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REPUBLIC OF THE PHILIPPINES

FINAL REPORT
FOR
THE MASTER PLAN STUDY
ON
THE CAGAYAN RIVER BASIN WATER RESOURCES DEVELOPMENT

MAIN REPORT

AUGUST 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to the request of the Government of the Republic of the Philippines, the Japanese Government has decided to conduct a Master Plan Study on the Cagayan River Basin Water Resources Development Project and entrusted the study to the Japan International Cooperation Agency. JICA sent to the Philippines a survey team headed by Mr. Hideki Sato of Nippon Koei Co., Ltd. from October 1985 to March 1987. The team exchanged views with the officials concerned of the Government of the Philippines and conducted a field survey. 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 Project 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 the Philippines for their close cooperation extended to the team.

August, 1987

Keisuke Arita
President
Japan International Cooperation Agency

THE MASTER PLAN STUDY
ON
THE CAGAYAN RIVER BASIN WATER RESOURCES DEVELOPMENT

August 1987

Mr. Keisuke Arita
President
Japan International
Cooperation Agency
Tokyo

Dear Sir,

LETTER OF TRANSMITTAL

We are pleased to submit to you the Final Report for the MASTER PLAN STUDY ON THE CAGAYAN RIVER BASIN WATER RESOURCES DEVELOPMENT, prepared for consideration by the Government of the Philippines in implementing water resources development in the specified region, in line with nation's socio-economic development objective.

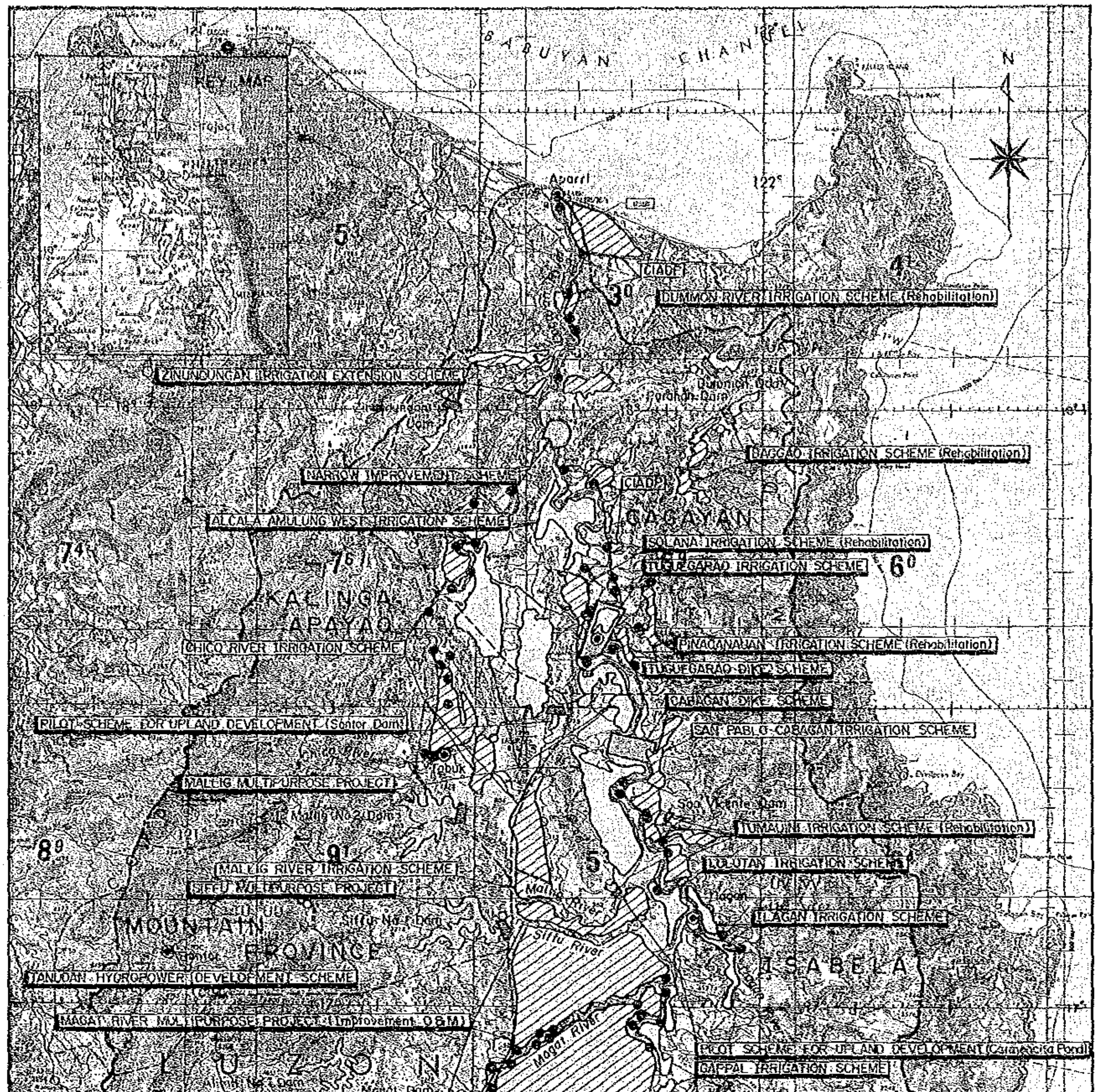
The report presents a master plan comprising various proposed schemes for flood control, agricultural development and hydropower development. The several multipurpose dams and single purpose dams are also proposed in the Master Plan in order to meet the anticipated water demands incurred by the proposed developments.

The Report consists of the Executive Summary, Main Report and Supporting Report. The Executive Summary briefs the summaries of the findings and the Master Plan proposed. The Main Report contains background and conditions, flood control plan, agricultural development plan, dam and hydropower development plan, conclusions and recommendations. Supporting Report contains supporting data and technical details.

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, Ministry of Agriculture, Forestry and Fisheries and Embassy of Japan to the Philippines as well as officials and individuals of the Philippines for their assistance 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 Cagayan river basin.

Yours sincerely,

Hideki Sato
Team Leader



LOCATION OF PROPOSED SCHEME IN THE MESTER PLAN

SUMMARY

I INTRODUCTION

1. The Study is performed in conformity with the stipulations of the IMPLEMENTING ARRANGEMENT on the Study agreed by both the Governments of Japan and the Philippines on August 1, 1985.

2. Thereby, the objectives of the Study is specified to formulate a Master Plan for the water resources development in the Cagayan river basin covering an area of 27,300 km^2. The target period of the plan is defined as about 20 years from 1985.

3. JICA organized the Study team with the selected consultants in order to carry out the Study. The team conducted the Study with a close and effective cooperation extended by the Government of the Philippines through the Counterpart Officers. JICA also established an Advisory Committee formed by staff of the Ministry of Construction and the Ministry of Agriculture, Forestry and Fisheries, Japan in order to guide the Study team and review the findings thereby. A Steering Committee formed by staff from the various related agencies with advisory members and a Technical Working Group established by the Government of the Philippines also guided the Study in various aspects.

4. The Study established the regional socio-economic development framework in terms of population, GRDP and GVAs. With due respect of the stipulations of the IMPLEMENTING ARRANGEMENT, the Study duly envisaged the development of flood control works, irrigation systems and hydropower generating facilities which will sustain the development framework plan. The Study projected future water deficits to be incurred by increasing water demands corresponding to the socio-economic developments mentioned above. Accordingly the Study proposes the construction of several impounding dams in the Cagayan river basin as preferred water resources developments which will remedy the water deficits projected. In addition, a flood control capacity is provided in the proposed impounding reservoir if it is judged to be effective.

5. The Study Team prepared and submitted a Draft Final Report to JICA at the end of March, 1987. This was duly distributed to the relevant committees by JICA. Meetings of the Advisory Committee in Japan and the Technical Working Group in the Philippines were held to discuss the comments received on the Report. Finally a joint meeting of JICA Advisory Committee, the Steering Committee of the Government of the Philippines and the Study Team was held on June 15, 1987 in Quezon City. All the conclusions of the meeting were incorporated in the Report from which this Final Report has been prepared.

II PROFILE OF THE CAGAYAN RIVER BASIN

1. The Cagayan river basin lies between 15°52′ and 18°25′ north in latitude and between 120°51′ and 122°18′ east in longitude. The basin is bordered as follows;

   - East : Sierra Madre mountain range
   - West : Cordillera Central mountain range
   - South : Caraballo-Maparang mountain range
   - North : Babuyan channel

2. The basin administratively comprises 8 provinces belonging to Regions I, II and IV as follows;

   - Region I : Mountain Province
   - Region II: Cagayan, Ifugao, Isabela, Kalinga-Apayao, Nueva Vizcaya and Quirino
   - Region IV: Aurora

   In total, 107 municipalities are included in the Cagayan river basin. The locations of provinces and municipalities are shown in Fig. 2.1.

3. According to the results of a census carried out by NEDA, the total population in the Cagayan river basin was 1,885,000 in 1980. The urban population was estimated to be 316,000 and the rural population 1,569,000. The most urbanized municipality is Tuguegarao which has an urban population of 30,000 or 41% of total population. The average population density is 69 person/km^2. The figure appears extremely low as compared with the national average of 160 person/km^2.

4. The gross regional domestic production (GRDP) in the Cagayan river basin was ₱1,825 x 10^6 in 1985 at 1972 constant prices. The compositions of the gross value added (GVA) by sector was as follows;

Item	GVA ($₱10^6$)	Ratio (%)
GRDP	1,825	100
Agriculture	862	47.2
Industry	272	14.9
Services	691	37.9

(At 1972 constant prices)

The per capita GRDP of ₱854 is extremely low as compared with the national average of ₱1,654 at 1972 constant prices.

5. The topography of the basin is generally sloping. The lowlands which have a slope less than 8% cover only 6,800 km^2 or 25% of the total land area. The upland areas with slopes between 8% and 18% cover 9,000 km^2 and the mountainous area with slopes of more than 18% cover 11,500 km^2. The land use may be summarised as follows;

(Unit: km^2)

Land Use		Area
Lowland	Paddy	2,470
	Corn and others	1,300
	(Sub total)	(3,770)
Upland	Permanent crops	270
	Pasture	1,270
	(Sub total)	(1,540)
Mountain	Forest	11,500
	(Sub total)	(11,500)
Idle land, Bare land and others		(10,490)
Total		27,300

Noteworthy land resources to be developed is around 3,000 km^2 of potential arable land in the lowland and 7,000 km^2 of mainly potential pasture land in the upland areas.

6. Meteoro-hydrologic features of the basin may be judged from the following data;

1) Average annual rainfall:

- Maximum: more than 4,000 mm in the mountainous area.
- Minimum: less than 2,000 mm in the northern lowland.
- Average: 2,600 mm

2) Seasons:

- Dry season: From December to May (NE monsoon period)
- Wet season: From June to November (SW monsoon period with frequent typhoon)

3) Average annual runoff:

River	Catchment area (km^2)	Runoff (m^3/s)	Specific discharge ($m^3/s/km^2$)
Magat	5,113	263	0.051
Upper Cagayan	6,633	291	0.044
Whole basin	27,300	1,343	0.049

4) 100-year flood peak discharge:

River	Catchment area (km^2)	Discharge (m^3/s)	Specific discharge ($m^3/s/km^2$)
Magat	5,113	10,600	2.1
Chico	4,551	8,700	1.9
Cagayan/1	11,993	23,900	2.0
Whole basin	27,300	21,600	0.8

Note: /1; Just upstream from the junction of Ilagan river.

These figures indicate the abundance of water resources with a biased distribution over the year.

7. The riverbed slope and flood water surface slope of the Cagayan river are estimated and presented as below;

River stretch	Length (km)	Riverbed slope	Water surface slope
Ilagan-Tuguegarao	70	1/5,620	1/5,670
Tuguegarao-Alcara	75	1/8,680	1/12,080
Alcara-River mouth	65	1/8,680	1/3,450

The differences in slopes of the riverbed and the water surface demonstrate the possibility of a bottle-neck around Alcara.

8. The flow capacities of the existing river channels are small in the aluvial plain and inundation is rather frequent. The capacity of the Cagayan river between Alcara (Catchment area: 21,400 km^2) and Tuguegarao (Catchment area: 19,500 km^2) is estimated to be only 0.23 $m^3/s/km^2$ in terms of specific discharge, which is no more than the equivalent peak discharge of a 2-year flood.

The floods of 1973 and 1980 are noted for the overwhelming havoc they caused. The former accompanied typhoon Openg and submerged a land area of 1,860 km^2. The latter was brought about by typhoon Aling and flooded an area of about 1,740 km^2. Flooded areas caused by typhoons Openg and Aling are shown in Fig. 2.5.

The average annual cost of flood damage is estimated to be ₱3,793 x 10^6 in the basin at 1985 current prices under existing situations.

9. Agricultural production in the Cagayan river basin tends to be extensive rather than intensive because intensive agriculture is considered to be risky due to frequent flood damage. Agricultural production in the basin at 1972 constant prices is estimated to be as follows;

- Paddy : ₱ 439 x 10^6
- Corn : ₱ 120 x 10^6
- Other crops: ₱ 72 x 10^6
- Fisheries : ₱ 7 x 10^6
- Live stock : ₱ 77 x 10^6
- Forest : ₱ 147 x 10^6

10. The electrification rate was estimated to be 40% in the Cagayan river basin in 1984. The energy demand was 83 GWh and the peak load is 33 MW in 1984 against the installed capacity of 365 MW. The daily load factor is estimated to be 87.5% according to the daily demand curve. The power plants located in the basin are as follows;

- Magat	(Hydropower)	:	Installed capacity	360 MW
- Ramon	(")	:	"	1,440 kW
- Tumauini	(")	:	"	760 kW
- Ilagan	(Dendro thermal)	:	"	3,100 kW

11. LWUA and DPWH are substantial authorities which supply most of the municipal water to the more urbanized areas, while the Rural Waterworks Development Corporation and Barangay Water Program take care of water supply to the rural areas. 27,000 households were served in 1985 making the service factor about 59%. Half of these households are served only by a public well (Level I). 25% have public faucets (Level II) and 25% enjoy a piped system (Level III). The total water supply amounted to about 141 x 10^3 m^3/day in 1985.

III SOCIO-ECONOMIC PROJECTION AND TARGET

In line with the Government's policy of equitable development, the economic development target is to enhance the economy and per capita GRDP of the Cagayan river basin to the equivalent of the national average by 2005. In this comparison, NCR and Region IV are excluded from the estimate of the national average because these regions are extremely industrialized and their economic structures are of a different category. The socio-economic projections and targets envisioned on the basis of MEDIUM-TERM PHILIPPINE DEVELOPMENT PLAN assessed on this basis may be summarized as follows;

	1985	1990	1995	2000	2005
Population (10^3)	2,136	2,413	2,702	2,989	3,259
GRDP (₱10^6) /1	1,825	2,689	4,014	5,536	7,080
Agriculture /1	862	1,062	1,383	1,631	1,837*
Industry /1	272	444	743	1,568	2,544
Service /1	691	1,183	1,888	2,337	2,699

Note /1; At 1972 constant price

*; 70% of maximum development (₱2,408 x 10^6) of agriculture excluding forest (₱147 x 10^6).

The per capita GRDP is accordingly set at ₱2,172 in the year 2005.

IV FLOOD CONTROL PLAN

1. Structural and non-structural measures are contemplated to mitigate flood damage. In this study, priority has been given to structural measures because these are expected to become effective within the short time target of 20 years. Nevertheless, the non-structural measures such as watershed management, afforestation and reforestation, flood warning and evacuation will also play important roles in flood control in future and should also be incorporated into the flood control plan for the Cagayan river basin.

2. In establishing an overall water resources development Master Plan, two plans were formulated a flood control framework plan and a long-term plan.

3. The flood control plan was framed in line with the following principles which were established through studies on present river conditions.

   1) Flood control dams should be provided in the upper watershed areas to reduce peak flood discharge over the extensive lower reaches.

   2) The existing channel retardation function should be conserved in the upper reaches of the Cagayan river and tributaries. In these reaches, efforts should be concentrated on bank protection.

   3) For the middle and lower reaches of the Cagayan river, a diking system should be provided as well as bank protection works so as to protect lowlying lands from flooding. Channel normalization to accelerate smooth and swift drainage of flood water should also be undertaken. Improvement of the Magapit narrows could be a key to the flood control in these reaches.

4. The framework plan was formulated after comparative studies of the following 6 alternative plans consisting of flood control dams, diking systems, and improvement of Magapit narrows:

1) Alt. OD: With diking system, but without dam and narrows improvement. The estimated project cost: ₱35,688,000,000

2) Alt. 5D: With 5 dams and diking systems but without narrow improvement.
The estimated project cost: ₱36,466,000,000

3) Alt. 9D: With 9 dams and diking systems but without narrow improvement.
The estimated project cost: ₱45,796,000,000

4) Alt.ODM: With narrows improvement and diking system but without dams. The estimated project cost: ₱38,278,000,000

5) Alt.5DM: With 5 dams, narrows improvement and diking systems. The estimated project cost: ₱34,394,000,000

6) Alt.9DM: With 9 dams, narrows improvement and diking systems. The estimated project cost: ₱45,603,000,000

The locations of these alternative plans are shown in Fig. 5.10.

The combination of 5 dams and the narrows improvement with diking system (Alt. 5DM) was selected as the framework plan on the least cost basis.

The plan contemplates alleviating flooding by flood control dams in the upstream reaches and lowering the flood water levels in the downstream reaches by improvement of the Magapit narrows. The areas along the middle reaches of the river will be protected from flooding by diking systems. Dams encompassed in the framework plan are Cagayan No. 1, Ilagan No. 1, Siffu No. 1, Mallig No. 2 and Magat dams. A 100-

year flood is adopted as the design discharge of the framework plan.

5. Following this, a long-term plan was formulated on the basis of the framework plan. The design discharge, however, was reduced to the 25-year flood. The principal features of the long-term plan are as follows:

1) Project cost (economic): ₱27,543,000,000

- Channel work including dike embankment, revetment, drainage sluices, narrows excavation, cut-off channels, bank protection and appurtenant facilities amounting ₱21,345,000,000.
- Dam works for Cagayan No. 1, Alimit No. 1, Ilagan No. 1, Siffu No. 1 and Mallig No. 2 amounting ₱6,198,000,000.

2) Economic evaluation

- Benefit (₱mil./yr)	3,834.1 (at 1985 curent price)
Flood damage reduction	3,698.6
Bank protection	135.5
- IRR (%)	14.2

6. The economic viability of each element in the Long Term Plan was examined in terms of EIRR. The results are shown in Table 5.14 and summarized below:

Rank	Scheme	EIRR
1	Tuguegarao dike	23.1 %
2	Narrow imp. (Site-NLL)	18.9 %
3	Bank protection	13.7 %
4	Cabagan dike	13.6 %
5	Narrow imp. (Site-NLR)	13.5 %
6	Magat/Alimit No. 1 dam	13.1 %
7	Siffu No. 1 dam	12.8 %
8	Cagayan No. 1 dam	11.6 %
9	Mallig No. 2 dam	9.3 %
10	Ilagan No. 1 dam	5.4 %
11	Narrow imp. (Site-NUP)	-

V AGRICULTURAL DEVELOPMENT PLAN

1. Agricultural development is based the following concepts;

   1) The potential paddy fields of 306 x 10^3 ha will fully be irrigated, through realization of the following measures:

      - Completion of on-going projects
      - *Rehabilitation/improvement of existing* NIS and CIS schemes
      - Development of new irrigation schemes

   2) Productivity of rice production will be increased by extension of improved farming practices under irrigation.

   3) The potential diversified cropland of 170 x 10^3 ha will be fully developed, and the increased cropland will be allocated mainly to corn production.

   4) Productivity in the diversified cropland will be increased by improved farming practices under rainfed conditions.

   5) The upland area will be utilized mainly for production of permanent crops and cattle grazing.

   6) Recommended permanent crops are cashew nuts, mango and citrus fruits.

   7) Cattle will be grazed in pastures and fattened in feedlots.

   8) Fresh water aquaculture will be the main source of fishery products. The production increase of fisheries will be set at 4.5% per annum based on "The Medium-Term Plan of BFAR".

9) Forestry production will be maintained at the present selective logging level in due consideration of government policy on environmental conservation.

10) In view of the development policy of the Government of the Philippines, the maximum possible development of agriculture is envisioned by the year 2005. In this connection, 70% of the potential is assumed to be the practicable maximum development.

2. Along these lines, the following land use plan in the cultivable land is contemplated:

(Unit: 10^3 ha)

Land Use	Present Land Use (1985)	Future Land Use (2005) (1)	Land Use Plan in P.M.A.* (2)	Ratio of Attainment in 2005 (%) (1)/(2)
I. Lowland				
1. Paddy field	247	306	306	100
2. Diversified cropland - Corn field	102	142	142	100
- Others	28	28	28	100
3. Grassland (idle)	99	-	-	-
Sub-total	476	476	476	-
II. Upland				
1. Permanent cropland	27	57	200	29
2. Pasture	127	210	300	70
3. Grassland (idle)	450	337	104	-
Sub-total	604	604	604	-

* Potential maximum area.

3. Irrigation is considered as the principal scheme for lowland development. The locations of the proposed schemes are shown on Fig. 6.16 and the major features thereof are summarized in Tables 6.22 and 6.23. The proposed irrigation schemes are listed below.

Irrigation Scheme	Service area (ha)
I. New Irrigation Scheme	65,330
1. Chico Mallig Irrigation Project	31,200
2. Matuno River Development Project	12,680
3. Dabubu River Irrigation Project	1,000
4. Zinundungan Irrigation Extension Project	1,750
5. Alcala Amulung West Irrigation Project	6,750
6. Tuguegarao Irrigation Project	1,400
7. Lulutan Irrigation Project	2,950
8. Ilagan Irrigation Project	3,200
9. Gappal Irrigation Project	4,400
II. Rehabilitation/Improvement Scheme	12,212
1. Dummon River Irrigation System	2,070
2. Baggao Irrigation System	1,812
3. Solana - Tuguegarao Irrigation System	3,143
4. Pinacanauan Irrigation System	1,200
5. Tumauini Irrigation System	3,987

Lowlands which will not be irrigated will be developed as rainfed diversified crops fields.

4. At present, only 127×10^3 ha or 20% of the total cultivable land of 604×10^3 ha is utilized for cattle grazing in the uplands. This area is to be extended to 210×10^3 ha, and permanent crops land of 27×10^3 ha is to be enlarged to 57×10^3 ha by the year 2005. The recommended crops are cashew nuts, mango and citrus fruits.

5. Fresh water fisheries are recommended for development of inland water ponds. New reservoirs and ponds proposed may be available for the purposes.

6. Economic internal rates of return (EIRRs) were estimated for each proposed irrigation scheme for two different cropping patterns as follows;

(Unit; %)

Proposed Scheme	Proposed Cropping Pattern A & C	Proposed Cropping Pattern B & C
I. New Irrigation Scheme		
1. Chico Mallig IP	15.7	12.9
2. Matuno RIP	12.4	10.1
3. Dabubu RIP	19.5	17.2
4. Zinundungan IEP	13.4	12.5
5. Alcala Amulung West IP	17.3	14.9
6. Tuguegarao IP	19.4	18.7
7. Lulutan IP	22.8	18.0
8. Ilagan IP	28.0	27.7
9. Gappal IP - Pump	20.2	16.2
- Dam	13.5	11.4
II. Rehabilitation/Improvement Scheme		
1. Dummon RIS	8.0	5.7
2. Baggao IS	7.3	5.7
3. Solana IS	39.0	28.5
4. Pinacanauan IS	75.7	56.0
5. Tumauini IS	12.6	11.7

The applied cropping patterns A, B and C are illustrated and shown in Figs. 6.19, 6.20 and 6.21.

7. The priority of each irrigation scheme was determined through the following procedures: (i) the proposed schemes were classified into two categories; schemes with EIRR of more than 15% and schemes with EIRR of less than 15%, (ii) the priority of each proposed scheme within each category was given in accordance with the net firm income per hectare to be derived thereby; higher priority was given to schemes with higher net firm income per hectare and (iii) if the proposed two schemes yield same net firm income, higher priority was given to the scheme with larger number of beneficiaries per hectare. The results of

ranking are summarized as below;

Scheme	Net firm income (₱10³/ha)	Rank-ings	Benefici-alies (Person/ha)	Rank-ings	Overall rank-ings
Above 15% of EIRRs (1st Class)					
Pinacanauan IS	33	1	8.3	2	1
Chico Mallig IP	32	2	3.1	8	2
Dabubu RIS	30	3	5.1	5	3
Lulutan IP	29	4	4.4	7	4
Solana IS	28	5	8.1	3	5
Gappal/IP (Pump)	28	5	4.8	6	6
Ilagan IP	26	6	8.4	1	7
Tuguegarao IP	24	7	6.1	4	8
Alcala Amulung West IP	24	7	1.9	9	9
Under 15% of EIRRs (2nd Class)					
Baggao IS	33	1	4.8	3	10
Dummon RIS	32	2	3.2	4	11
Matuno RIS	30	3	6.3	1	12
Tumauini IS	27	4	6.0	2	13
Zinundungan IES	27	4	2.9	5	14

8. The agricultural developments proposed as above entail the following water demand;

Irrigation Water (Monthly)

(Unit: m^3/s)

Year	J	F	M	A	M	J	J	A	S	O	N	D
1985	130	158	94	69	139	124	156	93	48	19	67	73
1990	220	251	202	94	173	232	287	183	109	50	63	161
1995	264	302	254	101	218	281	338	217	124	59	65	195
2000	281	323	278	106	235	298	360	232	133	63	67	207
2005	295	338	296	105	255	317	379	244	134	66	66	222

Livestock Water (Annual)

	1985	1990	1995	2000	2005
($10^6 m^3/y$)	3.74	4.84	5.94	7.04	8.15
(m^3/s)	(0.12)	(0.15)	(0.19)	(0.22)	(0.26)

VI HYDROPOWER DEVELOPMENT PLAN

1. The demands of electric power in Luzon island have been projected up to the year 2005. The projected demands are compared with the existing power supply capacities in 1990. The projected demands in the years of 1990, 1995, 2000 and 2005 are 2,927, 3,813, 4,953 and 6,428 MW. Meanwhile, the installed capacity in 1990 is to be 4,101 MW which is expected to yield an output of 3,280 MW. If the installed capacity is not increased, a certain deficit in electric supply will be entailed. A deficit of some 3,000 MW is projected in the year 2005.

2. In order to meet the deficit, the following hydropower schemes are envisaged within the Cagayan river basin as the candidate schemes;

Scheme	MW	GWh	Q (m^3/s)	Gross H. (m)	Turbine	Unit
(Casecnan)	(268)	(1,379)	(110.0)	(208.5)	(Francis)	(3)
Matuno	180	528	110.0	220.0	Francis	2
Ibulao	17	85	7.8	274.0	Francis	3
Tanudan	25	130	11.9	270.0	Francis	2
Diduyon	352	957	85.2	486.0	Francis	2
Chico IV	360	955	355.0	151.0	Francis	4

Casecnan scheme is regarded as an on-going project.

3. The project costs thereof are estimated as follows:

(Time basis 1985 December)

- (Casecnan) (\$445.8 x 10^6)
- Matuno \$267.0 x 10^6
- Ibulao \$29 x 10^6
- Tanudan \$34 x 10^6
- Diduyon \$469.2 x 10^6
- Chico IV \$534.9 x 10^6

VII MUNICIPAL WATER DEMAND PROJECTION

1. Municipal water demand is projected with assumptions presented hereunder;

Item	1985	1990	1995	2000	2005
Unit water consumption					
Domestic water (lit/capita/day)					
Level 1	30	30	30	30	30
2	60	60	60	60	60
3	100	105	110	115	120
Service (m^3/establishment/day)	1.0	1.25	1.5	1.75	2.0
Public					
School (m^3/unit/day)	1.0	1.25	1.5	1.75	2.0
Hospital (m^3/unit/day)	3.0	3.25	3.5	3.75	4.0
Others (m^3/unit/day)	2.0	2.25	2.5	2.75	3.0
Construction (m^3/day/GVA (₱10^6 at 1972 prices))	31	31	31	31	31
Other Industries (m^3/day/GVA (₱10^6 at 1972 prices))	763	743	723	703	684
Service factor of domestic water supply (%)					
Rural Level 1	44	47	50	53	50
2	16	28	30	32	35
No service	40	25	20	15	15
Urban Level 1	50	25	0	0	0
2	25	25	25	0	0
3	25	50	75	100	100
Existing supply capacity (10^3 m^3/day)	52.4	58.1	58.1	58.1	58.1
Loss rate (%)	35	32.5	30	27.5	25

2. The treated water demands are projected assuming that the socio-economic developments envisioned are to be realized as follows;

(Unit: m^3/day)

Year	Domestic use	Service and Public use	Manufacturing use	Total
1985	82,465	17,258	41,538	141,261
1990	111,495	23,722	47,023	182,240
1995	143,504	30,308	77,220	252,032
2000	179,761	39,872	204,881	424,514
2005	211,343	91,182	431,672	692,197

3. The source water demands are projected on the basis of the treated water demands projected as mentioned above. The projected are allocated to the assumed 20 waterworks over the Cagayan river basin. The projected and allocated water demands are presented as follows;

(Unit: m^3/day)

Assumed Waterworks	1985	1990	1995	2000	2005
Block 1	11,236	14,639	20,483	34,891	57,111
Block 2	6,977	8,713	11,306	17,472	26,918
Block 3	21,951	28,174	40,017	70,948	118,574
Block 4	9,550	11,519	14,590	22,291	33,851
Block 5	14,901	18,792	25,544	42,376	67,597
Block 6	9,143	11,613	15,991	26,932	43,332
Block 7	12,664	15,901	22,034	7,980	62,110
Block 8	13,568	17,107	24,008	42,131	69,598
Block 9	14,465	18,101	24,165	39,124	61,488
Block 10	10,445	12,542	15,387	21,821	30,941
Block 11	6,563	7,616	8,662	10,801	13,665
Block 12	12,911	16,261	22,842	40,209	66,558
Block 13	6,159	7,569	9,436	13,569	19,586
Block 14	4,359	5,440	6,584	8,517	11,147
Block 15	10,947	13,884	19,561	35,062	60,082
Block 16	2,823	3,420	3,833	4,243	4,647
Block 17	12,290	14,780	20,419	35,766	57,778
Block 18	13,075	15,874	19,768	28,419	40,356
Block 19	7,528	9,122	11,201	15,663	21,775
Block 20	15,772	18,916	24,214	37,320	55,814
Total (m^3/day)	217,325	269,985	360,046	585,537	922,930
(m^3/sec)	2.52	3.12	4.17	6.78	10.68

VIII WATER DEMAND AND SUPPLY BALANCE

1. Water demand and supply balances are simulated at various points in the Cagayan river basin. The physical distribution of water is illustrated and shown in Fig. 10.1. The simulation is performed using the average 10-day runoff estimated for 22 years period from 1963 to 1984 at relevant points.

   In this simulation, the following river maintenance flows are assumed;

   1) River maintenance flow for general use: 0.0046 $m^3/s/km^2$
      N-th minimum among N-year record
   2) At the pump station in Magapit: 140 m^3/s
      80% dependable flow under the condition with present (1985) water demand
   3) At the existing Magat and Siffu intakes: Zero

2. Water deficit of 109 x 10^6 m^3 is projected against the water demand in 1985. The deficit will increase to 1,373 x 10^6 m^3 in 2005 if no water resources are developed. The details are given in Table 10.1.

3. In order to augment the natural flow and to remedy the projected water deficit, provision of the following dams is proposed:

Dam	Balance Point	Purpose	Required storage (10^6 m^3)
Sto. Niño	6	Dabubu irrigation	2
Santa Maria	8	Gappal irrigation	
Colorado	"	"	118
Calaocan	"	"	
Matuno No. 1	11	Matuno irrigation	61
San Vicente	33	Tumauini irrigation	7
Mallig No. 2	23, 26, 30, 31	Chico Mallig irrigation	545
Paranan	42	Baggao irrigation and hydropower	18
Zinundungan	44	Zinundungan irrigation and hydropower	53
Dummon	46	Dummon irrigation and hydropower	24

The water deficit projected in the Magat project is to be met by the dams of Matuno No. 1, Siffu No. 1 and Alimit No.1 , which are discussed in the next chapter as the Master Plan.

All the water deficits are can be met by the water released from these dams or the return flow thereof. The location of damsites are shown in Fig. 10.2.

IX MASTER PLAN

1. The least costly alternative to meet the deficit of the Magat project and to allocate a part of the Magat reservoir space to flood control was found to be the optimum combination of the proposed Siffu No. 1, Matuno No. 1 and Alimit No. 1 dams. The results of study are presented in Fig. 11.2.

2. The optimum combination was identified as that providing the maximum Net Present Value (NPV) in comparison with various least costly combinations corresponding to the various flood control capacities discussed above. The maximum NPV is obtained if a storage volume of 139×10^6 m^3 is allocate to flood control at Magat dam. The benefit-cost curve developed is shown in Fig. 11.3.

   The optimum apportionment of flood storage capacity of each dam is listed below;

   - Flood control space of Magat reservoir: 139×10^6 m^3
   - Contribution of Matuno No. 1 reservoir: 36×10^6 m^3
     (deficit supply of Magat dam)
   - Contribution of Alimit No. 1 reservoir: 156×10^6 m^3
     (deficit supply and subrogate of flood control of Magat dam)
   - Contribution of Siffu No. 1 reservoir : 41×10^6 m^3
     (deficit supply of Magat dam)

   In addition to this, the implementation order of Siffu No. 1, Matuno No. 1 and Alimit No. 1 turns out to be the optimum.

3. The necessary scales of water supply dams are obtained as discussed in the previous chapter for WATER DEMAND AND SUPPLY BALANCE in terms of the required storage. The said scales are just enough to cope with the projected water demand up to the year 2005, the target year of the Study. Water demand, however, will continue to increase beyond the

target year, but the preferable damsites will be limited. In this respect, further dam development should be designed to take maximum advantage of hydrological and topographic conditions as far as it is economically advantageous. The optimum scale of dam was then examined through NPV analysis by applying the water demands assumed up to the year 2040 and the assumed water supply benefits of ₱1.0/m^3 for municipal and ₱0.38/m^3 for irrigation water supplies. The growth rates of population and GDP projections made by the NEDA were applied to project the water demands for the period from 2006 to 2020. The water demands, for the period from 2021 to 2040 were projected by linear extrapolation of the water demands in 2015 and 2020.

Since the assumed increases in water demands are small, the increases in benefits are negligible as compared with the increases in costs corresponding to the required additional storages. Thus the optimum scales of all dams were found to be the scales previously designated as the required scales. The benefit and cost curves are developed and exhibited in Fig. 11.4.

4. The flood control capacity is accumulated at the obtained optimum scale of water supply dam if the flood control function is as proposed by the flood control study. The scales of such dams are thus modified as follows;

1) Siffu No. 1 dam

Water supply and hydropower	93×10^6 m^3
(Equivalent to Magat 41×10^6 m^3)	
Flood control	115×10^6 m^3
Total	208×10^6 m^3

2) Mallig No. 2 dam

Water supply	545×10^6 m^3
Flood control	112×10^6 m^3
Total	657×10^6 m^3

3) Matuno No. 1 dam

Water supply (Magat) and hydropower	36×10^6 m^3
Irrigation and hydropower	61×10^6 m^3
Total	97×10^6 m^3

5. The cost of a multipurpose dam is allocated to each purpose by applying the Separable Cost and Remaining Benefit method. The priority of each scheme is re-allocated utilizing the allocated costs. The revised priorities are as follows;

Flood Control

1	Tuguegarao dike
2	Narrow improvement (Nassiping left bank: Site-NLL)
3	Siffu No. 1 dam (Multipurpose)
4	Bank protection
5	Cabagan dike
6	Narrow improvement (Nassiping right bank: Site-NLR)
7	Magat dam (Alimit No. 1 dam, Multipurpose)
8	Cagayan No. 1 dam
9	Mallig No. 2 dam (Multipurpose)
10	Ilagan No. 1 dam
11	Narrow improvement (Upstream from Nassiping: Site-NUP).

Irrigation

1	Pinacanauan	Rehabilitation	
2	Chico Mallig	Development (Multipurpose)	
3	Dabubu	"	
4	Lulutan	"	
5	Solana	Rehabilitation	
6	Gappal	Development	
7	Ilagan	"	
8	Tuguegarao	"	
9	Alcala-Amulung	"	
10	Baggao	Rehabilitation	(with hydropower)
11	Dummon	"	(")
12	Matuno	Development	(Multipurpose)
13	Tumauini	Rehabilitation	
14	Zinundungan	Development	(with hydropower)

Hydropower

1	Matuno (Multipurpose)
2	Ibulao
3	Tanudan
4	Diduyon

6. The multipurpose projects comprising multiple schemes to be connected by multipurpose dams were evaluated in terms of EIRR reflecting whole the costs and benefits as follows;

- Matuno Project: EIRR; 15.3%
- Mallig " : EIRR; 15.2%
- Siffu " : EIRR; 14.5%
- Alimit " : EIRR; 12.1%

7. In order to select schemes for inclusion in the proposed Master Plan, following principles are employed;

1) Although the economic viability of a multipurpose project is of importance, high priority must be given a project which satisfies a deficit in water or hydropower.

2) To achieve the GVA target in 2005, it is assumed that more than 10% of the projected flood damage of ₱8,998 x 10^6 in 2005 at 1985 constant prices should be prevented.

3) To develop the lowlands fully, all the proposed 9 irrigation development and 5 irrigation rehabilitation schemes should be selected.

4) The uplands are to be developed and the present land use area of 154 x 10^3 ha should be extended to 267 x 10^3 ha by 2005.

5) The least costly alternative schemes should be selected to satisfy the hydroelectric demands.

8. In conformity with these principles, the following projects and schemes were selected for inclusion in the proposed Master Plan;

1) Multipurpose projects: Siffu project, Mallig project, Matuno project and Alimit project.

2) Flood control schemes: Tuguegarao dike, Narrows improvement (NLL), Cabagan dike, Narrows improvement (NLR) and Bank protection works.

3) Agricultural development schemes: 9 irrigation development schemes, 5 irrigation rehabilitation schemes, permanent crops development (30,000 ha) and cattle grazing (83,000 ha).

4) Hydropower development schemes: Ibulao, Tanudan and Diduyon scheme Hydropower developments of Dummon, Paranan and Zinundungan are incidental to the relevant irrigation schemes.

The location of the selected projects and schemes are shown in Fig. 11.16.

Regarding the flood control schemes, non-structural measures such as watershed management, afforestation and reforestation, flood warning and evacuation should also be incorporated as well as the structural measures mentioned above. And as for agricultural development, the improvement project for the operation and maintenance of the Magat River Integrated Irrigation System is considered as proposed.

9. The costs to be incurred by these projects and schemes selected were estimated as follows;

1) Multipurpose projects:

Siffu	₱1,057 x 10^6
Mallig	₱3,715 x 10^6
Matuno	₱5,855 x 10^6
Alimit	₱2,037 x 10^6
Sub total	₱12,665 x 10^6

2) Flood control schemes:

Tuguegarao dike	₱554 x 10^6
Narrows imp. (NLL)	₱978 x 10^6
Bank protection	₱970 x 10^6
Cabagan dike	₱307 x 10^6
Narrows imp. (NLR)	₱2,957 x 10^6
Sub total	₱5,766 x 10^6

3) Irrigation development schemes:

Pinacanauan	₱ 23 x 10^6	
Dabubu	₱ 99 x 10^6	
Lulutan	₱184 x 10^6	
Solana	₱ 73 x 10^6	
Gappal	₱606 x 10^6	
Ilagan	₱166 x 10^6	
Tuguegarao	₱ 99 x 10^6	
Alcara-Amulung	₱434 x 10^6	
Tumauini	₱378 x 10^6	
Dummon	₱449 x 10^6	(Including hydropower)
Baggao	₱451 x 10^6	(")
Zinundungan	₱418 x 10^6	(")
Magat O & M	₱1,060 x 10^6	
Sub total	₱4,441 x 10^6	

4) Hydropower development schemes:

Ibulao	₱551 x 10^6
Tanudan	₱646 x 10^6
Diduyon	₱8,915 x 10^6
Sub total	₱10,112 x 10^6
Grand Total	₱32,983 x 10^6

10. The implementation schedule was considered in accordance with the following concepts:

1) Schemes or projects which ensure safety or security are to be implemented with high priorities.

2) The implementation of schemes should be scheduled so as not to cause any water or power deficits.

3) Schemes or projects with high EIRRs should be realized as soon as possible.

4) The annual increase in irrigation area should be constant as far as possible throughout the period of master planning.

5) The annual investment should be constant as far as possible throughout the period of master planning.

With regard to the supplement to Magat dam and the apportionment of the Magat flood control space, Siffu No. 1 dam is to be implemented first as described earlier. Matuno No. 1 dam will follow and then Alimit No. 1 dam comes next.

Since meeting the estimated water deficit in Magat project is significant, Siffu project should be implemented as soon as possible. Matuno hydropower scheme should also be in operation by 1998 according to the hydropower development plan. Meanwhile, the priority of the flood control scheme by Magat dam is not urgent. Consequently the implementations of these dams are scheduled to commence as follows;

Siffu No. 1	1990
Matuno No. 1	1992
Alimit No. 1	1997

The economic viability of Mallig project is higher than that of Siffu project. And Chico Mallig irrigation scheme has the second highest priority among the proposed irrigation schemes. Consequently the implementation of Mallig project is scheduled to commence in 1990 following Pinacanauan and Dabubu irrigation schemes.

Since bank protection work sites are located at 75 sites and can be implemented independently, bank protection is considered to be implemented through out the period of master planning.

The implementation schedule proposed is shown in Fig. 11.17 and the disbursement schedule of estimated project costs is given in Table 11.2.

11. The value added induction factor of construction works was estimated by applying the Inverse Matrix for Input Output Analysis prepared by NEDA. The factor of 1.01 was yielded by the Study. This implies that implementation of the Master Plan will bring about considerable beneficial impacts on the regional socio-economy.

84,000 families or 462,000 persons are expected to benefit by 2005 from the effects of the proposed flood control schemes included in the proposed Master Plan even against a 2-year flood.

The agricultural, manufacturing and services industries will be developed as programmed if the proposed Master Plan is realized. In this case, the total labour requirement in the year 2005 is estimated to be 880×10^3 persons which is about 77% of the potential labour force of $1,140 \times 10^3$ persons.

In addition to the above, the removal of water deficit problems and the improvement of electrification may contribute substantially to the cultural development of the region.

The effects of the Master Plan may be summarized as follows;

1) Increase of family income and consumption.
2) Increase and stabilizing of job opportunities.
3) Change in quality of job due to the development of manufacturing and services.
4) Land enhancement due to the flood protection.
5) Improvement of sanitary conditions due to the flood control.
6) Improvement of sanitary conditions due to improved municipal water supply.
7) Improvement of cultural situation due to the electrification.
8) Evolution of diversified life styles due to the improvement of electrification.
9) Technical innovation by industrialization.
10) Technical improvement due to the evolved complexity in agricultural management.
11) Evolution of urbanization.
12) Environmental pollution due to industrialization.
13) Environmental pollution due to the development in livestock industry.
14) Environmental pollution due to agricultural chemicals.

X SHORT TERM PLAN

1. Schemes proposed for implementation within 10 years were selected for inclusion in the proposed Short Term Plan. The preparation of project proposals and implementation programs is recommended. Related preparatory work such as topographic surveys, geological investigations and budgetary arrangements are specified and recommended.

2. Selected multipurpose projects are as follows;

1)	Mallig project:	Mallig No. 2 multipurpose dam Chico Mallig irrigation scheme Flood control
2)	Siffu project :	Siffu No. 1 multipurpose dam Siffu hydropower scheme Supplement of deficit in Magat project Flood control
3)	Matuno project:	Matuno No. 1 multipurpose dam Matuno irrigation scheme Matuno hydropower scheme Municipal water supply Supplement of deficit in Magat project

3. The selected flood control schemes are as follows:

1)	Tuguegarao dike :	Dike length	22.1 km
		Embankment	$2,340 \times 10^3$ m^3
2)	Narrow improvement (NLL):	Channel length	3.8 km
		Excavation	$5,830 \times 10^3$ m^3
3)	Bank protection works :	Numbers of sites	75
		Total length	112.3 km

4. The selected agricultural development schemes are as follows;

1) Rehabilitation of Pinacanauan irrigation scheme: 1,200 ha

2) Dabubu irrigation development scheme : Sto. Niño dam
1,000 ha

3) Model developments in the uplands : Santor dam
Carmencita pond

In parallel with the model developments in the upland, a master plan study on the development of whole uplands is recommended to formulate a comprehensive plan.

Hydropower development schemes are included in the proposed multi-purpose projects.

5. The implementation schedule of the proposed Short Term Plan is shown in Fig. 12.3.

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A B B R E V I A T I O N S

(1) Domestic Organizations

BAI	:	Bureau of Animal Industry
BAECON	:	Bureau of Agricultural Economics
BFAR	:	Bureau of Fisheries and Aquatic Resources
BFD	:	Bureau of Forest Development
BL	:	Bureau of Lands
BPI	:	Bureau of Plant Industry
BS	:	Bureau of Soils
CASUCO	:	Cagayan Sugar Corporation
CAVADECO	:	Cagayan Valley Development Corporation
CSU	:	Cagayan State University
DAF (MAF)	:	Department of Agriculture and Food
DAR (MAR)	:	Department of Agrarian Reform
DOH (MOH)	:	Department of Health
DPWH(MPWH)	:	Department of Public Works and Highways
FSDC	:	Farm System Development Corporation
ISELCO	:	Isabela Electric Company
ISU	:	Isabela State University
LWUA	:	Local Water Utilities Administration
MERALCO	:	Manila Electric Company
MHS	:	Ministry of Human Settlement
NAPOCOR	:	National Power Corporation
NCSO	:	National Census and Statistics Office
NEDA	:	National Economic and Development Authority
NFA	:	National Food Authority
NFAC	:	National Food and Agriculture Council
NIA	:	National Irrigation Administration
NPCC	:	National Pollution Control Commission
PAGASA	:	Philippine Atmospheric, Geophysical and Astronomical Services administration
SN	:	Samahang Nayon

(2) International or Foreign Organizations

ADB	:	Asian Development Bank
FAO	:	Food and Agriculture Organization
IBRD(WB)	:	International Bank for Reconstruction and Development
IRRI	:	International Rice Research Institute
JICA	:	Japan International Cooperation Agency
WHO	:	World Health Organization

(3) Others

AFT	:	Agricultural Food Technician
BWP	:	Barangai Water Program
CIADP	:	Cagayan Integrated Agricultural Development Project
CIP	:	Communal Irrigation Project
CIS	:	Communal Irrigation System
EIA	:	Environmental Impact Assessment
EIRR	:	Economic Internal Rate of Return
GDP	:	Gross Domestic Product
GRDP	:	Gross Regional Domestic Product
GVA	:	Gross Value Added
IAD	:	Integrated Area Development
IRPP	:	Intensified Rice Production Program
MAO	:	Municipal Agricultural Officer
NCR	:	National Capital Region
NIP	:	National Irrigation Project
NIS	:	National Irrigation System
PAO	:	Provincial Agricultural Officer
PIS	:	Pump Irrigation system
RD	:	Regional Director
SWIM	:	Small Water Impounding Management

ABBREVIATIONS OF MEASUREMENT

Length

mm	=	millimeter
cm	=	centimeter
m	=	meter
km	=	kilometer

Area

cm^2	=	square centimeter
m^2	=	square meter
ha	=	hectare
km^2	=	square kilometer

Volume

cm^3	=	cubic centimeter
l	=	liter
kl	=	kiloliter
m^3	=	cubic meter
MCM	=	million cubic meter

Weight

mg	=	milligram
g	=	gram
kg	=	kilogram
ton	=	metric ton
lb	=	pound

Electrical Measures

V	=	Volt
A	=	Ampere
Hz	=	Hertz (cycle)
W	=	Watt
kW	=	Kilowatt
MW	=	Megawatt
GW	=	Gigawatt

Other Measures

%	=	percent
PS	=	horsepower
o	=	degree
'	=	minute
"	=	second
^oC	=	degrees centigrade
10^3	=	thousand
10^6	=	million
10^9	=	billion (milliard)

Derived Measures

m^3/s	=	cubic meter per second
kWh	=	Kilowatt hour
MWh	=	Megawatt hour
GWh	=	Gigawatt hour
kWh/y	=	kilowatt hour per year
kVA	=	kilovolt ampere
BTU	=	British thermal unit

Time

s	=	second
min	=	minute
h	=	hour
d	=	day
y	=	year

Money

₱	=	Philippine Peso
US$	=	US Dollar
¥	=	Japanese Yen

CONVERSION FACTORS

	From Metric system	To Metric system
Length	1 cm = 0.394 inch	1 inch = 2.54 cm
	1 m = 3.28 ft = 1.094 yd	1 ft = 30.48 cm
	1 km = 0.621 mile	1 yd = 91.44 cm
		1 mile = 1.609 km
Area	1 cm^2 = 0.155 sq. in	1 sq. ft = 0.0929 m^2
	1 m^2 = 10.76 sq. ft	1 sq. yd = 0.835 m^2
	1 ha = 2.471 acres	1 acre = 0.4047 ha
	1 km^2 = 0.386 sq. mile	1 sq. mile = 2.59 km^2
Volume	1 cm^3 = 0.0610 cu. in	1 cu. ft = 28.32 lit
	1 lit = 0.220 gal. (imp.)	1 cu. yd = 0.765 m^3
	1 kl = 6.29 barrels	1 gal.(imp.) = 4.55 lit
	1 m^3 = 35.3 cu. ft	1 gal.(US) = 3.79 lit
	10^6 m^3 = 811 acre.ft	1 acre.ft = 1233.5 m^2
Weight	1 g = 0.353 ounce	1 ounce = 28.35 g
	1 kg = 2.20 lb	1 lb = 0.4536 kg
	1 ton = 0.984 long ton	1 long ton = 1.016 ton
	= 1.102 short ton	1 short ton = 0.907 ton
Energy	1 kWh = 3,413 BTU	1 BTU = 0.293 Wh
Temperature	$^oC = (^oF-32)\ 5/9$	$^oF = 1.8^oC + 32$
Derived Measures	1 m^3/s = 35.3 cuses	1 cuses = 0.0283 m^3/s
	1 kg/cm^2 = 142 psi	1 psi = 0.703 kg/cm^2
	1 ton/ha = 891 lb/acre	1 lb/acre = 1.12 kg/ha
	10^6 m^3 = 810.7 acre.ft	1 acre.ft = 1,233.5 m^3
	1 m^3/s = 19.0 mgd	1 mgd = 0.0526 m^3/s
Local Measures	1 kg = 0.02 cavan	1 cavan = 50 kg

I INTRODUCTION

1.1 Authority

This study conforms to the IMPLEMENTING ARRANGEMENT ON THE TECHNICAL COOPERATION BETWEEN THE JAPAN INTERNATIONAL COOPERATION AGENCY AND THE MINISTRY OF PUBLIC WORKS AND HIGHWAYS FOR THE MASTER PLAN STUDY ON THE CAGAYAN RIVER BASIN WATER RESOURCES DEVELOPMENT IN THE REPUBLIC OF THE PHILIPPINES, which was agreed by both the Governments of Japan and the Philippines on August 1, 1985.

1.2 The Objective of the Study

The objective of the Study is to formulate the Master Plan for Water Resources Development of the Cagayan River Basin covering its entire drainage area of 27,300 km^2. The Plan includes a comprehensive water resources development program to be materialized within 20 years or by the year 2005.

1.3 The Study Contents

The Study was commenced in October 1985 and was completed in July 1987. In the initial stage of the study period, the socio-economic development target was studied on the basis of projected macro frames. Present conditions, problems, needs and potentials were studied in the next stage in regard to flood control, agricultural development and hydropower development in order to formulate a water resources master development plans which will sustain the socio-economic target of the Region. Future water demands were projected assuming that the proposed development plans would be realized. The Study entailed proposals for provision of several dams and ponds to meet increasing water demands.

The Study focussed on a flood control planning, irrigation planning, hydropower planning and dam planning. However, livestock development, permanent crop development and other agricultural developments were also studied since these are expected to play important roles in the economic development of the target area. Environmental studies were also performed to assess the impacts of the proposed master plan from the biological environmental point of view.

1.4 Technical Cooperation

The government of the Philippines organized a Steering Committee, an Advisory Committee, a Technical Working Group and a Counterpart Team with supporting staffs seconded from various agencies, while JICA organized a Advisory Committee comprising staff from the Ministry of Construction and the Ministry of Agriculture, Forestry and Fisheries to give technical advice to the Study Team.

All the committees, groups and teams have cooperated effectively in guidance and assistance to the Study Team.

1.5 The Final Report

This Final Report presents the results of all the Studies carried out from October 1985 to July 1987. The contents of the Draft Final Report prepared by the Study Team in March 1987 were overviewed by both the Governments of the Philippines and Japan. Comments on the Report derived therefrom were discussed between the two Governments and the Study Team and the conclusions thereof were incorporated in this Final Report.

This Final Report comprises a volume of executive summary, a volume of main report and a volume of supporting report which provide supporting information and data, and thorough briefing on methods adopted in the analyses and estimations. It also presents more detailed information than the main report such as intermediate results. The accompanying data book presents all the original data collected and will help in future planning and development in the Cagayan river basin.

1.6 Acknowledgements

The contributions to the Study by officials of the Government and by individuals who have provided information and data, participated in discussions, given valuable advice and provided other forms of assistance to the Study are gratefully acknowledged, and in particular the contributions of the Steering Committee chaired by Mr. Teodoro G. Gener the Undersecretary, DPWH, who succeeded the former chairman Mr. Oscar Rodriguez, the then Deputy Minister MPWH; the Advisory Committee; the Technical Working Group chaired by Mr. Jose G. Guanzon, Project Manager, DPWH; and all the Counterpart Officers led by Mr. Jose G. Guanzon. The assistance of officials of the Ministry of Foreign Affairs, the Ministry of Construction, and the Ministry of Agriculture, Forestry and Fisheries of the Government of Japan, and of the Japanese Embassy to the Philippines, who have given advice and provided various supports in performing the Study, is all gratefully acknowledged. These people are listed in Tables 1.1, 1.2, 1.3, 1.4 and 1.5.

II CAGAYAN RIVER BASIN

2.1 The Objective Area

The Objective area of 27,300 km^2 covers whole the Cagayan river basin, the largest catchment area in the Philippines as a single watershed area, which is located in the northern part of Luzon island. It lies between 15°52' and 18°25' north latitude and between 120°51' and 122°18' east longitude. It is bounded on its east, west and south by the Siera Madre, Cordillera Central and Caraballo-Maparang mountain ranges respectively. The area faces the Babuyan Channel in the north.

The Cagayan river basin lies administratively in Regions I, II and IV. It occupies 25,120 km^2 or 92.1% of Region II, 1,844 km^2 or 6.7% of Region I and 320 km^2 or 1.2% of Region IV. The basin administratively covers the majority of Cagayan, Ifugao, Isabela, Kalinga-Apayao, Nueva Vizcaya, Quirino and Mountain provinces and a mountainous portion of Aurora province, as shown in Fig. 2.1. There are 127 municipalities in total within the provinces mentioned above. The basin area comprises 107 municipalities out of 127 as follows: 19 municipalities of a total of 29 municipalities in Cagayan; 7 of 10 in Ifugao; 37 of 37 in Isabela; 11 of 15 in Kalinga-Apayao; 15 of 15 in Nueva Vizcaya; 6 of 6 in Quirino; 8 of 10 in Mountain Province and 4 of 8 in Aurora Province.

2.2 Socio-Economy

The population within the Cagayan river basin was estimated to be $1,885 \times 10^3$ persons in 1980 on the basis of census results by the National Census and Statistics. The average growth rate in the basin during 1970 to 1980 was estimated to be 2.80% per annum, which is similar to that for the whole country of 2.79%. On the other hand, the estimated number of in-migrants for the same period recorded 33,259 while out-migrants constituted 36,041, accounting for a decrease of 2,782 population in the region. This signified that the natural rate of increase would be much higher than that of the nation.

The population density in the basin was about 69 persons/km^2 in 1980. This density was far smaller than that for the whole country of 161.1 persons/km^2. Hence, the basin is located in a relatively sparsely populated region in the country. The most densely populated municipality in the basin is Tuguegarao with 509 persons/km^2 in 1985. Most of densely populated municipalities are located in the plain with cultivated areas along the Cagayan river and its tributary the Magat river, and along the coastal area facing the Babuyan channel. These areas are well developed as agricultural lands and are subject to frequent flooding.

The urban population in the basin, as defined by NCSO, reached 316,067 in 1980. This accounted for 16.8% of the total basin population, which was lower than that of the country of 37.3%. This means that the basin has been rather slow in urbanization. The most urbanized municipality in terms of urban population is Tuguegarao in the basin, which rate is 41.0%. The average number per family in the basin was 5.5 persons in 1980. This was somewhat smaller than that of the country of 5.6 persons in the same year.

In Region-II except Batanes province, the population of working age, belonging to the 15-64 year group, was 1,000 x 10^3 person or 53.2% of the total population in 1980. For the Philippines, it was 54.6%. The rate for the area is thus lower than that of the country. This means that economically active people in the region are fewer than the national average.

The agricultural sector, the primary sector in the area, absorbed 420 x 10^3 or 77% of the total gainful workers in 1970 and 470 x 10^3 or 73% in 1980. The percentage of the agricultural workers in the area in relation to the country declined drastically from 7.3% in 1970 to 6.4% in 1980. This shows that the structure of the basin industry is tending to move slightly to be services' sector oriented, although the basin economy still depends far more on the agricultural sector than on other sectors.

The industrial sector absorbed 40 x 10^3 in 1970 and 41 x 10^3 in 1980, respectively, representing 7.2% of the total workers in the area in 1970 and 6.5% in 1980. These were also 2.1% of the total workers in the Philippines in 1970 and 1.9% in 1980.

The services' sector, the tertiary sector, such as transportation, commerce and various kinds of services in the area absorbed 80 x 10^3 in 1970 and 120 x 10^3 in 1980, respectively, representing 15.0% of the total workers in the area in 1970 and 19% in 1980. These were also 2.6% of the total workers in the Philippines in 1970 and 2.7% in 1980.

The Gross Regional Domestic Product (GRDP) of Region II amounts to ₱14,504 x 10^6 at 1984 prices, which increased by 34.4% as compared with the previous year. GRDP accounts for 2.65% of GDP of ₱548 x 10^9. Per capita GRDP is ₱5,898 which showed an increase of about 30.9%. But, the difference between the per capita GDP and GRDP aggregates ₱4,382 and the per capita GRDP accounts for only 57.4% of the per capita GDP. Moreover the disparity between the two per capita values has gradually been increasing.

Real growth rates of GRDP and per capita GRDP are -8.7% and -11.0%, respectively, while those of GDPs are estimated to be -4.7% and -6.9%. These figures mean that the regional economy has deteriorated more drastically than the national economy. Furthermore, actual per capita GRDP has decreased by more than 20% over the last three years, in spite of the fact that the actual per capita GDP has decreased by less than 8%.

The biggest share of GVA of ₱7,203 x 10^6 at current prices or 50% comes from the agricultural sector among the three sectors in Region-II in 1984. Among the sub-sectors in agriculture, paddy production of ₱2,753 x 10^6 ranks top with regard to GVA. Forestry with ₱1,094 x 10^6 is the second largest sub-sector among the agricultural sub-sectors. Its percentage share of national GVA is 27% and is the largest among all the sub-sectors in Region II, in spite of the fact that growth has been negative for the recent five years. Corn production of ₱799 x 10^6 is about 9% of the national figure. Although livestock and poultry production have a modest share in the country, other agricultural production seems to be low as compared to national production.

GVA of the industrial sector is estimated to be ₱2,139 x 10^6 at current prices or 15% of GRDP in 1984. The share is small as compared with the national one of 34%. In the industrial sector of Region II, construction had the largest share of GVA, i.e., 21% of GRDP during 1980 to 1982. Since 1983, however, it has seriously declined to less than one-third of GVA in 1982. The growth rates were -24.1% in 1983 and -59.1% in 1984. It may be attributable to the Magat River Multipurpose Project (MRMP) having been completed in October 1982 and that construction of supporting irrigation facilities in the Magat river basin being delayed because of national economic recession. Regional production of mining and quarrying is less than the national average. Other sectors were almost the same as for the country as a whole.

The regional services sector presented GVA of ₱5,162 x 10^6 in 1984 at current prices. The GVA represents about 35% of GRDP. The figure is relatively small as compared with the national one of 40 %. The regional services' sector has experienced the same growth tendency as the country, but the regional growth of 1.6% has been smaller than that of the country of 1.9% in the last decade. These socio-economic figures are presented in Table 2.1.

2.3 Topography and Geology

The Cagayan river emanates in the Caraballo Mamparang mountain range and flows to the north. It travels 522 km along the Cagayan valley which is formed by the western slope of the Sierra Madre mountain range and the eastern slope of the Cordillera Central mountain range. It flows into Babuyan Channel at Aparri.

The basin area is mostly hilly to mountainous. According to the topographic data, land with a slope of less than 8% is 6,800 km^2 which has been rather well developed as agricultural land. Hilly land with slopes between 8% to 18% covers 9,000 km^2 in total. The substantial parts of hilly land are left to be grass land. The remaining 11,500 km^2 are mountainous and are covered by forests. A slope map of the Cagayan river basin is given in Fig. 2.2.

Tributaries drain the sloping lands and join the Cagayan river. The main river flows through a flat alluvial plain from south to north between the slopes of the valley. The alluvial plain is comparatively narrow as compared with the river channel width. It becomes narrowest at Magapit located about 30 km from the river mouth. Low hills extend up to both river banks at this portion and the river channel forms a gorge. The narrow river channel of about 40 km long upstream from Magapit is called Magapit narrows.

The Cordillera central is composed of intermediate to mafic plutonic masses with great thickness of bedded volcanics and metasediments (basalt and greywackes) along the marginal areas. Silicic intrusives and extrusive are known in this area. In Cordillera central major lineaments have a north-south orientation essentially parallel with the trends in the mountains. Infolded and down-dropped blocks of Miocene carbonates and clastics occur at many places.

Sierra Madre and Caraballo mountains are composed of intermediate (andesitic) igneous rocks in their cores with early Tertiary bedded metavolcanics and metasediments along their margins. Coarse crystalline diorite intrusive are also found at various places.

Alluvial plain of the Cagayan river is a sedimentary trough whose sedimentary rock is dated late Paleogene to Recent. The thickness is estimated to be more than 7,000 meters. Rock in the plain are predominantly sedimentary clastics with interbedded limestone. Volcanic and volcanoclastics constitute the next widely distributed rocks in the area. A Cretaceous to Paleogene volcanic and a sedimentary rocks form the basement upon which the sediments were deposited. Rocks within the basin also include intrusive, consisting mainly of diorite and granodiorite distributed generally at the core of the mountain ranges. A general geological map is given in Fig. 2.3.

2.4 Meteorology and Hydrology

The climate in the Cagayan river basin is tropical monsoonal with two wind systems, the southwest monsoon and the northeast monsoon. According to the climate classification of PAGASA, the climate in the Cagayan river basin falls on Type III characterized by not very pronounced seasons relatively dry from December to April and wet during the rest of the year.

The average annual rainfall varies from under 2,000 mm in the lower plain of the basin to over 4,000 mm in the eastern mountainous parts. The average annual basin rainfall is estimated to be 2,600 mm according to the long term record.

The Cagayan valley is frequently visited by tropical storms. The occurrence of typhoons is centered within a six-month period, July through December. In order to practice agriculture during the typhoon free period, water resources development is indispensable because this period is, in other words, the dry season.

The average monthly air temperature ranges from 23.1°C in January to 29.9°C in May at Tuguegarao. High relative humidity is observed in the basin ranging between 70% and 90%. At Tuguegarao, the average monthly relative humidity varies from 68% in April to 83% in December. The daily evaporation is measured using A-pan at several observatories in the basin and the annual mean daily value is between 3.5 mm at Bontoc and 5.9 mm at Alimanao and Tuguegarao. The average wind speed is about 10 km/hour at Aparri and 5 km/hour at Tuguegarao throughout the year. The daily sunshine duration ranges from 2.7 hours in December to 8.0 hours in April at Tuguegarao.

2.5 River System and Floods

The river channel takes a course closer to the Sierra Madre mountain range. Accordingly the channels of tributaries which flow into the main river from the right side have generally steeper slopes and shorter lengths. Meanwhile, the left bank tributaries have longer river channels and larger catchment areas. These are the Chico river of 4,600 km^2, the Siffu-Mallig river of 2,000 km^2 and the Magat river of 5,100 km^2. The Ilagan river has the largest catchment area of 3,100 km^2 among the tributaries which join to the main river at the right bank. The catchment areas of four major tributaries of the Chico, Siffu-Mallig, Ilagan and Magat rivers amount to 14,800 km^2 or 54% of the total drainage area of 27,300 km^2. The substantial alluvial plain extend along the left bank of the middle reaches of the Cagayan river between the Magapit narrows and the confluence with the Magat river. The plain is used for paddy and other diversified crops cultivations.

With regard to the condition, the most notable is found at Magapit located 30 km upstream from the river mouth, where the Cagayan river has formed a narrow gorge among the hills. Upstream of this narrow channel of 350 m wide on an average extends for about 20 km. It is considered that the gorge is the reason for the extreme meandering and side erosion in addition to flooding in the reaches upstream. The river has been liable to change its course within the alluvial plain as may be seen from Fig. 2.4 which is based on a comparison of maps prepared in 1954, superimposed on those prepared in 1979. Side erosion at meandering portions is active and significant.

The bed slope of the main river is gentle in the alluvial plain. It is around 1 in 8,700 for more than 130 km from the river mouth to Tuguegarao. It become a little steeper upstream of that. The average bed slope of the river is estimated to be 1 in 5,600 for about 100 km from Tuguegarao to the upstream reaches. Most parts of the river channel have been left unimproved. However at some limited portions, DPWH has provided revetment works, shortcuts and spur dykes.

The Cagayan river basin is located on the track of many typhoons. A typhoon which attacks the area often accompanies stormy rainfall and causes flooding. According to the records, noteworthy floods occurred in the years 1959, 1964, 1967, 1973 and 1980.

The occurrence of floods is concentrated in 6 months from June to November, among which October shows the highest frequency of flood occurrence. The biggest floods in recent years have been those in 1973 (Nov. 23-26) by typhoon Openg and in 1980 (Nov. 1-7) by Typhoon Aring. The 1973-flood is said to have been the worst flood since 1906 and the 1980-flood since 1973. According to the field survey, the total flooded area was estimated to be 1,860 km^2 for the 1973-flood and 1,740 km^2 for the 1980-flood. Generally the flooded areas are limited to areas located along the river course. A survey of the flooded areas is illustrated in Fig. 2.5.

There are 107 municipalities in the Cagayan river basin. Among these, 52 municipalities are susceptible of flooding. Most of flood prone municipalities are located in the provinces of Cagayan, Isabela and Nueva Vizcaya. About 63 % of the total basin population live in the flood susceptible municipalities. Tuguegarao, Ilagan, Santiago and Cauayan are the four principal municipalities in the basin having populations of more than 60,000 and being susceptible of flooding.

2.6 Land Use

In the Study area, forest occupies 11,500 km^2 or 42% of the total area. The cultivated lands for agriculture are only 5,300 km^2 or 20% including lands for fisheries although the major industries of the area are agriculture and fisheries. Bare lands, swamp and other lands tally about 5,000 km^2 including built-up areas of 50 km^2. What is to be noted is the remaining 5,500 km^2 which is identified as idle grass lands. The substantial grass lands are located in the hilly areas with slopes between 8% and 18%.

Almost all the forests are natural and located in mountainous areas. The share of logging production has decreased recently in Region-II but GVA thereof is about ₱180 x 10^6 in 1984 at 1972 constant price or 15% of the regional agricultural GVA.

The areas for paddy fields is estimated to be 2,470 km^2 in 1985. Paddy is cultivated in almost 46% of the total agricultural lands.

The areas for diversified crops cultivation and pasture lands for cattle grazing occupy about 1,300 km^2 and 1,270 km^2 respectively. The agricultural practices are rather extensive and productivities are comparatively low.

The areas of permanent crops and fish ponds are minor in the Cagayan river basin. They occupy about 270 km^2 and 30 km^2 respectively.

2.7 Existing Water Source Facilities and Water Uses

Water is abstracted and utilized mainly for paddy irrigation and municipal water supply. Irrigation systems have tapped surface water through diversion weirs and pumps. Meanwhile, waterworks have abstracted mainly groundwater by providing wells.

The existing irrigation systems in the Study area are classified into four categories: the national irrigation systems (NIS), communal irrigation systems (CIS), pump irrigation systems (PIS) and private pump irrigation systems. As of 1986, there are eight NISs with a total service area of 131,500 ha. Of these existing systems, Solana-Tuguegarao irrigation system taps water from the main river through pumps. The Magat River Integrated Irrigation System provides regulated water to a service area of 97,400 ha from the Magat reservoir situated on the Magat river. The remaining NI systems divert water from tributaries by means of headworks. The aggregated irrigation area served by NIS is estimated to be 94,300 ha for the wet season crop and 85,200 ha for the dry season crop.

There are 1,156 CIS in the Cagayan river basin commanding a total service area of 58,300 ha. Most of the CIS abstract water from tributaries. The average irrigation intensity is 0.73 for wet season and 0.63 for dry season. The average annual irrigation intensity is estimated to be as high as 1.36.

PIS serve a total area of 2,800 ha by 40 existing pump irrigation systems. Almost three quarters of the pump stations are provided along the Cagayan river. The rate of operation is not high because of the high operation and maintenance costs and of the unstable hydrological conditions.

Private irrigation system have installed pumps as the water source facilities. At present about 1,800 systems are operating with service areas of 12,000 ha in total. The pumping stations are located in the main river and tributaries.

In addition to these, two further National Irrigation Projects were expected to be completed in 1986, and a National Irrigation Project, CIADP, is scheduled to be completed in 1988. The total service area contemplated is about 19,300 ha.

The total irrigation water demand in the Cagayan river basin was estimated to be 3,100 x $10^6 m^3$ in 1985. A demand of 2,000 x 10^6 was concentrated in the Magat river basin with a catchment area of 5,113 km^2 since Magat dam and the intake of the Magat River Irrigation System of 97,400 ha is located on the river. The Chico River Irrigation System of 20,100 ha follows the Magat System as a single project which consumes a considerable amount of water. The water demand thereof was estimated to be 235 x $10^6 m^3$ in 1985. The total water demand in the Chico river basin was estimated to be 350 x $10^6 m^3$ in 1985 against the catchment area of 4,551 km^2.

The irrigation water demand depend on the Cagayan river main stream was estimated to be 420 x $10^6 m^3$ in 1985. Almost 90% or 370 x $10^6 m^3$ of the total demand was located on about 200 km of the river course between Magapit and the confluence of the Magat river. The Magapit pump station of CIADP and Solana-Tuguegarao pump stations are situated in this portion. The other 50 x $10^6 m^3$ was scattered in the upper reach of the river.

A comparative large demand of 270 x $10^6 m^3$ was estimated for the Siffu-Mallig river basin with a catchment area of 2,015 km^2. This was mainly attributable to the Siffu intake for the Siffu River Irrigation System of 12,000 ha and the Mallig River Irrigation Project of 2,400 ha. Diversion weirs are provided to these intakes.

The irrigation water demand in the Ilagan river basin is estimated to be as small as 8 x $10^6 m^3$ against the catchment area of 3,132 km^2.

The DPWH has constructed and maintained about 1,700 water works in Region-II. In addition the Rural Waterworks Development Corporation (RWDC) provided 1,800 primitive waterworks with point source without distribution system in various remote communities. The highlights of the water supply organizations in the Region are Local Water Utility Administration (LWUA) and Barangay Water Program (BWP). LWUA and BWP have constructed and maintained 5 and 4 waterworks respectively with piped system and individual connections. The served households are about 274 x 10^3 families in 1985. The service factor is, accordingly, estimated to be 60%. The waterworks supplied about 52 x $10^3 m^3$/day on an average in 1985.

Meanwhile the average per capita water consumption is estimated to be 30 litre/day in a rural area. It is as high as 100 litre/day in an urban area. In addition, according to the records of LWUA the water consumptions of service and industrial establishments are estimated to be 1,000 litre/day/establishment and 54,000 litre/GVA of ₱10^6 respectively.

Consequently it is considered that 217 x $10^3 m^3$ of municipal water was consumed in total in the Cagayan river basin in 1985. This amount is almost three times the total supply capacity of the existing public waterworks. The excess demand is assumed to have been provided by private intakes.

III HYDROLOGICAL ANALYSIS

3.1 Low Flow Analysis

The water stage data recorded at some 20 hydrological gauging stations in the Cagayan river basin are attested to be reliable after verification of 76 stations. However the recording periods are mostly less than 10 years. These records alone are not sufficient to estimate the long term water resources potentials all over the catchment area. The locations of gauging stations are shown in Fig. 3.1.

Meanwhile, daily rainfall data recorded at some rainfall gauging stations are available for more than 20 years. As a result, stream flow analysis has been used to generate long term runoff at strategic points by means of simulation models. The locations of rainfall and meteorological gauging stations are shown in Fig. 3.2.

The generation of runoff is performed by applying following procedures;

a) Selection of water level gauging stations which represent the local hydrological characters of the Cagayan river basin,
b) Establishment of runoff simulation models,
c) Generation of long term runoff at the selected water level gauging stations by a runoff model which developed in advance,
d) Division of the whole Cagayan river basin into subbasins for the catchment areas of major tributaries and existing and on-going water sources facilities,
e) Estimation of long term runoff in the subbasins by the generated runoff above in proportion to the catchment areas and rainfall ratio and
f) Verification of the estimated long term runoff.

After due examination of the obtained information, it is considered that following six water level gauging stations represent the Cagayan river basin;

- Guinalvin gauging station for Upper Cagayan river basin
- Dulao " " for Magat river basin
- Minanga " " for Ilagan river basin
- Larion Alto " " for Lower Cagayan river basin
- Ampawilen " " for Upper Chico river basin
- Pinukpuk " " for Lower Chico river basin

Tank Model is adopted as the runoff simulation model because of simpleness of the structure and easy simulation of non-linear relationships between rainfall and runoff. A calibration of the model is performed by trial and error by applying the recorded rainfall and runoff data. The calibrated models are presented in Fig. 3.3. The fitness of the models are shown in Fig. 3.4 comparing the generated runoff with the estimated runoff on the basis of the recorded water level. Long-term 10-day runoff are generated at these gauging stations applying rainfall data recorded in 22 years from 1963 to 1984.

The Cagayan river basin is divided into 53 subbasins for each damsite or confluence of a main tributary. And the long term runoff for 22 years is estimated in each subbasin by the generated runoff at the relevant gauge as mentioned before in proportions to the catchment area and the estimated annual rainfall. The generated runoff are summarized in Table 3.1.

The average 10-day runoff from the subbasin estimated as mentioned above is verified by comparing this with the estimated runoff on the basis of the recorded water level. The summary of comparison is presented in Table 3.2. In this table, the estimated runoff show good fits to those recorded in terms of the annual average or the drought runoff.

The discharge duration curve at Nassiping gauging station was developed on the basis of the generated runoff and is compared with that of the runoff estimated from the recorded water stage as shown in Fig. 3.5.

The runoff estimation is made utilizing the stage-discharge curve derived from the non-uniform flow calculation. The duration curves of the generated and the estimated runoff show good similarity. Consequently, the generated mean 10-day runoff is considered to be valid for this Study.

The flow duration curves of estimated runoff were developed and are illustrated in Fig. 3.6 for major tributaries.

The average annual runoff of the basin is estimated to be 1,343.2 m^3/s for the catchment area of 27,300 km^2.

3.2 Flood Runoff Analysis

Long term daily rainfall records are available at 10 gauges which are used for the estimate of basin mean rainfall. These gauges are Aparri, Tuao, Tuguegarao, Naneng, Ilagan, Bontoc, Nayon, Echague, Consuelo, and Dakgan. Hourly rainfall record series are available at Aparri and Tuguegarao gauges, which represent the hourly distribution pattern of a daily rainfall.

Flood hydrographs at the Magat damsite are available together with the corresponding hourly rainfall to establish the flood runoff model. Annual maximum flood water level data are available at Calantac, Larion Alto, Pasonglao, Palattao, Minanga and Oscariz. However the available periods, in some cases, are as short as a few years.

Flood runoff analysis was then performed by the following three procedures; a) construction of river system model, b) stormy rainfall analysis and c) flood runoff analysis by means of simulation method.

Since flood runoff is largely determined by the local topographic and meteorologic conditions, the whole catchment area of 27,300 km^2 is divided into several subbasins, and base points were introduced in each subbasin as points to represent the local characteristics within the Cagayan river basin.

Subsequently 9 base points were determined at the junctions of main river and major tributaries (Chico, Siffu, Ilagan, Magat) as illustrated in Fig. 3.7. A flood runoff simulation model was then built for each base point.

The most significant stormy rainfall recorded in Aparri and Tuguegarao shows that the duration is usually 4-days or less. On the other hand, the lag time of flood runoff estimated is about 64 hours in the longest watercourse. The rainfall duration for the flood runoff analysis at base points was therefore decided to be 4 days for the Cagayan river. Meanwhile, the duration was determined to be 1 day for runoff analysis at damsites because the time of concentration was estimated to be one day.

The Thiessen polygon method was applied to estimate the basin mean rainfall from point rainfall. An adjustment factor for basin mean elevation was applied to estimate the basin mean rainfall at the damsites. Frequency analysis was carried out for the estimated annual maximum basin mean rainfall, and the probable basin mean rainfall was derived by the Pearson III method, as shown in Table 3.3.

A 1-day rainfall duration curve was developed using the hourly rainfall data at Aparri and Tuguegarao. This 1-day rainfall duration curve was linearly extrapolated for 4 days. In this manner, the 4-day duration curve was developed. The 1-day rainfall amounts to 65% of the 4-day amount, in accordance with the rainfall records. The hourly rainfall distribution is assumed to be center-concentrated on the basis of the recorded data. The hourly rainfall distribution of probable 4-day rainfall is, consequently, estimated as shown in Fig. 3.8.

The storage function method is adopted as the method for flood simulation because the method reflects river channel storage. The method is also convenient for flood routing study. Topographic maps in the scales of 1 to 25,000 and 1 to 50,000 were utilized for model building together with the results of non-uniform flow calculation. However most of the constants calibrating the models against the recorded data were found through trial and error. The results of calibration are illustrated in

Fig. 3.9.

Various probable stormy rainfalls were tried out on the flood runoff models previously established. Thus probable flood runoff was estimated for various occurrence probabilities. The flood peak discharges are distributed over the Cagayan river and major tributaries under the present river conditions. The 100-year flood discharge distribution is depicted and shown on Fig. 3.10. The estimated specific discharges are plotted on the Creager's curves as shown in Fig. 3.11 which increase confidence in the estimates.

3.3 Sediment Analysis

Suspended sediment loads have been observed at several gauging stations in the Cagayan river basin and sediment rating curves have been developed for Pasonglao in the Chico river, Oscariz in the Magat river and Dippadiw in the Cagayan river as shown in Fig. 3.12. The sediment yield is estimated at the reliable runoff gauges, Ampawilen, Oscariz and Guinalvin, using the developed sediment rating curves for Pasonglao, Oscariz and Dippadiw. In addition to the suspended sediment load, bedload is assumed to be 20% of the derived suspended load.

The estimated total sediments at Ampawilen, Oscariz and Guinalvin are 1,060, 1,520 and 1,280 m^3/km^2/year respectively. The largest of the above values, 1,520 m^3/km^2/year or 1.5 mm/year, is adopted as the design sediment yield for the proposed damsites assuming that the watershed areas have the similar conditions as the selected gauging station.

The sediment transport capacity of the present river channel is calculated for 26 selected points on the Cagayan river and its tributaries. The Einstein-Brown formula was applied sediment transport capacity estimation, as commonly applied to suspended and bedload estimation. The physical properties of the sediment were estimated on the basis of the results of water sample tests and river bed material tests. The result of these calculations are shown in Fig. 3.13.

The sediment transport capacities estimated are less than half the sediment loads estimated above. This implies that half of the load must be deposited before it reaches the main river because no extreme degradation nor aggradation of the main riverbed is reported.

Water quality analysis aimed to evaluate the appropriateness of river water quality for irrigation, municipal and industrial uses. The water quality test results are tabulated in Table 3.4 for the Cagayan river basin. According to the water quality criteria adopted by NPCC, water in the Cagayan basin is judged to be usable for irrigation, municipal and industrial purposes.

IV REGIONAL ECONOMIC DEVELOPMENT

4.1 Projection of Macro Socio-Economy

The NEDA presents population estimates for the country and for its subdivision down to municipal level for the period 1980 to 2030 in the publication of "Philippine Population Projection 1980-2030". The projection follows the most common demographic procedure of population forecast by age and sex, namely, the cohort component method.

In this projection, following assumptions are adopted:

a) the population at the initial period is taken from the result of 1980 census of population;
b) the number of births is estimated assuming a change in fertility. The fertility will decline from its 1980 level such that an net replacement rate of 1 will be achieved by the year 2010;
c) the number of deaths is estimated based on an assumption of mortality level. The mortality level will be reduced since present health conditions will be improved. Thus the projected value of life expectancy at birth is improved from 61.6 years in 1980 to 73.5 years in 2030; and
d) International migration will have very little effect on the national population due to strict immigration laws. Inter-migration levels are assumed to maintain the present pattern.

The future populations projected in 1990, 1995, 2000 and 2005 are $61,480 \times 10^3$, $68,424 \times 10^3$, $75,224 \times 10^3$ and $81,591 \times 10^3$ respectively. The respective average annual growth rates are 2.38%, 2.16%, 1.91% and 1.64%.

The NEDA is formulating a long term projection for socio-economic development. The growth scenario in this prospect assumes that the domestic economy can fully internalize the structural reforms and establish a much stronger economic base for sustained and healthy future growth. Likewise, an improvement in the international environment is also envisioned. In particular, the following international favorable circumstances are assumed to come out in the future: stable and reliable markets; reduced trade barriers; expanding capital flows to developing countries; and successful implementation of economic growth in industrial economies. Domestically, in pursuance of the Balanced Agro-Industrial Development Strategy (BAIDS), agriculture and export will spur fairly economic growth, while the industrial sector keeps stable pace as it becomes more efficient. As a result, a healthy, stable and sustained economic growth will be attained. By the year 2000, a highly industrialized economy as well as a modernized agricultural structure will be envisaged.

In addition to this, MEDIUM-TERM PHILIPPINE DEVELOPMENT PLAN was established by the NEDA as summarized in Table 4.1. The plan projected GDP and GRDPs for six years starting from 1987. Therefore GDPs are projected on the basis of both the long term projection and the MEDIUM-TERM PHILIPPINES DEVELOPMENT PLAN. The projected results are presented in Table 4.1.

The annual growth rates estimated are in between 5.8% and 7.7% in the first 6 years up to 1992 by Regions. The GDP in 1992 is estimated to be ₱135.3 x 10^9 at 1972 constant price. However growth rates in 1985 and 1986 are estimated to be minus or zero.

Annual growth rates will subside gradually towards the year 2005. It is estimated to be 3.9% for the period between 2000 and 2005. A GDP of ₱229 x 10^9 is projected for the year 2005 at 1972 constant prices. The average annual growth rate between 1985 and 2005 is estimated to be 4.75%. Long term projections of GDP are given in Table 4.2.

4.2 Projection of Regional Population

Regional populations are projected also on the basis of "Philippine Population Projection 1980-2030". The projected population by municipality up to the year 2005 is shown in Table 4.3. In 2005, the population of Region II will be 3,835 x 10^3, or 4.7% of the country. Within the basin, the population will be 3,259 x 10^3, or 4.0% of the country.

Table 4.4 shows the projected basin population classified into urban and rural inhabitants up to the year 2005. The urban population will increase from 403 x 10^3 in 1985 to 998 x 10^3 in 2005. On the other hand, the rural population will increase from 1,733 x 10^3 in 1985 to 2,261 x 10^3 in 2005. This means that the urban population will increase about 2.5 times in 20 years and will account for 30.6% of the basin population by 2005 despite being only 18.9% in 1985.

4.3 Target of Regional Economic Development

GRDP of Region II occupied only 2.56% of GDP in 1985. This share is extremely low as compared with other economic potential indices such as water resources, land resources and population. In view of the fundamental national goals, that is, more equitable distribution of the fruits of development, the target of regional economic development is to raise the per capita GRDP of Region II up to that of the national average by the year 2005. In this target, NCR and Region IV which are highly industrialized are excluded in estimating the national average. This target is assumed to be attained through the annual linear growth from 1992 to 2005. As a result, the average annual economic growth in Region II is expected to be about 6.69% per annum during 20 years, that is, from 1985 to 2005, although the national average growth is estimated to be 4.75% per annum during the same period.

The economic growth process in Region II is expected to be similar to the national one, because the basic economic policy, BAIDS, is put into operation in order to contribute to an equitable growth process all over the country. The regional economic structure, however, is different from the national average structure. For example, the share of agriculture in GRDP was 52.2% in 1985, whereas the national one was 29.0%. Therefore, the GVA of each sector in Region II would be somewhat different from the national GVA projected in the previous section. In this regard, GVA of each sector is assumed as follows: (1) the agricultural production in the Cagayan river basin will reach 70% of its maximum potential by the year

2005; (2) the agricultural production in Region-II should be 1.41 times of that in the Cagayan river basin because the production in the basin represents 71% of that in the Region; (3) the rest of GRDP in the Region is produced by other sectors; (4) the shares of the industrial and services GVAs should be similar to those projected for the country because the projected agricultural GVA in Region-II has almost same share as that for the country; (5) the changes of growth rates and GVA's shares should have smooth trends. As a result, the industrial sector will have to grow at the comparatively high rate. In other words, industrialization in Region II must inevitably be introduced in the coming twenty years. Thus, each economic sector has to grow at the following average annual rate: 3.86% in agriculture; 11.76% in industry; and 7.03% in service sector. The expected economic growth of each sector in Region II up to the year 2005 is shown in Table 4.5.

As mentioned before the agricultural GVAs of the Cagayan river basin are assumed to be 71% those of Region-II. The industrial GVAs are, on the other hand, projected on the basis of that of Region-II in proportion to the urban population. Meanwhile, service GVAs are projected in proportion to the total populations in Region-II and the basin. Along this line GRDP in the basin in 2005 is projected to be ₱7,080 x 10^6 at 1972 constant price, which is 3.9 times of that in 1985 as shown in Table 4.6. The average annual growth rate is estimated to be 7.0% over 20 years period.

V SECTORAL STUDY ON THE FLOOD CONTROL

5.1 Present River Conditions

5.1.1 River Channels

The channel of the Cagayan river was studied and its principal features are illustrated in Fig. 5.1. The carrying capacity of the existing channels was estimated by means of non-uniform flow calculation using surveyed river cross section data. The result is shown in Table 5.1. Carrying capacities in the stretch from Alcala to Tuguegarao of the Cagayan river are extremely small as compared with the reaches up and downstream.

It is noteworthy that upstream of Magapit (Sta. 30 km) and downstream of Alcala (Sta. 65 km) the channel is constricted by hilly lands. It should be also noted that the immediate upstream reach above Alcala meanders heavily. It may be seen from the result of the flood mark survey conducted during the Study period, that the narrows raised the flood water level in the upstream reaches. The effect may be traced up to Tuguegarao as shown in Fig.5.2. The flood water surface slopes in the Cagayan river are estimated as follows:

Stretch	Flood water surface slope	River bed slope
- Mouth to Alcala	1/3,450	1/8,680
- Alcala to Tuguegarao	1/12,080	1/8,680
- Tuguegarao to Ilagan	1/5,670	1/5,620

Figure 5.3 shows the details of the survey results. The effects of the Magapit and Nassiping narrows can be seen from the changes in slopes.

5.1.2 Flood Damages

Floods in the basin usually occur during the period from June to November corresponding to the typhoon season. October shows the highest frequency of flood occurence. The biggest floods in recent years occurred in 1973 (Nov. 23 to 26) incurred by typhoon Openg and in 1980 (Nov. 1 to 7) by Typhoon Aring. The 1973-flood is said the worst flood since 1906 and the 1980-flood since 1973.

The intensive interview surveys were conducted in order to identify the flooded areas of the 1973 and 1980 floods. The survey results were correlated to the recorded water levels, topographic maps and flood marks. Finally the boundaries of flooded areas were delineated as shown in Fig.5.4. The figure shows that the flooded areas are similar for both floods. The flooded areas are estimated to be 1,860 km^2 for the flood in 1973 and 1,740 km^2 for the flood in 1980.

Bank erosion is another problem in the basin. Figure 5.5 shows the shifting of river course and average annual shifting rates estimated for the 25 years from 1954 to 1979 as shown in the figure. Bank erosion takes place in almost all the reaches of the Cagayan river and the tributaries except those confined by the hilly lands. Bank erosions are considered to be most active in the river course from Lallo to Cabagan in the Cagayan river and the middle reach of the Chico river.

There are 107 municipalities in the Cagayan river basin. Among these, 52 municipalities are susceptible of floodings. Most of these municipalities are in the provinces of Cagayan, Isabela and Nueva Vizcaya. The total population of the Cagayan river basin was estimated to be 1,885,000 in 1980, and 63% dwell in the flood susceptible municipalities. Tuguegarao, Ilagan, Santiago and Cauayan are the four largest municipalities in the basin in terms of population. Their populations are 60,000 or more. These are the municipalities subject to frequent floods.

5.1.3 Flood Control Facilities

Existing flood control facilities in the basin are spur-dikes, revetments, cut-off channels, earth dikes, etc. Locations are shown in Fig.5.6. The existing facilities except earth dike fall into the category may be of bank protection measures.

In spite of incessant efforts by the agencies concerned, the existing flood control and drainage facilities are of small scale and are provided sporadically. The small size of the flood control budget may be a reason of this.

Magat dam is the only impounding dam in the basin. The reservoir does not have flood control capacity. However, reservoir monitoring records show that the dam has substantially contibuted to flood peak reduction since the start of operation in 1983. For example in October 19 and 20, 1985, while the peak inflow was about 7,700 m^3/s and the peak outflow was reduced to 4,500 m^3/s.

5.1.4 Existing Problems and Needs

In view of the above, the problems and needs for flood control of the Cagayan river basin may be identified as follows:

1) Flood damage in the Cagayan river basin has been sufferred in two ways: by flooding and bank erosion. Therefore, flood control measures must cover both flood prevention and bank protection.

2) The Magapit narrows raise flood water level in the upstream reaches up to around Tuguegarao. The narrows constrict the channel's flow capacity and cause significant channel meandering in these reaches. The area from Alcala to Tuguegarao is the most flood susceptible area in the basin. Improvement of the Magapit narrows should be studied as an alternative flood control measures.