac	C	3	0.3	-	-	-	15,033.6	-0.89
S-2	Q. Redonda	B2	1	1.3	1.3	1	-	1,959.7	4.12
S-3	Q. Infiernilla	B1	-	0.4	0.4	-	-	1,028.2	5.07
S-5	Q. Lucuma	B1	-	0.9	0.9	1	-	1,093.0	4.73

Slope area		Proposed Main Structures: Bridge (No.)	Tunnel (km)	Retaining Wall (km)	Project Cost (x 10^3US$)	EIRR (%)
(A) Group A	: None					
(B) Group B						
R--/0	River mouth - Jicamarca	-	-	15.0	15,535	0.68
R--/1	River mouth - Chacracayo	-	-	18.0	19,077	-0.04
R-0/2	Jicamarca - Chacrasana	-	-	2.0	2,453	-
R-1/3	Chacracayo - California	-	-	0.05	52	13.67
R-4/6	Santa Maria - Ronda	-	-	0.11	114	-2.42
R-6/7	Quirio - Pedregal	-	-	1.5	1,558	-4.06
R-7/8	Pedregal - Carosio	-	-	0.68	706	0.15
R-8/9	Carosio - Corrales	-	-	0.2	207	2.29
R-9/--*	Corrales - Confluence	-	-	0.2	207	0.45
R-10/-	La Ronda - Confluence	-	-	0.04	41	6.68
R--/11	Confluence - Santa Ana	-	-	0.32	333	6.23
R--/12	Confluence - San Juan	1	3	0.08	83	10.64
R-11/13	Santa Ana - Cupiche	-	7	0	3,319	5.22
R-13/16	Cupiche - Guayabo	-	2	0.66	4,049	3.64
R-16/17	Guayabo - Agua Salada	2	8	0	2,157	3.46
R-19/20	Rio Seco - Esperanza	2	13	0.05	5,723	4.39
R-20/21	Esperanza - Verrugas	2	8	0.01	6,373	4.50
R-21/23	Verrugas - Huacre	1	2	0.08	4,863	4.76
R-22/27	Linday - Yamajune	-	7	0.04	5,077	4.47
R-26/29	Chacamaza - Barranco	-	3	0.04	482	1.02
R-31/33	Chucumayo - Chacahuaro	4	4	0.9	1,124	3.50
R-37/40	Parac - R. Blanco	-	-	1.12	2,340	8.92
S--/4	Confluence - Alcula	-	-	0.11	114	9.30
S-1/2	Cashahuacra - Redonda	1	5	0.11	429	3.02
S-2/3	Redonda - Infiernilla	-	4	0.09	345	2.86

In the above table, it is considered that the project is evaluated to be economically viable in case of the EIRR more than 8%. More than 25% of the whole projects show EIRRs higher than 8%, and about 70% reveals EIRRs higher than 3%. Then, the EIRR shows 5.4% for all the projects. Considering from the result of economic analysis and intangible social effect of disaster prevention such as the safety of human life and stabilization of social welfare, etc., this structural plan is evaluated to be sufficiently viable.

Note :

Based on the standard prepared by the international fund such as World Bank, etc., the opportunity cost of capital in Peru is set at 8% in this Study.

The opportunity cost of capital is defined as returns from capital investment. Namely, that is equivalent to the marginal return of the project to which capital investment is carried out last in case that the allocation is made in order from profitable project in the country.

The opportunity cost of capital is determined to each country according to the economic condition in the country. The project is evaluated to be viable in case that the EIRR is more than the opportunity cost of capital.

STRUCTURAL PLAN FOR FLOOD DISASTER

12. The structural plan against the flood disaster in the Rimac river basin is formulated by the following procedures:

(1) Division and classification of the study area

The classification for the divided areas is based on levels of the damageability and danger in the same way in the formulation of structural plan for the debris flow disaster. The divided areas are classified into three groups as follows:

Group A : Areas categorized as group A are supposed to have a high degree of danger and protective object. The countermeasures for flood disaster are fully examined in each area through a comparative study on alternative measures.

Group B : Areas of group B have relatively less degree of danger and damageability. Proper structural measures are proposed to the area of Group B based on the hydraulic analysis.

Group C : Damageability and danger are considered to be little. So no specific structural measures against disaster are taken into account.

The result of division and classification is shown in the following table.

Area division	Location	Classification
(1) Rimac river		
(a) Upper area	Upstream from Matucana	C
(b) Middle-upper area	Matucana to Confluence with Sta. Eulalia river	B
(c) Middle-lower area	Confluence with Sta. Eulalia river to Atarjea weir	A
(d) Lower area	Downstream from Atarjea weir	A
(2) Sta. Eulalia river		
(a) Upper area	Upstream from Autisha	C
(b) Lower area	Autisha to the confluence	C
(3) Jicamarca river		
(a) Upper area	Upstream from 4 km site from river mouth of Jicamarca river	C
(b) Lower area	River mouth of Jicamarca river to 4 km upstream	A

The area division and classification are shown in Fig. V-4-1.

(2) Structural plan and evaluation

(a) Group A

Alternative plans

In the preparation of alternatives, fundamental items in relation to the planning such as the river width, river alignment, effect of retarding basin, possibility of floodway and flood control dam, etc. are examined in consideration that this master plan aims at formulating the basic guideline for the disaster prevention.

The design discharges having 100-year probability are distributed to reaches: (1) 660 m^3/sec for the downstream reaches from the confluence with the Santa Eulalia in the Rimac river, (2) 310 m^3/sec for the upper reaches in the Rimac river, and (3) 370 m^3/sec for the Santa Eulalia river. Alternatives for handling the design discharge safely are as follows:

(i) Confluence with Santa Eulalia river to river mouth

The river stretch of about 12 km long in the downstream of the confluence with the Santa Eulalia river is remarkably narrowed artificially. The river width in the stretch is reduced to 20 m in an average despite the width of 40-50 m at least is considered necessary for the design discharge. Some countermeasures are essential in view of so high susceptibility to the serious disaster. As for the countermeasure, two measures, on which the comparative study is made, are conceivable as follows:

CASE A-1

The case that the river channel is planned in accordance with the existing river width as much as possible, protecting with the parapet wall or dike.

CASE A-2

The case that the river channel has the reasonable width and alignment for the design flood.

(ii) Huampani Bridge and Atarjea Weir

In the upstream reaches of the Atarjea weir, the river is largely widened, having a retarding effect on floods of the Rimac river. This retarding effect is considered to serve the reduction of flood peak in the downstream reaches, increasing the safety in the area. It is also considered to effectively prevent various sizes of the gravels from flowing down to the downstream reaches.

On the other hand, the river channel is not fixed there, disturbing a smooth river flow. The disturbed river flow attacks the river banks, causing inundations due to the damage of dike.

Therefore, the advantageousness between the following two cases should be examined:

CASE B-1

The case that the present river width is secured in the portion where the river is largely widened.

CASE B-2

The case that the river is provided with an usual channel width without such a wide portion.

(iii) Atarjea weir to the river mouth

There is a narrow gorge with a sharp bend and bank of 20-30 m height at about 10 km from the river mouth, originating various inconveniences such as the erosion due to the accelerated river flow, the danger of bank collapse for the inhabitants on both banks and raising up of the flood water level in the upstream reaches.

Some improvements on the above condition are essential, and two countermeasures, on which the comparative study is made, are conceivable as follows:

CASE C-1

The case that the narrow gorge is widened along the present river course.

CASE C-2

The case that a short-cut is provided in the portion of sharp bend.

(iv) Examination on floodway and flood control dam

Measures of floodway are judged not to be applicable in the basin since the construction of the floodway which requires a huge amount of compensation and construction cost due to the highly developed condition in the downstream areas will not be practical. As for the flood control dam, the study reveals that the flood control dam is evidently disadvantageous since the flood control volume is not possible to be secured effectively due to the remarkable sediment yield in the basin. Thus, these measures are deleted from the alternative study.

(v) Lower Reaches of Jicamarca River

The cause of disaster due to the flood inundation from the Jicamarca river is not in the shortage of flow capacity or alignment of river channel itself but in the unsatisfactory structures provided artificially; that is, the flow capacity at the mouth of Jicamarca river is extremely lessened due to the culvert provided for the traffic road, which causes serious flood inundations in the downstream area along the right bank of Rimac river.

Thus, only the improvement of culvert to augment the flow capacity is a conceivable way of the countermeasure, requiring no examination on other particular alternative plan.

Then, the alternatives in this study as shown in Fig.V-5-4 consist of the combination of the above-mentioned cases, i.e. (A-1,A-2), (B-1,B-2) and (C-1,C-2).

Construction cost

The construction cost for each alternative is listed as follows:

Unit : 10^3 US$

Items	Alternatives for Comparative Study							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.Main Stream :								
- Confluence to Huampani bridge								
A-1	13,643	13,643	13,643	13,643				
A-2					16,920	16,920	16,920	16,920
- Huampani bridge to Atarjea weir								
B-1	12,547	12,547			12,547	12,547		
B-2			46,572	46,572			46,572	46,572
- Atarjea weir to river mouth								
C-1	17,166		17,166		17,166		17,166	
C-2		24,369		24,369		24,369		24,369
2.Lower Reaches of Jicamarca River								
	599	599	599	599	599	599	599	599
Total	43,955	51,158	77,980	85,183	47,232	54,435	81,257	88,460

Selection of alternatives

The selection of alternatives is made through evaluations from socio-economic and technical aspects.

(i) Economic evaluation

The project benefit is assumed to be a damage mitigated by the proposed structural measures, which is assessed based on the result of flood damage study for the probable floods up to 100-year probability, hydrological and hydraulic analysis, and the damage rate established by Ministry of Construction in Japan.

The result of economic analysis is as follows:

Alternatives	EIRR (%)
A-1,B-1,C-1	16.6
A-1,B-1,C-2	15.9
A-1,B-2,C-1	10.5
A-1,B-2,C-2	9.5
A-2,B-1,C-1	15.9
A-2,B-1,C-2	13.8
A-2,B-2,C-1	10.1
A-2,B-2,C-2	9.2

(ii) Technical and social evaluation

In Case A-1, there still remains a high danger of occurrence of the disaster from small defects due to the violent flow (water depth of about 5 m and flow velocity of

7 m/sec for 100-year flood), even if the concrete parapet wall or levee is provided along the river. The increase of operation and maintenance for structures of case A-1, and the erosion make this alternative disadvantageous technically.

Case A-2 enables to largely decrease the water depth to the design flood discharge, and raise the degree of safety. Although social constraints increase in Case A-2, the problem is considered to be able to be solved by proper arrangements of resettlement area and the education for inhabitants.

Thus, Case A-2 is selected from the technical aspect as the structural plan for this river reaches.

The technical comparison between Case B-1 and Case B-2 recommends the selection of Case B-1 in view of its high technical merits, i.e. the retarding effect to the flood peak discharge and function of preventing sands and gravels from flowing down to the downstream reaches.

The evaluation on Case C-1 and Case C-2 reveals that technical merits of Case C-2 is not comparable to the remarkable increase of social constraints in Case C-2, recommending the selection of Case C-1.

(iii) Selection of alternatives

As for the economic viability of alternatives, alternative (A-1,B-1,C-1) indicates the highest EIRR of 16.6%. However, alternative (A-2,B-1,C-1) is proposed as the structural plan for the flood disaster prevention since this scheme shows the second highest EIRR of 15.9% and is also recommendable from technical and social aspects.

Fig.V-7-1 shows the proposed structural plans for protective reaches. It is, however, noted that the plan is preliminarily prepared at the master plan stage, requiring adjustments based on further detailed surveys and studies for its implementation.

(b) Group B

An area classified into Group B is that between Matucana and the confluence with the Santa Eulalia river in the Rimac river. The hydraulic analysis indicates that the flow capacity along this area is enough to handle the 100-year flood peak discharge of 310 m^3/sec.

But around Corcona, the ground elevation of existing road is lower comparing with river bed elevation, and the existing levees provided along the reaches require some reinforcements. Therefore, the supplemental works for the levees are proposed. In the river bed along Torna Mesa, the sedimentation of sand and gravel is remarkable, and river course is not fixed there. Therefore, the excavation of river bed is also proposed for this stretch.

The total construction cost for Group B is estimated at US$ 2,080 thousands. Although this plan does not give any benefit since there is no flooding along the riparian area under the present condition, it is desired to implement this proposed structural plan in order to keep the safety.

(c) Overall economic evaluation of structural plan for flood disaster prevention.

The proposed structural plan for flood disaster prevention is evaluated to be viable because of EIRR of 15.5% in the examination of overall economic feasibility including Group A and B. Further, from social effect of disaster prevention such as safety of human life, etc., this structural plan is considered to be sufficiently viable.

NON-STRUCTURAL MEASURES

13. The most controversial issue to be discussed in the field of non-structural measures is no definite organization to administer the watershed management of the Rimac river basin. Due to no regulation or control of illegal or uncoordinated actions, causes of disasters being attributed to human behaviors attract attention. Such the examples are seen in the illegal intrusion of people into the disastrous area, dumping of earth or garbage into rivers, and various uncontrolled land developments. Another aspect that would cause disasters to be induced more is observable in the lack of preparedness for preventing or minimizing damages due to such disasters. This argument is true of actual disaster occurred in March, 1987.

Under such circumstances, the approach to the non-structural measures is of great importance for the disaster prevention scheme.

14. In view of the present situation as mentioned above, the following non-structural measures are essential:

(a) The establishment and implementation of land use regulation in dangerous areas

(b) The establishment of coordinated administrative organ to implement the overall watershed management of the Rimac river basin

(c) The establishment of the following preparedness for disasters:

- Communication system at disastrous time
- Warning and evacuation system
- Regional organizations responsible for emergency actions at disastrous time
- Well-preparation for the supply of relief materials at a state of emergency
- Meteo-hydrological observation system
- The country-based relief system at disastrous time

(d) The clarification and establishment of implementing agencies to conduct the proposed structural plans

(e) Establishment of implementing agency for operation and maintenance of river and river structures

(f) Training of engineers who would be engaged in designs and implementations of the structural plans

Figs. VI-2-1 and VI-2-3 show the examples of the land use regulation in dangerous area, organizational structure for implementing the overall watershed management and structural plans, and country-based relief system at disastrous time.

IMPLEMENTATION PROGRAMMES

15. The proposed implementation programme for disaster prevention for the debris flow/slope failure and flood is presented in Figs.VIII-2-1 and VIII-2-4, although the implementation programme is just prepared preliminarily at this master plan study stage, requiring further rearrangements based on more detailed investigations and studies in the subsequent study stages. EIRRs based on the implementation programmes are (1) 5.4% for the debris flow/slope failure prevention, (2) 15.5% for the flood disaster prevention, and (3) 8.6% for all the project. The examination on implementation programmes reveals that the implementation of the proposed plan as early as possible is desirable from both economic and social aspects.

RECOMMENDATION

16. Recommendations for disaster prevention in the Rimac river basin are made as follows:

(1) The master plan formulated on the basis of structural and non-structural measures should be defined as the basic guideline for the disaster prevention works. It is, first of all, pointed out that it is most important to perform the comprehensive and consistent disaster prevention plan for the whole basin under this basic guideline.

(2) The realization of the overall disaster prevention plan will require a considerably long time. On the other hand, the plan involves some urgent matters for which actions should immediately be taken. The recommendations are made for such urgent matters as follows:

(a) The seven quebradas classified into Group A have a high urgency for implementation. On the other hand, the structural measures proposed for these quebradas require a more detailed confirmation of technical and economic feasibilities, investigating the topographic and geological conditions in detail.

Therefore, the necessary procedure for executing the feasibility study should be promoted with a high priority.

(b) In view that the urban area in the downstream reaches of Rimac river is exposed to an extreme danger of inundation disaster, some countermeasures should urgently be taken.

The necessary urgent measures are shown in order of priority as follows;

- River bed excavation and removal of garbage in the downstream of narrow gorge at 9 to 10 km from the river mouth, and revetment,
- River bed excavation and removal of garbage in the upstream of narrow gorge, and revetment,
- Widening the narrow gorge, and revetment.

In view that the land acquisition procedure takes a long time, it is also recommended to put into execution at the earliest the land acquisition necessary for widening the narrow gorge.

(c) There are some defects of dikes in the middle reaches. The repair for these defects also has the highest urgency, requiring the earliest implementation at the same time with the said measures for the lower reaches.

(d) The inundation disaster prevention plan proposed for the upper reaches (Huampani Bridge to the confluence) requires the land acquisition in a considerably large scale, which will take a long time. Thus, it is recommended to commence the acquisition at the earliest.

(e) Although all of the proposed non-structural measures are of the urgent necessity, the following two items have a particularly high urgency.

(a) Strict prohibition of disposal of garbage into the river, and

(b) Strict prohibition of new encroachment of inhabitants into the dangerous area.

The immediate and strict execution of above two items is recommended.

(f) Prior to the implementation of above items (b) to (d), more detailed investigation, survey and design works, etc. will become necessary. It is required to proceed with the procedures necessary for such works as mentioned.

(3) It is recommended, as a long-term scheme, to commence the research for successful vegetation in the basin which will be significant for the disaster prevention. The successful vegetation requires the continuous research and accumulation of data for independent conditions in each area. The research of vegetation for basin's own conditions should be promoted.

(4) In consideration of the pattern of precipitation and disaster in the basin, the basin keenly needs the installation of radar rain gauge system which will make it possible to forecast the state of precipitation. The installation of radar rain gauge system in the basin will technically be possible as well as highly effective for the disaster prevention.

Then, it is recommended to proceed with the examination for installing the radar rain gauge system in the basin.

In installing the system, it is especially noted that a satisfactory arrangement of primal matters such as establishments of communication system, warning system, data analysis system and its organization, etc. is extremely important in order that the radar rain gauge system can fully fulfill its function.

(5) Educations for bringing up specialists or engineers who would be engaged in the detailed plan and implementation of disaster prevention works, should be conducted as early as possible. The training center for disciplining specialists related to disaster prevention is desirable. Then, it is recommended to proceed with procedures necessary for establishing this kind of institution for training.

THE MASTER PLAN STUDY
ON
THE DISASTER PREVENTION PROJECT
IN
THE RIMAC RIVER BASIN

PREFACE

LETTER OF TRANSMITTAL

ABBREVIATION

LOCATION MAP

SUMMARY

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Chapter I

I. INTRODUCTION

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CHAPTER I INTRODUCTION

1. BACKGROUND

The Rimac River, passing through the metropolitan area of Lima-Callao in the Republic of Peru, plays a paramount role as the water resources for municipal and industrial water supply, irrigation and electric power.

On the other hand, the basin area sustains remarkable damages caused by the flood inundation and debris flow. The disaster occurs almost every year, resulting in serious damages such as the traffic blockade, loss of human life and destruction of structures, etc. In view that an extraordinary weather called "El Nino" has recently caused remarkable disasters in the basin including the Lima region, the development of disaster prevention measure comes to the most urgent subject.

Such being the situation, the Government of the Republic of Peru requested to the Government of Japan in January 1985 an extensive assistance in regard to the preparation of a master plan for the disaster prevention in the Rimac River basin.

In response to the request from the Government of the Republic of Peru, the Government of Japan decided to conduct a master plan study on disaster prevention project in the Rimac River basin (the Study) in accordance with the Agreement on Technical Cooperation between the Government of the Republic of Peru and the Government of Japan.

Then, the Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of the technical cooperation programmes of the Government of Japan, has undertaken the Study in close cooperation with the authorities concerned with the Government of the Republic of Peru. Comite Nacional de Defensa Civil (CNDC) acts as counterpart agency and also as coordinating body of the Government of the Republic of Peru. (It is noted the name of CNDC was changed to INDC (Institute Nacional de Defensa Civil) during the study period.)

JICA despatched the preliminary survey team to the Republic of Peru in August and November, 1986. Then, the scope of work was determined in detail through the discussion between the Japanese side and the Peruvian side.

The activity of the JICA Study Team commenced from the beginning of February, 1987 in accordance with the Agreement and the scope of work, and since then, various data collection and examination have been carried out through two times of field investigation executed during the period of February 1 to March 31, 1987 and June 10 to July 9, 1987.

The Interim Report, which presented all the findings obtained through the field investigation as well as a proposed basic policy and the results of preliminary study for the disaster prevention planning, was prepared in early October, 1987. In January, 1988 the Draft Final Report, which summarized all the investigation and study results, was prepared.

Discussions were made on there Interim and Draft Final Reports among the Government of Peru, Advisory Committee and Study Term, through which various opinions of all the parties were confirmed.

This Final Report has been prepared based on the results of above discussions on the Interim and Draft Final Reports.

2. OBJECTIVE AND SCOPE OF THE STUDY

The objective of the Study is to formulate a master plan for the disaster prevention project in the Rimac River basin with a catchment area of about 3,200 km^2.

Thus, the Study covers the following scope of work for achieving the mentioned objective of the Study;

(A) Data collection including;

- topographic and geological maps,
- meteo-hydrological data,
- land and water use data,
- sedimentation and water quality data,
- existing facilities related to flood and erosion control,
- past damages by flood, erosion and other disasters,
- existing plan or study on disaster prevention,
- administrative and socio-economic conditions, and
- Others.

(B) Reconnaissance survey

(C) Field surveys such as;

- survey on past flood (including "HUAYCO") damage and sedimentation,
- river survey, and
- hydrological observation.

(D) Evaluation and analysis of the data relevant to the Study.

(E) Formulation of a master plan for disaster prevention such as;

- setting up a basic plan for disaster prevention,
- basic layout on structures related to disaster prevention,
- preliminary design of main structures for disaster prevention,
- operation and maintenance programme for the structures,
- implementation programme and cost estimation,
- river management system,
- warning and evacuation system, and
- socio-economic impact.

(F) Technology transfer to the Peruvian counterpart personnel in the course of the Study.

3. ORGANIZATION FOR STUDY

The organization for the Study consists of the Government of Peru, Advisory Committee and JICA Study Team.

INDC acts as the counterpart agency and coordinating body of the Government of Peru. The Advisory Committee is organized by the Government of Japan. The JICA Study Team is composed of the experts in the respective fields.

The Study Team carries out the Study and the technology transfer to the counterpart personnel through the Study. The Government of Peru renders various cooperations for the Study. The Advisory Committee properly reviews and advises on the Study, joining the discussions on the major reports to be prepared by the Study Team.

Members of the Advisory Committee, the Study Team, and Peruvian counterparts and other relating officers are listed in Table I-3-1.

4. TECHNOLOGY TRANSFER

It is strongly intended to make the technology transfer to the Peruvian counterpart personnel in the course of the Study as well as the Study on the disaster prevention in the Rimac river basin. Then, the technology transfer has intensively been carried out in the course of the Study through the lectures by the respective experts, seminars and despatch of counterpart personnel to Japan for training, etc.

During the period that the Study Team stayed in Lima, several lectures and seminars were given for the purpose as abovementioned to the Peruvian counterparts and other governmental officers. Name of lecturers and outline of lecture, etc are summarized as below.

Name of Lecturer	Outline of Lecture/Instruction	Date	Place
Y. Motoki (Hydrologist)	Field instruction of discharge measurement by current meter	Mar. 18, 1987	San Mateo
R. Nishikawa (Team Leader)	Natural Disaster and administrative System for disaster prevention in Japan	Feb. 27, 1987	INDC
M. Tada (Socio-Economist)	Necessity and method of economic evaluation for disaster prevention study	Feb. 27, 1987	INDC
H. Okada (Debris flow control planner)	Brief introduction of measures against land slide, slope failure and debris/mud flow disaster	Jul. 6, 1987	ONERN
M. Suzuki (Geologist)	Mechanism of natural disaster	Jul. 6, 1987	ONERN
M. Sakurai (Disaster survey expert)	Introduction of debris and mud flow in Japan and method of disaster survey	Jul. 6, 1987	ONERN
M. Onodera (Construction Planner)	Basic conditions for construction plan and cost estimate	Jul. 6, 1987	ONERN
N. Fujita (Acting Team Leader)	Detailed explanation on the Interim Report for the Master Plan Study on the Disaster Prevention Project in the Rimac River Basin	Sep. 18, 1987	INDC
E. Oda (Special Lecturer)	Formulation of policies for Nation Disaster Prevention	Jan. 21, 1988	CENTRO CIVICO
S. Ohkubo (Member of Advisory Committee)	Administration for Flood Control	Jan. 21, 1988	CENTRO CIVICO
K. Yano (Chief of Advisory Committee)	Sabo Planning	Jan. 21, 1988	CENTRO CIVICO
M. Fukuda (Member of Advi-	River Planning	Jan. 22, 1988	CENTRO CIVICO

sory Committee)			
K. Yano (Chief of Advisory Committee)	Basic Concepts in Disaster Prevention Plan of Rimac River Basin	Jan. 22, 1988	CENTRO CIVICO
R. Nishikawa (Term Leader)			
N. Fujita (Acting Term Leader)	Outline of Disaster Prevention Plan for Rimac River Basin	Jan. 22, 1988	CENTRO CIBICO
H. Okada (Debris Flow Control Planner)			

5. CONSTITUTION OF REPORT

The report of the master plan study on the disaster prevention project in the Rimac river basin consists of (1) Summary Report, (2) Main Report, (3) Supporting Report and (4) Data Book.

The Supporting Report consists of three (3) volumes of Supporting Report I, II and III.

The constitution of the report is summarized as follows:

Constitution of Report

Vol.1. Summary Report (Spanish)

Vol.2. Main Report

Vol.3 Supporting Report I

Appendix

I: Geological and Topographical Feature

II: Meteorological and Hydrological Conditions

III: Land Use and Vegetation Conditions

IV: River and River Basin Features

V: Conditions of Related Structures

VI: Conditions of Past Disaster and Damage

VII: Disaster Management Conditions

VIII: Conditions for Project Cost Estimate

IX: Socio-Economic Conditions

Vol.4. Supporting Report II

Appendix

X: Study on Structural Plan for Debris Flow and Slope Failure Disaster

Vol.5 Supporting Report III

Appendix

XI: Study on Structural Plan for Inundation Disaster

XII: Study on Non-Structural Plan

Vol.6 Data Book

Tables

Table I-3-1 LIST OF DIRECT PARTICIPANTS OF THE STUDY

Advisory Committee

Chairman :

K.Yano (/1)

Member :

Y.Ogawa (MOC)
(1987.1-1987.3)
S.Ohkubo (MOC)
(1987.4-)
M.Fukuda (MOC)

Coordinator :

K.Nakagawa (JICA)

Study Team

Team Leader :

R.Nishikawa (NK)

Acting Team Leader :

N.Fujita (NK)

Member :

H.Okada	(NK)
M.Suzuki	(/2)
M.Sakurai	(/3)
Y.Motoki	(NK)
S.Ezaki	(NK)
M.Onodera	(NK)
M.Tada	(NK)

Special Abbreviations

MOC	:	Ministry of Consruction
JICA	:	Japan International Cooperation Agency
NK	:	Nippon Koei Co., Ltd.
INDC	:	Instituto Nacional de Defensa Civil
UNMSM	:	Universidad Nacional Mayor de San Marcos
DHINA	:	Dirección de Hidrología y Navigación de la Marina
ELECTROLIMA	:	Empresa de Electricidad de Lima
SEDAPAL	:	Servicio de Agua Portable y Alcantarillado de Lima
IGN	:	Instituto Nacional Geografico
DIGAF	:	Direccion General de Aerofotografía
CORLIMA	:	Cooperacion de Desarrolo de Lima
COOPOP	:	Cooperacion Popular
INGEMET	:	Instituto Geógráfico Minero y Metalurgico
SENAMHI	:	Servicio Nacional de Meteorología y Hidrología

Remarks :

/1 Sabo and Landslide Engineering Center
/2 Tobishima Construction Co., Ltd.
/3 Ringyodoboku Consultant

Counterpart Officers

Chief Counterpart :

Jorge A.Del Aguila Sánchez (INDC)

Counterpart :

César Arguedaz Madrid (INDC)
Guillermo Chamorro Rodriguez (INDC)
Victor Murillo Pino (INDC)
Oscar Trejo Oviedo (INDC)

Other Contacting Offrcers :

Lenkisa Angulo Villarreal	(INDC)
Enrique Huiza Valverde	(USMSM)
Filiberto Matos Flores	(DHINA)
Jorge Lam Ramírez	(DHINA)
Cesar Del Carmen	(DHINA)
Nicolas Carrión	(ELECTROLIMA)
Jose Córdova	(SEDAPAL)
Gerardo Perez	(IGN)
Vivar Gamarra	(DIGAF)
Juan de La Cruz	(UNMSM)
Herman Gabanillas	(II RDC)
Pedro Quevedo	(Privado Espec. obras Hidraul.)
Edmundo Turpaud	(Minist. Agric.)
Angal Lema	(CORLIMA)
Fernando Moreno	(COOPOP)
Juan Medina	(Minist. Viv.)
Benjamín Villanueva	(Minist. Transp.)
Maximo Fuentes	(Minist. Agric.)
Pedro Abad Velez	(CORLIMA)
Luis Cabrera López	(INDC)
Benites	(Minist. Agric.)
Water Gómez	(SENAMHI)

Chapter II

II. STUDY AREA

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CHAPTER II STUDY AREA

1. SOCIO-ECONOMIC CONDITIONS

1.1 General

The section covering the study of socio-economy consists of two parts. One is the national socio-economy where general descriptions about the Peruvian country are presented to clarify social conditions and economic performance of Peru. The other is the socio-economic study in the Rimac river basin where is the study area of master plan of disaster prevention projects.

This section aims principally at making clear the widely-perceived understanding that how important or urgent disaster prevention works contemplated under this master plan are, by considering the necessity of these works from the viewpoints of socio-economic circumstances surrounding the Rimac river basin. Eventually, analytical viewpoints are more concerned to the said basin area than Peru herself.

The regional characteristics of the Rimac river basin are understandable by its locational and geographic feature being central part of Peru, and the basin's dimension from Costa to Sierra extending in the west-east direction despite of its catchment area being only 3,500 km^2. The most of metropolitan Lima is identified in the Rimac river basin. Administrative and economic activities are concentrated on metropolitan area where is considered to be the significant part of Peru strategically.

Economic importance of the basin's geography is also characterized by interdependence between Metropolitan area and mountainous area called Sierra. Like the most of countryside in Peru, the basin's economy is roughly explained by the supply of raw materials from Sierra to Costa, and of consumer goods from Costa to Sierra. In this respect, transportation infrastructure plays an important role in activating regional economy.

Under such circumstances stated above, the importance of disaster prevention works is readily understood in terms of preventing the major parts of the basin and principal infrastructure from incurring tremendous damage cost due to disaster like flood or debris flow. In this study, social problems about poor settlement area and housing schemes for the poor are also presented since the solution of these problems would contribute to the reduction of further human loss due to disaster.

1.2 National socio-economy

1.2.1 Natural conditions

The country of Peru has its marked geographic categories which are classified into three zones, namely, costa, Sierra and Selva. Costa bounded by coastal line and the Andes mountains is low-lying plain field like long corridor from the North to the South. Many rivers having their sources on the Andes mountains penetrate into Costa with the fast-flowing stream and debouch into the Pacific Ocean.

Sierra is the Andes mountains' area where most of land still remains to be underdeveloped. Sierra is basically endowed with mineral and water resources. Selva is an extensive forest area spreading the Amazon river basin. Selva having high elevation near the Andes is generally called Selva Alta where potentiality of developing agriculture is high due to good soil and drainage conditions.

1.2.2 Population

Population in the Census year of 1981 is demonstrated in the form of geographic and administrative demography shown in Table II-1-1. Geographic distribution of population shows that about 51% of total population concentrates on costa, followed by 41% of sierra, and 8% of Selva. Population distribution by urban and rural category demonstrates that about 85% of population in costa concentrates on urban area, while population in sierra and Selva is almost evenly distributed into urban and rural areas.

The remarkable feature of administrative demography is observed by contrasting metropolitan Lima with other area. About 28% of total population settle down in Callao and Lima city with its areal ratio of only 3% of total land. As a result, the difference of population density is outstanding between metropolitan area and other by showing 1,197 persons per km^2 in the former and only 10 persons per km^2 in the latter.

1.2.3 Macro-economy

As far as the recent economic performance of Peru is concerned, 1983 was marked by severe recession accompanied by a sharp acceleration in inflation. Real gross domestic products (GDP) fell 12% while consumer price climbed 110% between December 1982 and 1983.

"Economic and Social Progress in Latin America" issued by IADB reports the Peruvian economy of 1983 in the following way;

Adverse climatic factors affected overall economic sectors. Agricultural production and fisheries' output dropped remarkably. Changes in ocean current temperature affected the output of the fishery sector, and rainfall led to floods that ruined crops in the north of the country. Oil production was lower than in the previous year. This lower output was due to flood and landslide damage to the northern Peru pipeline.

Although to what extent disaster caused by adverse climate affected the Peruvian economy was not clear, the shortage of consumer goods caused by disasters was one of causes of pushing up inflation rate. Consequently, purchasing power of wage declined, and real private consumption dropped by 10% in 1983. 1983 is also marked by the government budget. Budget deficit increased up to 2,350 million intis in 1983 because public-oriented investment was required for recovering damaged economic sectors.

Unfavorable balance of payments position in 1981 led to an increase of total debt. Debt service consisting of interest and amortization also augmented in 1981. Although debt service ratio declined down to 26% in 1983 due to reschedule of repayment condition, total debt was reported to increase up to 12,630 million US$. Data relating to budget and debt is shown in Table II-1-2.

1.3 Basin's socio-economy

1.3.1 Administrative division

The Peruvian standard of classifying administrative division is based on Departmentos, Provincias, Districtos, and a special Provincia constitucional. Administratively, the Rimac river basin is identified in Provincias Constitutional Callao, and Departmentos Lima.

To be more precise, administrative units of province relating to the said basin are Callao, and province of Lima and Huarochiri within Departmentos Lima.

1.3.2 Geographic condition

The Rimac river basin with its catchment area of about 3,500 km^2 is featured by costa covering Callao and Lima city, and Sierra covering the rest of basin area where corresponds to the northern part of Huarochiri.

In costa area where coastal line faces with the Pacific Ocean, average temperature is around 18°C due to a cold current called Corriente de Humboldt. The northern part of province Huarochiri categorized as Sierra is characterized by mountainous area with elevation ranging from 1,000 to 5,000 m.

1.3.3 Social conditions

As shown in Table II-1-3, metropolitan area of Callao and Lima forms a striking contrast to province of Huarochiri. Since 26% of the country's total population concentrated on metropolitan area of only 3,850 km^2, population density in the Census year of 1981 reveals the most marked contrast between metropolitan area and province Huarochiri. Population density in Lima and Callao was more than 1,000 persons per km^2 while Huarochiri had only negligible density record of only 14 persons per km^2.

In Peru, social movement of population into metropolitan area from the rest of Peru has been outstanding. The number of increased population during 1972 - 1981 was recorded at 405,863 of which about 60% of them can be attributed to migrants. Migration into metropolitan area has been accelerated due to land reform and caused a social problem like Pueblo Joven forming slum settlement in illegally occupied area.

A major social concern is improvement of social environment surrounding human life and activity. Like other developing countries, Peru has also faced with the growing urban population. The lock of houses has been a major social concern in metropolitan area. The problem of homeless family is identified in every district of Lima city. Insufficient level of house construction is closely related to the expanding migrants who tend to form new settlement area called Pueblo Joven.

In the Census year of 1981, the percentage of houses categorized as P. Joven out of total number of houses in Lima city turn out to be about 23%. Most of them belongs to area surrounding central Lima city. The Rimac river basin crosses over some of districts where many of slum settlement scatters along the river side.

As far as social conditions of inhabitants in the northern Huarochiri are concerned, the lack of houses identified in metropolitan area is not observable. Nevertheless, many houses are identified on the steep slope of hilly side or on a alluvial fan where debris flow tends to damage or destroy houses devastatingly once a torrential rainfall breaks out. In this respect, human life of inhabitants in those areas faces with high probability of danger at disastrous time.

1.3.4 Macro-economy

Although data on GRDP is based on departments, the value of GRDP in Lima-Callao department is assumed to be approximate to GRDP in province relating to the basin, except for GRDP shared by agriculture. It is because labour force of the secondary and tertiary sectors in province Lima (Lima city) constitutes more than 90% of labour force of Lima department.

Table II-1-4 shows that the recent GRDP of Lima-Callao departments has kept its steady growth rate of about 4% between 1979 and 1982. 1983 was marked by a sharp recession. GRDP fell by about 13%. Manufacturing was the hardest-hit sector whose GRDP dropped by 19%. GRDP shared by its sector was 416 million intis which was lower than in 1979. GRDP shared by commerce and service sectors also fell by 14% and was lower or equivalent to GRDP in 1979. In other words, regional economy was almost traced back to 1979 level.

1.3.5 Economic sectors

Province Huarochiri is well-known for production of mineral resources and on enormous amount of mineral deposits. Mining industries of producing lead, copper, and zinc are quite active in Chicla. In particular, production of lead and zinc almost turns out to be about 10% of national production.

Since mineral resources are the most leading export items constituting about 45% of total exports in 1984, those natural resources produced or potentially deposited in the Rimac river basin is an important material in terms of earning foreign exchanges.

The condition that metropolitan area of Lima-Callao has been industrial base of Peru is clearly understood by its high concentration of manufacturing activities on metropolitan area. The said ratios indicated by the number of establishment, value added, and gross production was around 70% while about 75% of workers engaged in manufacturing sector is identified in metropolitan area.

Consumer goods are still the leading manufacturing products, whereas intermediate goods are principally chemical products such as paint, medicine and soap, and refinery of petroleum. A substantial number of manufacturing establishments are identified in small size of ones where employees per establishment ranges from 5 to 9 persons although more than 75% of value added and production value was shared by big size of establishment.

As far as agriculture is concerned, major crops produced in the Rimac river basin are maize, cassava, avocado, pumpkin and so on. A substantial number of farm houses are identified in Lurigancho, Chicla, Matucana, and San Mateo.

1.3.6 Infrastructure

Housing problem in Lima-Callao area is already mentioned in social conditions of 1.3.3. Since the lack of residences has been on apparent social matter, Ministry of House put an emphasis on construction of new residential houses though public fund for this scheme has been negligible. Housing schemes are principally for homeless people and poor settlement having to be relocated. The lack of budget for housing schemes also makes it difficult to realize a relocation programme for people who dwell in disastrous area of middle or upper reaches along the Rimac river.

The connection of water pipe to houses with no water supply service has been the recent major concern of SEDAPAL which is an implementing agency of water supply. Nevertheless, insufficient amount of public budget impeded the improvement of water supply service up to the target level. Furthermore, water quality of the Rimac river is deteriorated owing mainly to inflow of debris or mud flow into the river in the middle reaches, and drainage of contaminated waste from mineral industries in the upper reaches.

The principal trunk lines penetrating into the Rimac river basin are represented by national road of route 20 and railway along the Rimac river. This transportation infrastructure connecting metropolitan area with Sierra is economically important since both economies of Lima-Callao and Sierra area are interdependent to a certain extent. Since topographic conditions surrounding Carretera Central (Route 20) in the middle and upper reaches of the Rimac river is featured by mountainous area with unstable earth, the road as well as railway are in danger of being blocked by debris flow. The recent rehabilitation works were conducted on Carretera Central between Ricald Palma and Matucana. New by-pass around Surco and Matucana are also under construction.

1.3.7 Economic importance of disaster prevention works

Disaster prevention works are economically important in such a way that if prevention works remain to be intact for a long time in area where disaster such as Huaycos or flooding are almost a permanent problem, cumulative economic loss or damage due to disasters would be a tremendous cost to socio-economy.

The rehabilitation cost of damaged road called Carretera Central reached five million intis which corresponds to about 2% of total development budget allocated to transportation sector in 1983. Total cost of rehabilitating damaged infrastructure of public utilities was recorded at 1.5 million intis which was approximately a quarter of development expenditure allocated to energy sector.

Economic framework of interdependence between metropolitan Lima and Sierra would further strengthened by the recent government policy to promote development in Sierra and Selva. Under such circumstances, if Carretera Central and railway is blocked by debris flow, economic loss derived from value added lost by operation stop of industrial sectors would be an substantial amount. Furthermore, the shortage of consumer goods due to disaster would push up price level, which would result in the reduction of real purchasing power of consumers.

The recognition that economic benefit would have accrued to society if disaster prevention works had been implemented makes it reasonable to justify economic importance of disaster prevention works.

2. GEOLOGICAL AND TOPOGRAPHICAL FEATURES

2.1 Geological Features in the Basin

(1) General Geology of the Basin

The geological map and lithological pattern of the Rimac river basin are shown in Fig. II-2-1 and Fig. II-2-2 respectively prepared on the basis of the data collected. In general, the basin is covered by elastic sedimentary and volcanic formations of the age from Jurassic to Tertiary, intrusive rocks of the age from Cretaceous to Tertiary and also Quaternary deposits. The kinds of rock formulating the Rimac River basin is shown in Table II-2-1.

Jurassic formations are exposed in the northern part of Lima and extend to NW-SE direction along the Pacific coast. The formations consist predominantly of andesitic extrusives associated with chert, shale and etc.

Cretaceous formations are distributed in the northwest direction, and found with irregular form in the Rimac river basin. The formations are rich in calcareous marine facies indicating unconsolidated condition. These are composed of limestone associated with marl, shale and quartzite. Some volcanic facies, however, consisting of predominant andesitic lava and volcaniclastics are exposed in the coastal area. The cretaceous rocks have been notably subjected to folding with NW-SE axis, and also are cut by many faults with NW-SE and EW directions.

Some formation from upper Cretaceous to middle Eocene in age is found in a narrow zone in the uppermost reaches. The formation unconformably overlies some late Cretaceous formation. The formation is principally sediments of continental condition. The lower part consists of sandstone, shale, and mudstone, and the upper mainly of conglemerate associated with sandstone and shale with red colour.

Tertiary groups and formations are extensively distributed in the middle and upper reaches. These are divided into three zones, that is, the lower, the middle and the upper. The rocks of this age are characterized by the presence of predominant volcanic materials.

The volcanic extrusives from the lower zone to the lower half of the middle zone are andesitic facies which consist mainly of lavas, breccias and tuffs intercalated with tuffaceous sandstone, lapili tuff, sandstone and mudstone.

Subsequent volcanism changes to acidic facies. Therefore, many formations from the upper half of the middle zone to the upper zone comprise rhyodacitic or rhyolitic facies. These are composed of extrusive and volcanic sediments such as alteration of tuffaceous sandstone and siltstone.

Andesitic and basaltic rocks are seen in the uppermost horizon of the upper zone. These rocks are probably Mio-Pliocence in age.

Various facies of intrusive rocks are found in the western area of the Western Cordillera. These intrusives consist of granite, granodiorite, and tonalite, etc. of Cretaceous and Tertiary ages and andesite of Cretaceous. Their general trend is NW-SE parallel to the Western Cordillera. Some plutonic rocks exist in large batholiths.

Small intrusive bodies such as andesite, rhyodacite and trachyandesite are found in the Tertiary area.

There are many metal mines in the investigated area. Principal mineralization has been associated with igneous activity in Miocene deformation stage during Andean geotectonic process. The minings excavate various types of minerals which consist of galena, spherlite, chalcopyrite, barite with pyrite, etc.

Quaternary deposits are divided into Pleistocene and Holocene.

Quaternary deposits consist of terrace with various levels, glacial, recent river and talus deposits. The deposits forming the ground of Lima is largest among them in scale. Thick piles of sand and gravel with clay are found. Major part of the deposits are presumably Pleistocence in age and covered by fan deposits of the Rimac river.

(2) Weathering

The basin is situated in the arid or semi-arid climate area with less vegetation. Furthermore, the mountains in the basin (the Andes mountains) upheaved during the Tertiary are accompanied with various faults and fractures.

As such, the basin is severely subject to the weathering, making the basin vulnerable to the various disasters.

The situation of weathering in the basin is detailed as follows;

Downstream and Middle Reaches

An extensive distribution of granitic rocks is found in the downstream and middle reaches. A remarkable weathering process is recognized on these rocks; that is, many rocks are under the decomposed condition of granite, which is called "Masa" in Japan. The "Masa" points out such a weathering process that a rock mass, subject to the mechanical and chemical actions, alters to a sandy rock mass by keeping original structure and texture of granite.

Although the said weathering process is generally seen on rocks with coarsegrained minerals like granitic rocks, the above suggests a strong effect of mechanical and chemical actions in the area.

A huge amount of relatively large rock blocks is yielded in the area. Its reason is considered as follows:

The weathering process proceeds primarily along joint system. Then, it penetrates into the rock mass. Thus, the weathering mainly develops along the joints, resulting in the production of rock blocks separated along the weathered joints. The granitic rocks in the area have joints at a relatively large interval, and therefore, the rock blocks produced are of relatively larger size. The rock blocks in the area are mostly round-shaped, indicating the character of joints in the granitic rocks and reflecting the mentioned process of weathering.

Middle and Upstream Reaches

Rocks belonging to the Cretaceous formation in the middle reaches have been affected by strong tectonic movements, which is evidenced by marls or limestones with slaty cleavages developed parallel with the bedding plane. Further, water percolating into faults softens fault clay, which eventually worsens the rock mass condition.

The volcanic and sedimentary rocks of Tertiary are distributed in the middle and upstream reaches. The process of weathering for these rocks is similar to that for the above rocks belonging to the Cretaceous formation in the middle reaches, except that the area is subject to a higher effect of freeze and dissolution.

Then, various sizes of rock block as well as the clayey materials are yielded in the area. The rock blocks are very angular and relatively smaller as compared with those in the downstream reaches, reflecting the situation of joints formed in the volcanic and sedimentary rocks on the shape and size of rock blocks.

It seems that the yield of rock blocks in the area is smaller to some extent compared with the downstream reaches. The reason is considered to be the existence of vegetation. However, the area has numerous gullies where the erosion and weathering are remarkable, subject to the concentration of rainfall.

(3) Unconsolidated Deposits

River terraces formed at Pleistocene are found in several places along the Rimac and Santa Eulalia river. There is a distribution of two or three-layered terrace deposit having its height ranging from 10 to 50 m in the vicinity of Chosica. There is also terrace deposits in the upstream of Chosica. These deposits consist of gravel, sand, and clay having its thickness ranging from 30 to 50 m. Gravels which occupy a large part of the deposit have its size from a fist size to block more than 1 m. These gravels are shaped roundly.

There are also old deposits which have a height of around 120 m above river bed in the upstream of Santa Eulalia river. These deposits presumed to be formed during glacial epoch are composed of various size of angular rocky materials. The similar type of deposit is also extensively distributed in many tributaries of the basin. This is the so-called "Older Huaycos" in Peru.

The deposits categorized as the formation of Holocene age are classified into various size of fan deposits, recent river and glacial deposits, and deposits on slopes of mountains or hilly side.

Qda. Chucumayo in the left bank, and Qda. Canchacalla in the right bank of Rimac river form the fan deposit at outlet of valleys. Fan deposits are also found at Qda.Redonda, Qda. Alcula, and Santo Domingo of the Santa Eulalia river.

The recent river deposits is independently identified although they include fan deposits. In the area from middle to lower reaches, thick deposits consisting of various size of gravel, sand, and clay sediment on river bed exist extensively. This sedimentation volume is considered to be enormous especially in the downstream from Carapongo.

Terrace of inundation is also noteworthy because historical trend of debris flow is to be clarified if a further investigation will be made on these terrace. It is observed during field survey that there is at least the high and two-layered inundation terrace with its height ranging 50 to 150 m near fan deposits of Qda. Pancha. This is considered to be formed by recent inundation type of debris flow.

Slope deposits are widely distributed in areas from middle to upper reaches of the basin as talus deposits or debris cones. These deposits are distributed on steep slope having gradient from 36 to 38 degree.

2.2 Topographical Features in the Basin

Fig. II-2-3 shows a division in elevation at 1,000 m contour interval and the relief energy which is defined as a height difference in a unit area. The relief energy is simplified in Fig. II-2-4, dividing into four stages of (A) 0-450 m, (B) 500-950 m, (C) 1,000-1,450 m and (D) more than 1,500 m. Fig. II-2-5 shows the division of basin by elevation.

As seen, the greater part of the basin is included in the divisions (C) and (D). This fact suggests that the mountain slopes of the basin are generally very steep.

The basin can topographically be classified into four reaches of the uppermost, upper, middle and lower reaches. The topographic features of each of the above reaches are characterized as follows:

(1) Lower Reaches: River mouth-Caranpongo

A thick deposit consisting of sand and gravel with clay extensively distributes in the most lower reaches of

Rimac river, forming a large flat plane and a high cliff along the coast.

The Rimac river is flowing down in the northern part of the city. The width of the river is 80 to 60 m at the river mouth. The river stretch from 9 km to 10.5 km forms the extremely narrow portion with about 15 to 20 m in width and about 20 m in height. The river stretch from the extremely narrow portion to the Intake of La Atarjea is 40 to 80 m in width.

These sections can be classified as the river in the city, and has been remarkably changed artificially.

The upper stream from La Atarjea is as wide as 200 to 300 m or 400 m. It seems that the riverbed has been elevated by sediments of gravels, sands, and others. Similar conditions continue toward Chaclacayo.

A large part of mountains in this reaches consists of granitic rocks and forms steeper slopes over 30 degrees except the bottom portion of slope.

(2) Middle Reaches: Caranpongo - Matucana

Conditions of the middle reaches are comparatively variable. The terrace planes are found along the river. The banks of the river are relatively low.

The river has many tributaries such as Qda. Canchacalla, Rio Seco, Qda. Chucumayo and Qda. Pancha. These tributaries create large fans in their mouths.

The middle reaches are a full mature V-shaped valley of which river beds are commonly covered with thick alluvial deposits. Although the river has steeper gradients, outcrops of rocks are not found in any river beds. Such feature indicates obviously the fact that the valley is in the lateral erosion stage at present.

The slopes of valleys, including the Rimac river and the tributaries, are very steep, and have bluffs in many places. Except rock exposures, talus deposits or debris cones are found on the slopes and their inclinations are as steep as 36 to 38 degrees.

(3) Upper Reaches: Matucana - Chicla

The Rimac river is flowing down in the valley of high mountains of 4,000 to 5,000 m in altitude. The long slopes and high bluffs are found in many places. Therefore, all small gullies form slopes of taluses or debris cones on a large scale.

The river cuts deep valleys and gorges. In this area, V-shapes valleys are being actively deepened at present.

(4) Uppermost Reaches: Plateau Zone over EL.4,100 - 4,600 m

The plateau is located over 4,100 to 4,600 m in altitude. Many mountains and hills with permanent snow or ice are found in this area. The highest mountain is Nudo Sullcon of 5,650 m over sea level. The Ticlio pass is located on the border of the Rimac river basin and the river basin of Amazon, and 4,843 m in altitude.

2.3 Geological and Topographical Features in Disaster Prone Area

Each disaster prone area has the respective characteristics in the geological and topographic conditions. The characteristics of the major disaster prone areas such as Qda. Quirio, Pedregal, Carosio, Corrales, Rio Seco, Paihua and Cashahuacra, etc. are detailed in Appendix I, Supporting Report I.

3. METEO-HYDROLOGICAL CONDITIONS

3.1 Meteorological Conditions

3.1.1 General

The Rimac river basin is located in the range of 11°32'Lat. S and 12°15'Lat. S and in the range of 76°08' Long. W and 77°10' Long. W. The Basin has about 3,300 Km^2 of the drainage area included in the department of Lima located in around central of Peru. The Rimac river originates in the Andean Mountain Range and runs to south-west with gentle meandering to west in the middle reach, flows into the metropolitan area of Lima and reaches the Pacific Ocean at Callao.

The basin lies in the narrow strip zone in west coast of the South American Continent held between the Andes and the Pacific Ocean. The basin is characterized by a quite large scale of ground relief. Therefore, the climatic feature in the basin is complex though the span of east-west direction of the basin is only 150 km.

Annual total rainfall is ranged from 10 mm in the coastal area to around 1,000 mm in the mountainous area. And annual mean atmospheric temperature varies from approximately 20° C in the coastal area to 5° C in the mountainous area.

General characteristics of climatic feature in the basin is dominated more or less by El Niño. El Niño is a phenomenon of tropical sea water shift to southward along the coast of Ecuador and Peru. Periodically there is a powerful injection of warm water from the north that can reach into the sea area of Chile. In the last two decades, the principal El Nino occurred in 1972-73, 1976 and 1982-83, the last being the severest ever recorded.

3.1.2 Rainfall

In the coastal area, the rainfall amount is very few throughout the year. Because cold water of the Humboldt Current makes cool the air mass near the sea surface, it is prevented to produce an ascending air current. Thus, the closer to the coastal line of inland, the rainfall amount is less. On the contrary, mountainous area of Andes has relatively much rainfall because the influence of the air current from the cold sea is weakened.

The mean annual rainfall at Campo de Marte is 24 mm in the period between 1929 and 1982. The mean annual rainfall from 1965 to 1986 at Milloc is 860 mm. As seen in the records at Ñaña located at around 70 km eastward from Callao, the rainfall amount in the coastal area is deemed to be much less than that of Campo de Marte. The mean annual rainfall over the whole basin is approximately 400 mm.

A summary of monthly rainfall is shown in Table II-3-1 and historical records at Campo de Marte, Ñaña, Matucana and Milloc are shown in Table II-3-2 to II-3-5.

Isohyetal map of annual rainfall covering the basin is shown in Fig. II-3-1 with monthly rainfall pattern at representative five stations, that is, Campo de Marte, Santa Eulalia, Matucana, Bellavista, Milloc and Carampoma. As shown in the figure, the amount in the downstream area of Chosica is much less than that in the upstream area. The variation of annual rainfall amount in a long term in the basin is presented in Fig. II-3-2 by showing the record observed at Campo de Marte, Milloc and Matucana.

The probable basin mean one-day rainfall is analyzed as follows:

	Return Period (Year)							
	2	5	25	50	100	200	500	1000
Probable Basin Mean One-day Rainfall (mm):	12.8	16.6	22.3	24.6	26.9	29.2	32.3	34.7

The detailed analysis for the above is made in Appendix II, Supporting Report I. The probable rainfall is also analyzed for the major Quebradas in the basin. Those are given in the above Appendix II together with its detailed analysis.