MINISTRY OF COMMUNICATION

GOVERNMENT OF THE REPUBLIC OF KOREA

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JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF CONSTRUCTION

GOVERNMENT OF THE REPUBLIC OF KOREA

SURVEY REPORT
ON
THE LONG-TERM MULTIPURPOSE DAM SCHEMES

(FIRST STAGE)

—MAIN REPORT—

JUNE 1978

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

The Government of Japan, in response to the request of the Government of the Republic of Korea, agreed to carry out the survey for the long-term multipurpose dam schemes in the four major rivers in Korea, namely, the Han, the Nakdong, the Geum and the Seoumjin rivers and commissioned its implementation to the Japan International Cooperation Agency (JICA), an organization to execute overseas technical cooperation schemes of the Government of Japan.

JICA dispatched a preliminary survey team consisting of five (5) experts headed by Mr. N. Aihara to the Republic of Korea for a period from June 15, to June 30, 1977. The survey team confirmed the purpose of the survey and decided the scope of work.

The request of the Government of the Republic of Korea is to select 8 to 10 damsites out of the 24 prospective damsites which can be developed advantageously both technically and economically, and to carry out the preliminary feasibility study necessary for the long-term development of water resources in the Republic of Korea.

It was decided to carry out the survey in two stages; to select 8 to 10 damsites in the first stage, and to carry out the preliminary feasibility study on each of the selected multipurpose dam schemes in the second stage.

The period decided for the first stage was for six months from October 1977 to March 1978. The field survey team consisting of ten (10) experts headed by Dr. H. Waki was dispatched to the Republic of Korea from October 10, 1977 to December 17, 1977. Based on the results of the field survey, the study to select the high priority dam schemes was carried out in Japan.

The results of the first stage survey are contained in this report together with the recommendations necessary for conducting the second stage survey.

In closing, I wish to express my heartfelt gratitude to the survey team member for their effort, the Government officials of the Republic of Korea, officials of the Japanese Embassy in the Republic of Korea for their kind cooperation and the Ministry of Foreign Affairs, Ministry of International Trade and Industry, Ministry of Construction and Ministry of Agriculture and Forestry for their support in dispatching the survey team.

June, 1978

Shinsaku Hogen
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Date: June, 1978

Mr. Shinsaku Hogen
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

We are pleased to submit our survey report on the first stage survey conducted for the long-term multipurpose dam schemes in the four major rivers in Korea, namely, the Han, the Nakdong, the Geum, and the Seoumjin rivers.

The purpose of the first stage survey is to select, out of 24 proposed dam sites, 8 to 10 high priority project sites, on which the preliminary feasibility study is to be performed in the second stage survey.

To attain the above purpose, the survey team conducted the field investigation from October to December, 1977 and the preliminary studies and analysis at home office from January to March, 1978. All the results of the field investigation and study are compiled into the Draft Survey Report, which was submitted to the Government of Korea in March, 1978. With regard to the draft report, discussion meetings were held in Seoul on 27th through 30th, March, 1978, participated by the staffs of the authorities concerned of the Government of Korea and the First Stage Survey Team. Both parties agreed that the contents of the draft report were generally acceptable.

It is our sincere hope that the preliminary feasibility study of the selected schemes be successfully carried out in the near future.

Taking this opportunity, we would like to express our gratitude to the personnel of your Agency, the Japanese Embassy in Korea and the authorities concerned of the Government of the Republic of Korea for the courtesies and cooperation extended to us during our field survey and home office works.

Very truly yours,

H. Waki

Haruo Waki
Team Leader
First Stage Survey Team, JICA for
the Long-Term Multipurpose
Dam Schemes

Member of The First Stage Survey Team

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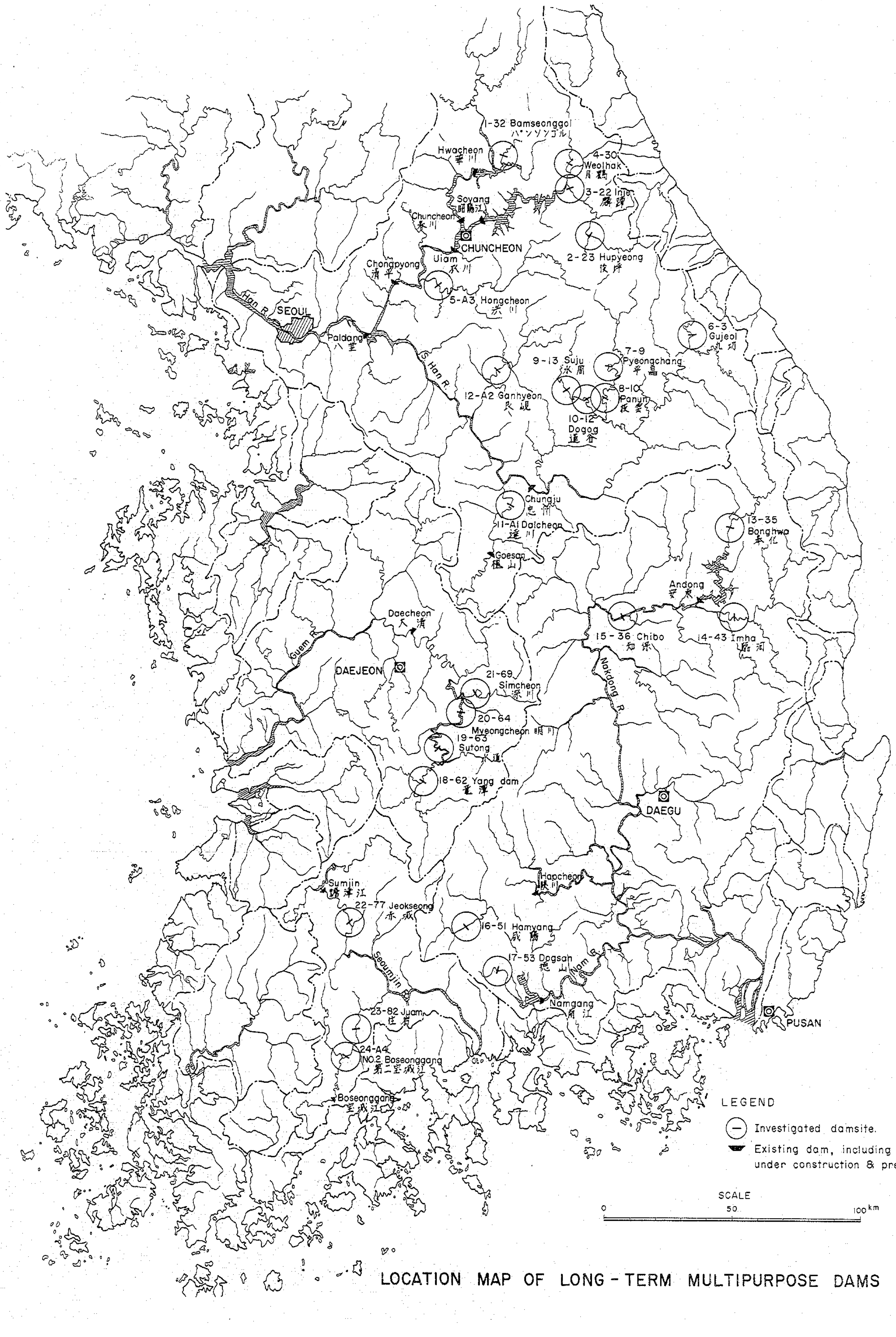

LOCATION MAP OF LONG-TERM MULTIPURPOSE DAMS

SURVEY REPORT

ON

THE LONG-TERM MULTIPURPOSE DAM SCHEMES

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SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The field survey of the Long-Term Multipurpose Dam Schemes in the four major river basins in Korea was carried out for about two months from October 10th to December 17th, 1977, with such scope of work as the dam sites reconnaissance, hydrological data collection, flood control survey, agricultural survey and municipal and industrial water survey. Based on this field survey, the proposed 24 dam sites were studied and compared in respect to the development scale and economic viability. As a result, 10 dam sites were selected for further investigation taking into consideration the magnitude of needs for development to meet the increasing demand for water in each basin.

In this first stage survey, the following manners were applied for survey, planning, cost estimate, benefit calculation, economic evaluation and selection of dam projects.

1. Procedures and Methods

(1) Proposed dam sites surveyed

In principle, those dam sites shown in "the Report on Potential Hydropower", "the Han River Basin Report" and other relevant reports were selected to be surveyed in this first stage survey. These are referred to in this report as "the proposed dam sites" by the Government of ROK. But in the following cases, the alternative sites were adopted:

a. In case the river gradient at the proposed dam site was steep and the alternative site could be found in its upper reaches: Hupeong, Gujeol and Hamyang

b. In case the proposed dam site was found geologically inappropriate for dam construction: No. 2 Boseonggang

c. In case the topography could not allow to construct a sufficiently high dam and the alternative site could be found in the lower reaches with a bigger catchment area: Chibo

d. In case the alternative site could be found in the vicinity of the originally proposed site, the both of them were studied: Bamseonggal and Inje.

(2) Development scale of dams

The appropriate development scale of dams was determined based on the economic study in which four alternative cases i.e. 100%, 80%, 60%, and 40% of development ratio, the ratio of effective storage volume to mean annual inflow, were compared.

In addition, the following conditions were taken into consideration:

a. The topographical and geological restrictions and the consideration to protect local towns located in the upper reaches from being submerged by reservoir: Bamseonggol, Weolhak, Hongcheon, Panun, Dalcheon, Ganhyeon and Chibo

b. The topographical and other restrictions caused by the location of another proposed dam site in the upper reaches of the dam site surveyed: Inje, Dogog, Sutong and Myeongcheon

(3) Hydrological data

The monthly discharge data shown in "the Report on Potential Hydropower", "the Han River Basin Report" and other relevant reports were utilized with supplementary correction as required.

(4) Design flood

The 200-year flood was assumed.

(5) Type of dam

Either concrete gravity type or rock fill type was adopted for each dam after the comparative study.

(6) Work quantities of main civil structures

a. Dam

The work quantities of dam were estimated based on the site reconnaissance by drawing the assumed rock lines on the surveyed cross section chart of the dam axis.

b. Spillway

The work quantities of spillway were calculated by applying an empirical formula based on the design flood.

(7) Facilities of power station, transmission line and substation

In principle, it was assumed that each dam would be equipped with its own facilities of power station, transmission line and substation. The installed capacity was determined to enable peak generation for five hours per day. The transmission line was planned to connect each power station with the nearest existing power station or substation.

(8) Compensation

"The Compensation Survey" provided by MOC was referred.

(9) Construction cost

a. Cost for civil works consisting of dam, spillway, waterway, power station and others: The unit construction cost including depreciation cost of machinery was determined referring to the unit cost provided by MOC.

b. Cost for facilities of power station, transmission line and substation: The unit cost per kilowatt and per kilometer were assumed. The cost for flood forecasting system is included as well.

c. Cost for preparatory works, general expense and contingency: These were calculated as a proportion of construction cost and compensation. The 20% of the total of construction cost and compensation including cost for preparatory works and general expense was considered as the contingency.

d. Interest during construction: The interest rate of 8% per annum was adopted.

(10) Annual cost

a. Capital recovery cost: The duration period of 50 years and annual interest rate of 8% were assumed.

b. Operation and maintenance (O&M) cost: The O & M cost was calculated based on 0.5% of construction cost for dam and 2.5% of construction cost of the facilities for power station including waterway, power plant, transmission line and substation.

(11) Benefit of hydro power generation

a. Kilowatt (kW) value: The kW value of 38,820 Won was derived based on the assumed thermal alternative with installed capacity of 300 MW, unit construction cost of 450 dollars per kW, duration period of 30 years and interest of 10.3% per annum.

b. Kilowatt-hour (kWh) value: The kWh value of 9.475 Won was derived assuming the fuel cost of 40.21 Won per litter.

(12) Benefit of water supply

For each basin, the unit benefit of water supply that ranges from 5.8 to 9.0 Won per cubic meter was derived from the weighted average of the unit cost of annual water supply in the drought year that was calculated from the construction cost of an alternative dam exclusively used for water supply.

(13) Benefit of flood control

The flood control was studied based on the surcharge method. In case no multipurpose dam was constructed downstream and consequently the flood control effect of the proposed dam was deemed to be big enough to protect the downstream area from flood, the benefit of flood control of the dam was determined by the construction cost of an alternative dam exclusively used for flood control. As for other dams than the above, the benefit of flood control was derived from the separable cost for flood control function of the multipurpose dam.

(14) Economic evaluation

Each dam project was evaluated by the benefit-cost ratio (B/C).

(15) Study on exclusion of power generation

In such cases that the exclusion of power generation would make the dam project more advantageous, the study of dam project with exclusive purposes for flood control and for water supply was carried out.

(16) Selection of the dams for second stage survey

The selection of dam sites for second stage survey was carried out based on economic evaluation taking into consideration the magnitude of needs for water resources development in each basin. The result of economic evaluation and the magnitude of needs for the construction of each dam area listed in the Table S-1.

2. Conclusion

The conclusion of the first stage survey obtained through the above procedures is shown in the following table in which the dam sites to be surveyed further in the second stage are listed.

Basin	Dams Proposed for Second Stage Survey: The Highest Priority Dams (B/C>1.5)	Dams Proposed for Second Stage Survey: High Priority Dams (B/C>1.0)	Dams not Proposed for Second Stage Survey
Han river	Bamseonggol (A_1) Inje (A_3) Hongcheon (A_2)	Gujeol (B_3) Dalcheon or Ganhyeon (B_2) Hupyeong (B_3)	Wolhak, Panun, Suju, Dogog, Pyeongchang
Nakdong river	Imha (A_2)	Bonghwa (B_3) Hamyang (B_3)	Chibo, Dogsan
Geum river	—	—	Yongdam, Sutong, Myeongcheon, Simcheon
Seumjin	—	Jeokseong or Juam (B_2)	No. 2 Boseonggang
	4 sites	6 sites	14 sites

where

- A_1: advantageous for each development of hydropower, water supply and flood control
- A_2: advantageous particularly for development of water supply and flood control
- A_3: advantageous particularly for development of hydropower
- B_2: advantageous for development of water supply and flood control
- B_3: advantageous for development of hydropower

Table S-1 Evaluation of 24 Long-Term Multipurpose Dams

No.	Name of Dam	V_E/Q_Y	B/C W/Power Plant: B_p/C	$\frac{B_p+B_w}{C}$	$\frac{B_p+B_w+B_f}{C}$	Total Const. Cost 10^6W	B/C W/O Power Plant: B_w/C	$\frac{(B_w+B_f)}{C}$	Characteristic: WS FC	P	WS FC P	noP	Econo. Evaluation	$\frac{\text{Comp.}}{\text{Cost}}$	Topo.& Geo.	Material	Access	Urgency: WS	FC	P	Evaluation	Remarks
																	km	Han R.		Electric power and energy at any damsite will be consumed in the system		
1-32	Bamseonggol (up)	58%	1.13	2.16	2.20	28,570	1.80	1.85	A	B	A		A	0.49	A	Soil	imp. 17.5	Development is required until 1990			A	
2-23	Hupyeong (up)	60	1.03	1.11	1.13	30,781	0.22	0.25		B	B		B	0.23	A	–	new 14.3				B	
3-22	Inje (up)	100	1.35	1.59	1.60	60,518	0.48	0.50		A	A		A	0.59	A	Soil	imp. 11.0				A	
4-30	Weolhak	31	0.56	0.65	0.68	28,570	0.13	0.18					D	0.65	C	–	new 3.5				D	
5-A3	Hongcheon	60	0.89	2.18	(2.20) 2.59*	58,564	2.18	(2.22) 2.87*	A		A'		A	0.79	B_1	Aggregate	imp. 23.0		O		A	
6-3	Gujeol (up)	60	0.91	1.06	1.10	18,104	0.44	0.53		B	B		B	1.21	A	Aggregate	imp. 12.0				B	
7-9	Pyeongchang	100	0.66	1.12	1.14	41,693	0.51	0.55			B		B	0.66	A	Soil	new 6.0				C	
8-10	Panun	5	0.49	0.57	0.59	16,581	0.13	0.16					D	0.96	A	Soil	–				C	
9-13	Suju	100	0.52	0.90	0.92	35,164	0.57	0.59					C	0.29	A	Soil & Aggre.	new 17.5				C	
10-12	Dogog	33	0.64	0.98	1.01	22,339	0.56	0.60					B	0.33	B	–	new 4.0				C	
11-A1	Dalcheon	40	0.42	1.39	(1.42) 1.91*	39,850	1.48	(1.52) 2.27*	A		A'		A	1.52	A	–	imp. 2.0		O		} B	
12-A2	Ganhyeon	35	0.46	1.61	(1.62) 2.03*	32,796	2.37	(2.39) 3.23*	A		A'		A	2.08	A	–	new 15.0		O			
																		N'dong R.				
13-35	Bonghwa	100	1.12	1.36	1.37	40,012	0.41	0.43		B	A		B	0.25	B	–	imp. 25.0	D'ment is required until 1990			B	
14-43	Imha	100	0.70	1.64	(1.66) 2.11*	45,381	1.40	(1.42) 2.09*	A		A		A	1.53	A	–	new 5.4		O		A	
15-36	Chibo (down)	32	0.49	1.24	(1.26) 1.79*	92,608	1.19	(1.22) 2.05*	B		B'		A	3.34	B	Aggregate	–		O		C	
16-51	Hamyang (up)	80	0.89	1.24	1.26	35,603	0.67	0.69			B		B	0.50	A	–	imp. 9.2				B	
17-53	Dogsan	80	0.49	0.96	0.98	25,932	0.70	0.74					B	0.78	A	–	–				C	
																		Geum R.				
18-62	Yongdam	100	0.62	1.23	1.24	52,773	1.03	1.04			B		B	1.81	A	–	new 6.0	not req'ed until 2000			C	These dams are developed when water demand in the basin exceeds capacity of Daecheong dam
19-63	Sutong	20	0.74	1.34	1.35	32,277	1.02	1.04			B		B	1.40	A	Soil	new 10.5				C	
20-64	Myeongcheon	34	0.58	1.34	1.35	56,766	1.16	1.17	B		B		B	3.23	A	Soil	imp. 5.5				C	
21-69	Simcheon	100	0.40	0.81	0.83	47,071	0.65	0.69					C	2.28	B	Soil	imp. 3.5				D	
																		S'jin R.				
22-77	Jeokseong	80	0.26	0.82	0.85	24,192	0.79	0.82					C	0.89	A	Aggregate	imp. 2.1	urgent			} B	
23-82	Juam	100	0.37	1.12	1.14	73,729	0.98	1.01					B	3.66	A	Soil & Aggre.	–					
24-A4	No. 2 Boseonggang (up)	40	0.15	0.86	0.89	13,644	1.15	1.30	B			O	B	3.14	B	Soil & Aggre.	–					

Remarks: V_E = Effective storage capacity, Q_Y = annual mean inflow; B = Benefit, p = power, w = water supply, f = flood control; In the column of B/C: flood control benefit for the figure with asterisk is derived from the construction cost of an alternative dam exclusively used for flood control and for the figure with no mark and in parentheses is the separable cost for flood control function of the multipurpose dam. WS = Water supply, FC = Flood control, P = power, noP = a case where it is profitable to delete power facilities; Comp./cost = ratio of compensation cost to dam construction cost; in column of Topo. & Geo. "A" ... the site is reliable to contruct dam, "B" ... not so reliable, "B_1" ... fault is expected in river bed, "C" ... troublesome; in the column of material, mentioned materials are required to be investigated; in the column of access, imp. = improvement of existing road is required, new = access road is newly constructed. "O" in FC of urgency ... effective to the lower reaches of the river.

3. Specific Features of Each Dam Site

The specific features of the 24 proposed dam sites are briefly described hereunder.

1-32/1 Bamseonggol (Rank : A1)

The benefit-cost ratio is greater than 1.0: for the sole purpose of hydropower generation. The upstream site was found more advantageous after studying the alternative sites. The scale of development is selected at such capacity of reservoir as VE = 0.58 Qy. (VE: effective storage of reservoir; Qy: mean annual inflow at the dam site)

2-23 Hupeong (Rank : B3)

The benefit-cost ratio is greater than 1.0: for the sole purpose of hydropower generation. Out of three alternative sites selected in the upper, middle and lower reaches, the upstream site was found most advantageous. The development scale of about VE = 0.60 Qy is more advantageous to this dam project.

3-22 Inje (Rank : A3)

The benefit-cost ratio is greater than 1.0: for the sole purpose of hydropower generation. The upstream alternative site was adopted as it was found more advantageous than the downstream alternative site. The large scale development such as VE = 1.00 Qy is deemed possible.

/1 In this report, the 24 proposed dam sites are, for convenience of reference, given their proper number in such a way that the consecutive numbers of 1 through 24 newly given in this first stage survey are hyphened with the one given in the "Report on Potential Hydropower" prepared by MOC. As an exception, however, these 4 dam sites that were not shown in the above report but surveyed this time are numbered headed by A: A1 through A4.

4-30 Wolhak (Rank : D)

The scale of development is restricted to about VE = 0.31 Qy from the topographical and especially geological reasons. The benefit-cost ratio is rather low.

5-A3 Hongcheon (Rank : A2)

This dam site is advantageous not only for water supply and flood control, but also for hydropower generation. The high water level (HWL) of the reservoir should be determined at such height that can avoid the submergence of Hongcheon town.

6-3 Gujeol (Rank : B3)

The dam site is selected at Dogam upstream of the gorge. The power station site is selected at Gujeol downstream end of the gorge.

The reservoir and power station are connected by a tunnel of 14.3 kilometers long. Although the available discharge is not enough, the highest head in Korea of more than 300 meters is available. The benefit-cost ratio is greater than 1.0 when benefits accrued from water supply and flood control are added to that of hydropower generation. This site has compensation problem at Kedari town. This town may be moved to the plateau in the vicinity facing on the reservoir. Situating along the highway connecting Seoul and Kanwon, this site has an advantage for tourism development. It is also conceivable to construct the dam on the middle reaches between Gujeol and Dogam aiming at avoiding the compensation problem of the Kedari town and increasing the catchment area and available discharge.

If reservoir water is diverted to the east coast, the head of more than 660 meters (2 times of the present plan) can be obtained with a shorter tunnel of about 10.0 kilometers. Thus, the power station with the highest head in Korea can be expected. In this case, it is conceivable to increase the available discharge by pumping up water from the adjacent basin. After the diversion through the high-head power station mentioned above,another power station to be located downstream could use both the diverted discharge and the discharge from its own basin. The released water through these power stations could be supplied to Kanwon city and its vicinity as municipal and irrigation water.

7-9 Pyeongchang (Rank : C)

The benefit-cost ratio is greater than 1.0: with total benefits accrued from hydropower, water supply and flood control. The large scale development such as VE = 1.00 Qy may be advantageous.

8-10 Panun (Rank : C)

The dam site is situated downstream of the Pyeongchang dam. The HWL is selected at such height that may protect Cheonben town from being submerged. The benefit-cost ratio is less than 1.0: with total benefits accrued from hydropower, water supply and flood control.

However, if the sand deposit could be reduced by the construction of Pyeongchang dam, the effective volume of reservoir will be increased and the more preferable conditions may be expected.

9-13 Suju (Rank : C)

Even if the development scale of VE = 1.00 Qy can be realized, the benefit-cost ratio is less than 1.0 with the total benefits accrued from hydropower, water supply and flood control.

10-12 Dogog (Rank : C)

Being located downstream of Suju dam site, the scale of development of this dam site is restricted to VE = 0.33 Qy. The benefit-cost ratio is nearly equal to 1.0: for total benefits accrued from hydropower, water supply and flood control. The favourable condition to be noted is that the ratio of compensation cost to construction cost of dam is comparatively low.

11-A1 Dalcheon (Rank : B2)

The HWL is settled at such height as can avoid the submergence of Goesan town. The benefits accrued from water supply and flood control are expected to be large. Its construction will largely depend upon the magnitude of demand for water supply and needs for flood control. The ratio of compensation cost to construction cost of dam is considerably high.

12-A2 Ganhyeon (Rank : B2)

The HWL is settled at such height as can avoid submergence of Weonju (about EL.124 m) and Heongseong (about EL.116 m). This dam site is advantageous for water supply and flood control. The ratio of compensation cost to construction cost is comparatively high.

13-35 Bonghwa (Rank : B3)

Two sites, the upstream and the downstream sites, are remained to be selected by further survey in the second stage. In this survey report, however, the upstream site is tentatively adopted. The benefit-cost ratio is greater than 1.0: for the sole benefit of hydropower generation. The development scale is selected at VE = 1.00 Qy. The following stage survey will include topographic survey of the right bank hill and study of railway relocation.

14-43 Imha (Rank : A2)

This dam site is located favourably to contribute to the development of the lower reaches of the main Nakdong river. The scale of dam is selected at VE = 1.00 Qy, by which Cheongsong village (about EL.170 m) will be submerged. The benefit-cost ratio is not raised up by lowering the HWL.

15-36 Chibo (Rank : C)

The height of this dam is restricted by the compensation problem of Andong city (about EL.90 m).

The dam site, located downstream of the originally proposed site, is selected to obtaid the bigger storage capacity. The left bank has a geological problem, which should be surveyed in the following stage survey.

Being located downstream of Andong and Imha dams, this dam can contribute in great extent to the development of the lower reaches of the Nakdong river. The dam site is advantageous for water supply and flood control, while the ratio of compensation to construction cost of dam is very high.

16-51 Hamyang (Rank : B3)

The dam site is selected at Shininwol upstream of the gorge and the power station site at Monhwa village downstream of the gorge. The dam and power station are connected by a tunnel of 8.4 kilometers long along the left bank side. The high head of 190.7 meters is obtained, which can produce an attractive amount of hydropower of about 53,800 kW.

A problem is the compensation of Silsang temple and its neighboring villages. These villages may be moved to the plateau by the reservoir to create a lakeside resort.

The scale of dam is selected at VE = 0.80 Qy, which should be studied in detail in the following stage taking into due consideration the amount of compensation.

17-53 Dogsan (Rank : C)

This dam site is planned with a tunnel type power station. As the benefit-cost ratio cannot exceed one even if the benefits from water supply and flood control are added to that of hydropower generation, this site will be developed in the later stage. The dam scale is selected tentatively at VE = 0.80 Qy.

18-62 Yongdam (Rank : C)

This dam site has been conceived very advantageous as a diversion dam, diverting the water of the upper main Geum river into the adjoining Mangyeong river basin through a hydropower tunnel.

However, as the irrigation water for the Mangyeong river basin originally planned to be supplied from the Yongdam dam has been changed to be supplied from the Daecheon dam through a long waterway from its downstream, the favourable characteristics of this dam as a diversion dam as described above was diminished. In this survey report, this dam is planned with a dam type powerstation. The benefit-cost ratio is greater than 1.0: with the total benefits including the effect of hydropower generation increase at the downstream Daecheon power station and the benefits accrued from water supply and flood control in the lower reaches. The ratio of compensation to construction cost of dam is high. The benefit-cost ratio may not be raised up even when the HWL is lowered. The development of this dam site depends on the magnitude of increasing demand of water in the Geum river basin.

19-63 Sutong (Rank : C)

Due to such favourable conditions that the ratio of compensation cost to construction cost of dam is the lowest in the Geum river basin and also endowed with favorable topography, the dam has a high benefit-cost ratio. The scale of development is selected at VE = 0.20 Qy to draw backwater to the Yongdam dam site. The development of the dam site depends upon the extent of the demand increase of water in the Geum river basin.

20-64 Myeongcheon (Rank : C)

This dam site is located downstream of Sutong dam and obtains a benefit-cost ratio as high as that of Sutong dam. But the ratio of compensation cost to construction cost is higher than that of the Sutong dam. The scale of dam is selected at VE = 0.34 Qy, which is determined by the height to draw back-water to the upstream Sutong dam. The timing of the dam construction depends upon the future increase of water demand in the Guem river basin.

21-69 Simcheon (Rank : C)

The benefit-cost ratio for the total benefits is less than 1.0. This dam site has such unfavourable conditions as compensation problem for Hwangkan town (EL.160 - 170 m), relocation problem of a national highway and some geological problems. Consequently, the priority for development is comparatively low.

22-77 Jeokseong (Rank : B2)

In the Seoumjin river basin, there are two existing dams; the Seoumjingang dam in the uppermost stream of the main stem and the No. 1 Boseonggang dam in the uppermost stream of the Boseong river, one of the tributaries of the Seoumjin river. Neither of them, however, contribute to supply water to the lower reaches of the Seoumjin river, because the water of the former dam is diverted to the Dogjin river basin and the latter to the southern coast, in both cases after generating hydropower.

Such being the present situation in the Seoumjin river basin, this dam site is conceivable to cover the shortage of water supply in the basin. Although its benefit-cost ratio is less than 1.0 and less than that of the Juam dam, this site has an advantage that the ratio of compensation to the construction cost is comparatively low. The discharge regulated at the Jeokseong dam can be taken in downstream.

The development scale is selected at VE = 0.80 Qy. In the following stage survey, the discharge data at the both existing dams should be collected and analyzed for more precise study and planning for development.

23-82 Juam (Rank : B2)

The scale of development of the dam is selected at VE = 1.00 Qy. The problem is that the ratio of compensation cost to construction cost of dam is the highest among all the dam sites surveyed this time. Even if the HWL is lowered, the benefit-cost ratio may not become higher.

24-A4 No. 2 Boseonggang (Rank : C)

Based on the site reconnaissance, the more favourable dam site than the original one was found from the view points of topography and geology. The dam scale is decided at VE = 0.40 Qy in consideration of No. 1 Boseonggang dam upstream.

The ratio of compensation cost to construction cost is very high. The benefit-cost ratio for the total benefits is less than 1.0, however, if the power generation is excluded, the above ratio will exceed 1.0. This is, among 24 dam sites, the only one case in which the exclusion of power generation favours the benefit-cost ratio.

4. The Seoumjin River Basin Survey

The overall basin survey has not been carried out for the Seoumjin river basin. It is desired that the overall basin survey will be made as soon as possible not only for the basin itself but also for the adjacent areas that can be benefitted by the dams to be constructed in the Seoumjin basin. The heightening of the existing No. 1 Boseonggang dam is desired to be studied as well.

1. PRESENT STATUS OF WATER RESOURCES DEVELOPMENT

1. PRESENT STATUS OF WATER RESOURCES DEVELOPMENT

1.1 Outlook of Land, Water Resources and Economy

The republic of Korea (ROK) is generally mountainous with peaks as high as 2,000 meters in the Daebaek mountain range that lies north-to-south along the east coast. About 80 percent of the land is below elevation 500 meters above sea level, and over half of it is above elevation 100. Most of the land below elevation 100 lies along the rivers and coast-line in the west and the southern part of the country. From geological point of view, most of the land is composed of weathering granite, some parts being laid exposed. In general, land has a poor water holding capacity due to thin top soil, small vegetation and forestation.

The average annual rainfall in Korea is 1,159 millimeters. During the four months from June to September, Korea receives 70 percent of its annual precipitation. Korea has thus a dry season in winter and a rainy season in summer.

The ROK covers a total area of approximately 98,480 km^2 which is composed of many big and small river basins. Of them, the four major river basins - the Han, the Nakdong, the Geum and the Seoumjin - spread in an area of 66,260 km^2 in total or about 67 percent of the total land.

The water resources endowment and characteristics of river discharge are as shown in the Table 1.1. The run-off coefficients are comparatively low and flood discharges are comparatively high throughout the country. At the same time big differences are found between the maximum and the minimum discharges, which results in big coefficients of river regime.

The population of the ROK as of 1975 was approximately 35.3 million, with a density of 359 per square kilometer, which is one of the highest in the world. The annual rate of increase in population was 1.8 percent during 1970-75.

The Korean economy has so rapidly expanded since early 1960s that its gross national product (GNP) in real terms rose 9.3 percent per annum between 1961 and 1975 reaching 18.8 billion dollars in 1975. During the same period, population increased 2.3 percent per annum from 25 million in 1961 to 35.3 million by 1975. As a result, per capita real GNP in current dollars increased from $83 in 1961 to $532 in 1975 at an annual rate of 7 percent.

The successful industrialization strategy has brought a considerable change in the industrial structure. In 1961, Korea remained a backward rural economy, with the primary sector accounting for about 40 percent of GNP, and the mining and manufacturing sector for only about 15 percent. As the industrialization proceeds, the share of mining and manufacturing sector in GNP increased and reached about 30 percent in 1975, while the share of the primary sector declined to 25 percent.

According to the Fourth Five-year Plan (1977-1981), the Korean Government has set a target growth rate of 9.2 percent per annum during the plan period. When this target is achieved, GNP in 1981 will reach 33.5 billion dollars (in 1975 price level). Total population of 35.3 million in 1975, if increased at 1.6 percent annually, will grow to 38.8 million in 1981. Thus real per capita GNP of 257 thousand won in 1975 will increase to 418 thousand won in 1981. If the exchange rate of 484 won to the U.S. dollar is maintained during the plan period, this is equivalent to an increase from $532 (in 1975) to $1,512 (in 1981) in current prices. (See Table 1.2)

Table 1.1 Water Resources Endowment and Characteristics of River Discharge

	Whole Country	Han R.	Nakdong River	Geum R.	Sumjin River	Four Basins Total
Catchment Area (km^2)	98,477	26,219	23,656	11,488	4,896	66,259
Average Annual Rainfall (mm)	1,159	1,200	1,106	1,230	1,344	1,158
Water Resources Endowment per annum (billion m^3)	114.0	30.4	25.5	14.0	6.6	76.5
Volume of Loss	51.0	12.4	10.5	7.0	2.7	32.6
River Run-off	63.0	18.0	15.0	7.0	3.9	43.9
Flood Run-off	39.0	12.1	8.5	4.0	2.4	27.0
Ordinary Run-off	24.0	5.9	6.5	3.0	1.5	16.9
Run-off Coefficient (%)	55.26	59.21	58.82	50.0	59.1	57.3
Coefficient of River Regime		1 : 393	1 : 372	1 : 298	1 : 715	
Annual Average Discharge (m^3/s)		573	476	203	124	
95-day Discharge		435	362	154	94	
Ordinary Discharge		183	152	65	40	
Low Discharge		115	95	41	25	
Droughty Discharge		69	57	24	15	

Table 1.2 Magnitude and Growth Rate of the Economy

	Unit	1975 Actual (A)	1981 planned (B)	B/A	1977 - 1981 Average Annual Rate of Growth (%)
GNP	Bil. won in 1975 prices	9,080	16,214	1.8	9.2
	Bil. dollars in 1975 prices	18.8	33.5	1.8	9.2
	Bil. dollars in current prices	18.8	58.7	-	-
Population	Million persons	35.3	38.8	1.1	1.6
Per capita GNP	Thous. won in 1975 prices	257	418	1.6	7.6
	Thous. won in current prices	257	732	-	-
	Current dollars	532	1,512	-	-

1.2 Present Status of the Four Major River Basins

(1) Han river basin

The mammoth cities of Seoul and Incheon, situating in the lower reaches of the Han River, are to be protected from flood and served with municipal and industrial (M & I) water. The supply of irrigation water, though developed farm land is comparatively small along the North Han River from topographical reason, is to be ensured as well.

In the North Han River basin, many dams and power stations are developed by stagewise; including, in order of their locations from upstream, Hwachon, Chunchon, Soyangang (on a tributary), Uiam and Chongpyong dam-hydropower stations. Out of them, Chunchon, Uiamand Chongpyong dams are mainly utilized for power generation. The Chongpyong pumped storage power station that will be the first of this type in Korea, is now under construction, utilizing the existing Chongpyong reservoir as the downstream reservoir for pumping up. In addition to these dams, there are many potential dam sites surveyed this time in this basin.

In the South Han River basin, only one small hydropower station, Goesan, is constructed on the uppermost of a tributary. In the middle reaches, the Chungju multipurpose dam will start its construction in the near future. The scale being big enough, the Chungju dam is expected to contribute so much for the development of water resources in the South Han River. There are many other promising dam sites in this basin which were surveyed this time.

There are the farm land of 10 to 20 thousand hectares downstream of Yeoju that would be irrigable by water from some upstream multipurpose dam.

At the downstream of the confluence of the North Han and the South Han rivers, the Paldang dam is constructed. This is the dam mainly used for hydropower generation with a low head.

Around the estuary of the Han River, there is a reclamation plan of so big scale that an estuary barrage will be required.

(2) Nakdong river basin

In the Nakdong river basin, irrigation area of 40 to 50 thousand hectares extends along the main stem including the estuary area. The irrigation and flood protection of this area have the utmost importance. In the lower reaches, demand for M & I water has been rapidly increasing recently. In the upper reaches of the main Nakdong river, the Andong dam was completed last year. The Andong power station is constructed as a pumped storage type utilizing the dam as an upper pondage and the re-regulating weir as a lower pondage. The Andong dam has another purpose of supplying river maintenance water that is needed in the lower reaches for protecting the intrusion of salty water. This purpose, however, will be attained by an estuary barrage which will be constructed in the future. In general, it may be said that the main stream of the Nakdong river is at the initial stage of its development of water resources. There are potential dam sites in the upstream as well as downstream area of the Andong dam, which were surveyed this time.

In the Nakdong river basin, its tributaries are not less important than the main stream in terms of the development of water resources. On the Nam river, one of the downstream tributaries, the Namgang dam is constructed to divert the maximum flood of 4,600 m^3/sec through the diversion channel of 12 kilometers into the southern Sachon Bay. This dam contributes not only for the flood control of the lower reaches of the main Nakdong river, but also for the development of newly cultivated farm land of the lower reaches of the Nam river. Further, the dam can supply M & I water to the area downstream of the diversion channel, along the Sachon bay. Any upstream dam surveyed this time will reinforce the Namgang dam in its capacity of water supply and flood control.

Considering the importance of the tributaries covering a wide irrigation area of about 280 thousand hectares, FAO survey team investigated 18 multipurpose dam sites, respectively representative of the major 18 tributaries, and made a recommendation to construct them in proper stages. Out of them, the Hapchon multipurpose dam is given the highest priority to be constructed in the earliest stage. This dam project has such advantage for hydropower generation that a high head can be obtained utilizing downstream gorge. Further, this dam will contribute to water supply and flood control of the lower reaches of the Hwang river, one of the tributaries of the Nakdong river, as well as the lower reaches of the main Nakdong river.

(3) Geum river basin

In the lower reaches of the Geum river, there extends a wide farm land of about 390 thousand hectares, covering the adjoining Mangyeong river basin and the downstream plain of the Dongjin river. The demand for water to irrigate these areas is very large. The irrigation water controlled by the Daecheon dam will be taken in the lower reaches and carried through a long waterway. The controlled discharge of the Daecheong dam will be diverted at the middle reaches and will irrigate an area of about 14 thousand hectares in Cheongju plain.

The M & I water for Daejeon and Cheongju cities will be taken from the reservoir. The dam also has a great advantage in hydropower generation. This dam is situated in the middle course of the main Geum river. In its upper reaches, four dam sites were studied in the present survey. When some dam will be constructed upstream, the Daecheon dam may be reinforced in its capacity for flood control, water supply and power generation.

In the lower reaches of the Geum river, an irrigation project with an area of more than 20 thousand hectares is under operation, whose uumping facilities are installed near Ganggyeong along the main Geum river. After the completion of the Daecheon dam, this project will be benefited greatly by the stabilized discharge of the dam.

Any dam studied this time would strengthen the capacity of the downstream Daecheong dam.

(4) Seoumjin river basin

In the Seoumjin river basin, the Seoumjingang dam is constructed in the uppermost reaches by submerging the old Unam dam. The water of the Seoumjin river is diverted to the Dongjin river basin through the waterway of the Chilbo hydropower station attached to the Seoumjingang dam. By this water diversion, the Seoumjingang dam is supplying irrigation water along the Dongjin river to the farm land of about 30 thousand hectares which constitutes the southern part of 390 thousand hectares extending widely along the west coast.

In the Boseong river, one of the southern tributaries of the Seoumjin river, the No. 1 Boseonggang dam is constructed. The water of the Boseonggang reservoir is also diverted to the southern coast plain by a tunnel and used for hydropower generation and irrigation water supply. These existing two dams are of diversion types, having no function to supply water to the Seoumjin river basin itself. As the demand for water is rapidly increasing in the Seoumjin river basin and in the southern coastal areas as well, the construction of a dam in the basin is strongly required.

To meet this demand, a dam is to be constructed in the upper reaches to increase the river flow in the downstream, which will be conveyed to the demand area through a waterway.

Meanwhile, the Seoumjin river is, among major rivers, the only one river on which the river basin survey was not carried out. Its early execution is desired covering the beneficiary areas adjacent to this basin as well.

2. NECESSITY OF WATER RESOURCES DEVELOPMENT

2. NECESSITY OF WATER RESOURCES DEVELOPMENT

In Korea, out of available water resources, only a small portion is estimated to be actually utilized because of the deviated seasonal distribution of precipitation and insufficient reservoir facilities. In recent years, to promote the utilization of water resources, several multipurpose dams have been constructed; these include Seoumjin, Chunchon, Nam, Soyang and Andong dams. In addition, the Daecheong dam is now under construction and Chungju and Hapcheon dams are now in their preparation stages.

The demand forecast of water in the four major river basins have been made in the Report on Comprehensive Survey of Rivers in Korea by MOC. Based on this report, demand curves are drawn in Figs. 2.1 through 2.3. These curves show that, in the Han and the Nakdong rivers, dam constructions will be needed to meet the increasing water demand. They also show that, in the Seoumjin river, whose existing dam waters are diverted and not used in its downstream areas, a new dam will be needed to fulfil the rising demand of water in the basin.

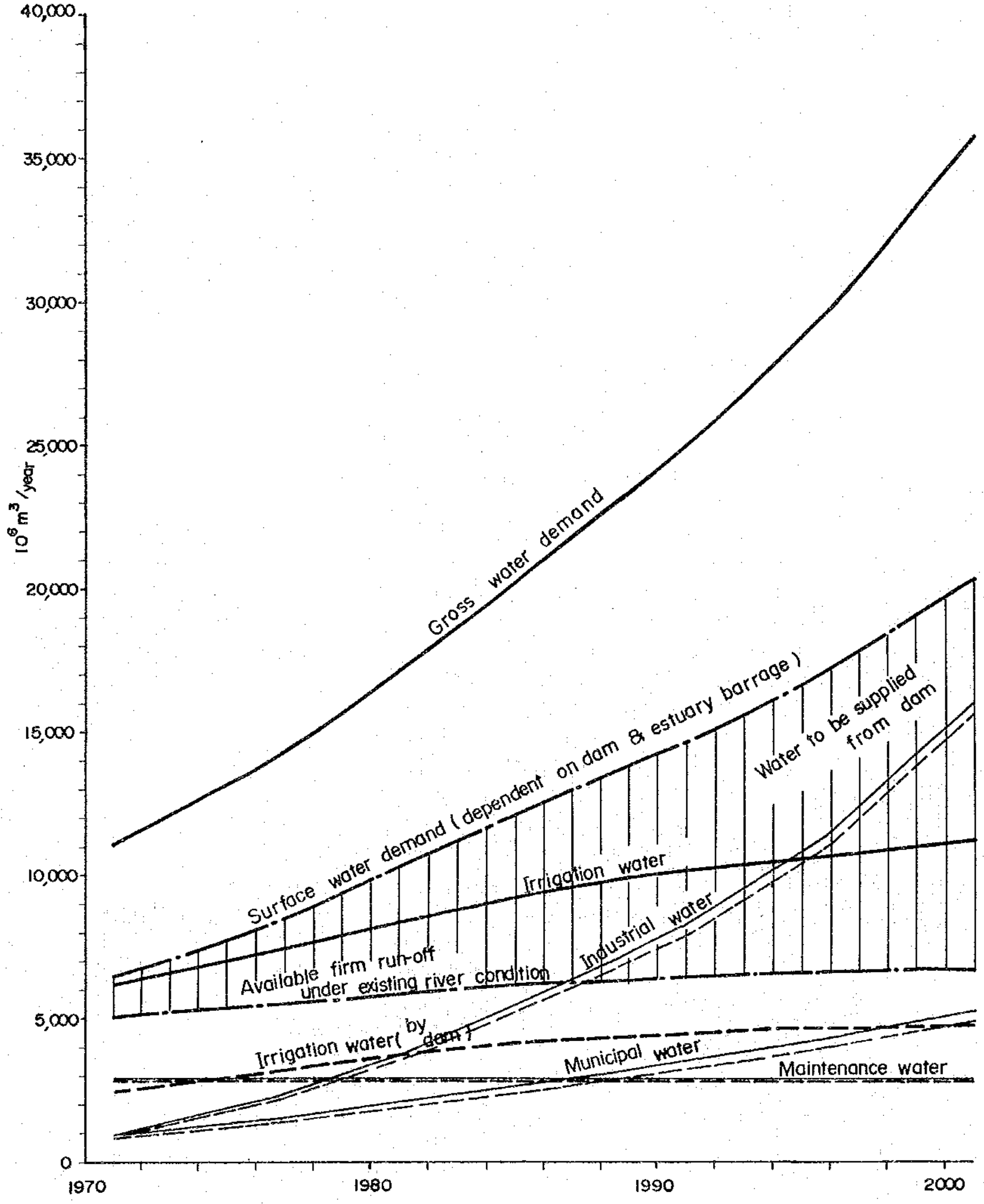

Fig. 2.1 Water Demand for whole Country

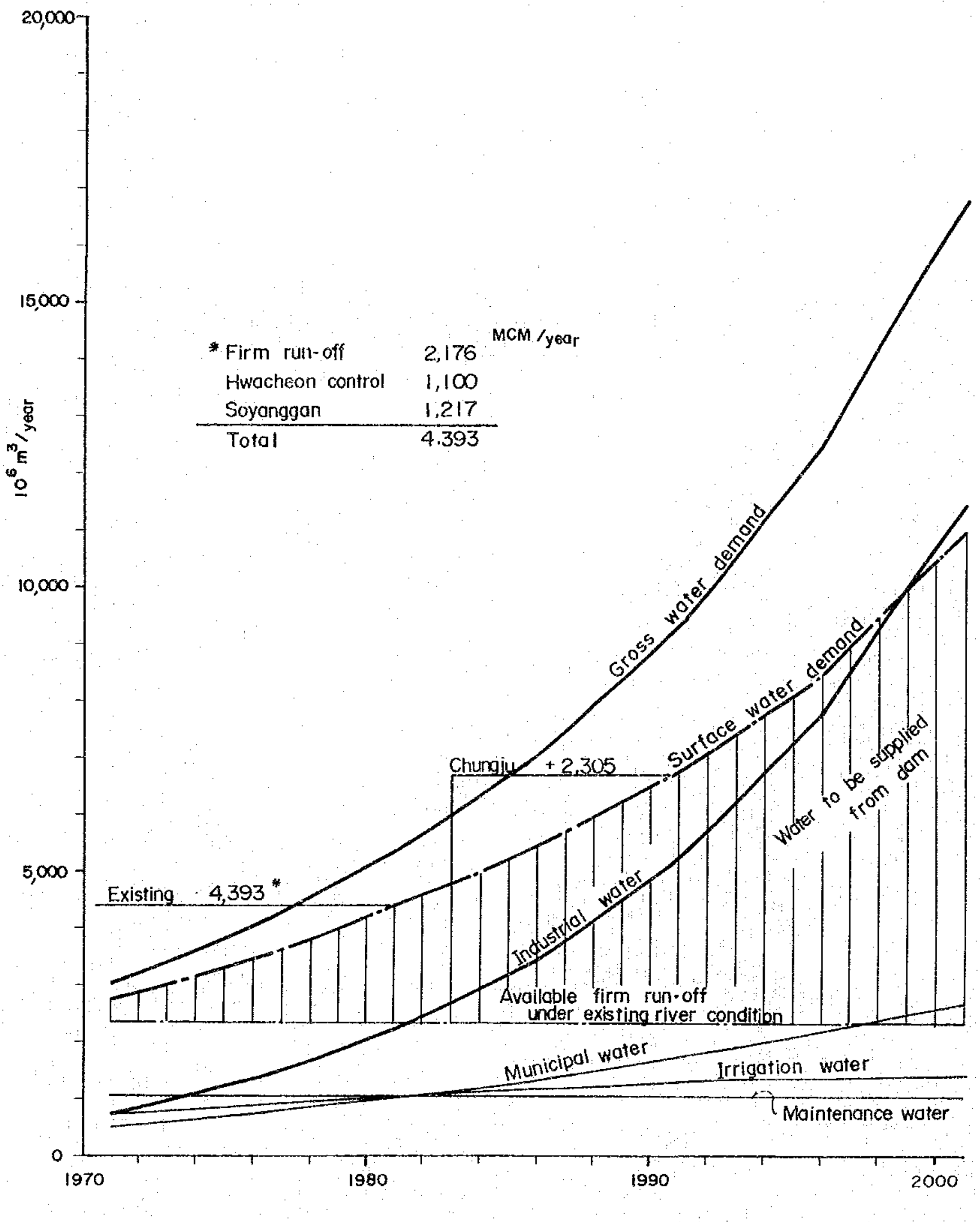

Fig. 2.2 Water Demand in The Han River Basin

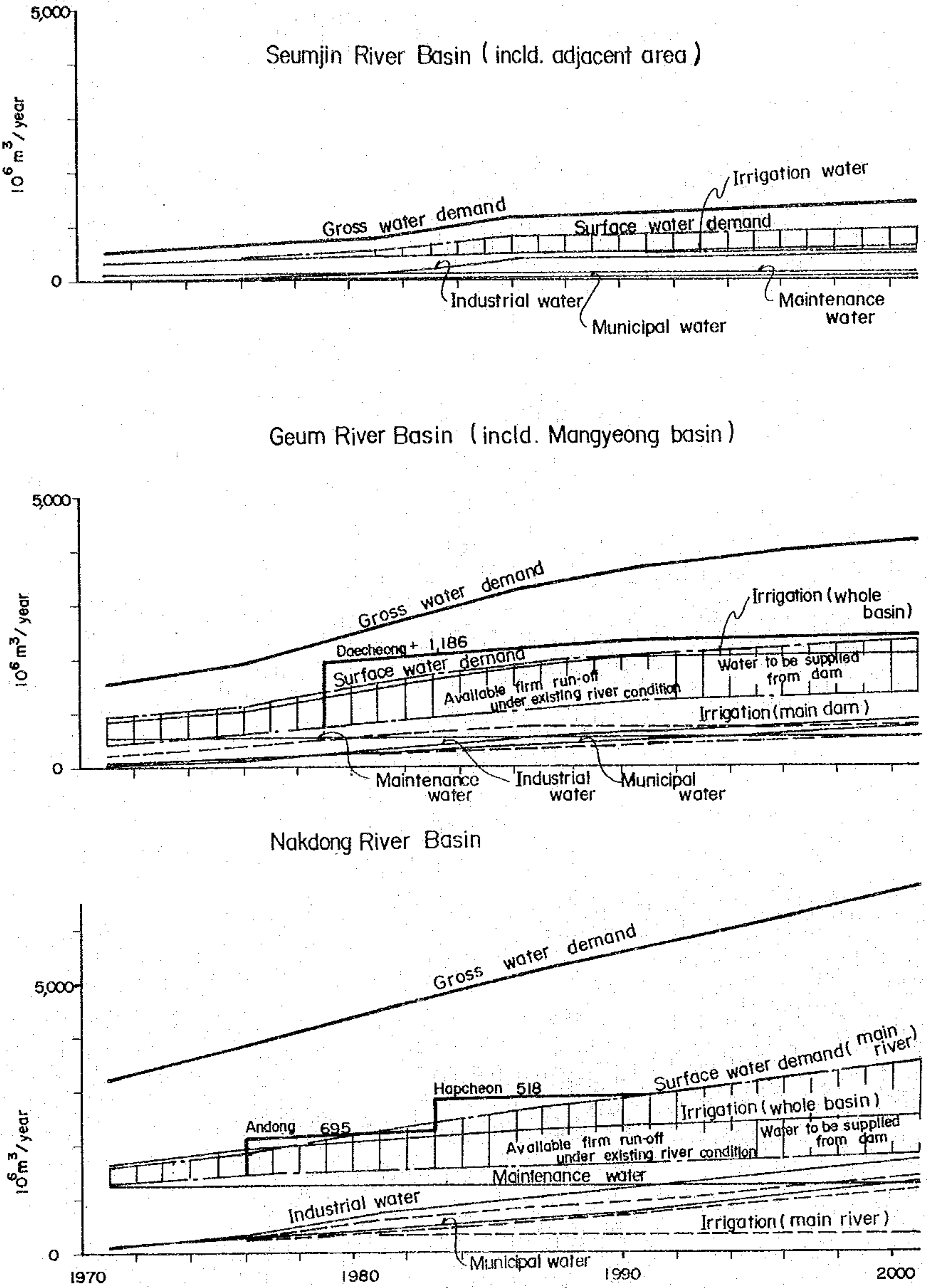

Fig.2.3 **Water Demand**

3. BASIC CONCEPT OF WATER RESOURCES DEVELOPMENT BY MULTIPURPOSE DAMS

3. BASIC CONCEPT OF WATER RESOURCES DEVELOPMENT BY MULTIPURPOSE DAMS

The water resources are one of the valuable natural resources of the Republic of Korea, giving her the firm bases of the national growth through agriculture and industry. As the agriculture and industry have been developing remarkably, the demand for water has increased rapidly in Korea. To meet such increasing demand for water, several multipurpose dams have been constructed on major rivers. Moreover, there are some dams now under construction and others under study.

The water resources are developed mainly by dams. Meanwhile, the appropriate sites for dam construction are limited by natural potentialities such as topographical and geological conditions. Consequently, the number of possible dam sites and the scale of their development are limited. Therefore, as the advantageous dam sites will be developed successively to meet the rapidly increasing demand for water, there remains scarce dam sites to be developed advantageously in future.

A dam site, when once developed, is very difficult to be redeveloped again. Therefore, water resources development through dam construction should be planned based on the long term perspectives.

All dam sites surveyed this time have, except for a few special ones, precious and characteristic potentialities.

Owing to such climatic features in Korea that precipitation is biased considerably by month and by year, some reservoirs would be required to have effective capacity of more than 100% of annual river flow, provided the flow is to be regulated firmly throughout a year.

Some dam sites can be determined their scales comparatively freely, but the other dam sites are restricted their scales by topographical and geological conditions and/or specific compensation problems.

As for the latter dam sites, it is desirable that they will be developed in such a sufficient scale as the conditions may allow. When dams are constructed stepwise successively, the scale of downstream dam is restricted by that of upstream dam. Even in such case, the scale of downstream dam should be as big as the conditions may allow. Thus, the water resources are desired to be developed in such a way to approach the ideal plan as close as possible.

In some cases, heads for hydropower generation are created not only by dams, but also by waterways advantageously. When there are some rapid or bend for short cut downstream of the dam, such topography can be utilized for creating head for hydropower generation by constructing waterway. The regulated discharge of the upstream dam can also be utilized by the downstream power station. Thus, it is desired that head potentialities should be utilized economically and completely.

It is desired that all dams newly planned are to be multipurpose type and that they are to be constructed successively in order of priority that will be determined comprehensively based on the effects of hydropower generation, water supply and flood control.

In evaluating the projects, in addition to tangible benefits, such intangible benefits are to be taken into consideration as the development of tourism and resort area that can be provided by creating lakes on plateau or in mountains. The development of forestry and fish culture are to be considered as well. These are also important benefits brought by the development of water resources.

In determining the priority of dams, all these benefits and needs are to be comprehensively taken into consideration.

4. PRELIMINARY SURVEY AND PLANNING CONDITIONS

4. PRELIMINARY SURVEY AND PLANNING CONDITIONS

4.1 Topographical Survey

The layout of dam and power station including their alternative plans were studied on the topographical maps on the scale of 1:50,000 and 1:25,000. Those maps were also used for the field reconnaissance. The stage-area-storage curves for all the proposed damsites were prepared based on the maps mentioned above.

The river cross section along the center line of the 15 proposed dam sites were newly surveyed and prepared by MOC in the scale of 1:1,000. As for the remaining 9 sites, the available data attached to each study reports were used. As for the alternative sites, of which surveyed data were not available, the rough river cross sections were prepared in the field reconnaissance. These data were used to estimate the work quantity of each dam.

All the data available are listed in Table 4.1.

Table 4.1 Availability of Topographical Survey Result

Dam	Provided by MOC this time	Others
North Han River		
1-32 Bamseonggol	0	Rough section measured on reconnaissance for upstream alternative site
2-23 Hupyeong		Section attached in study report, 1963 and rough section for alternative sites.
3-22 Inje		Section attached in study report, 1962 Rough section for alternative site
4-30 Weolhak	0	
5-A3 Hongcheon		Section in HRBR, 1971
South Han River		
6-3 Gujeol	0	Rough section for upstream alternative site
7-9 Pyeongchang	0	
8-10 Panun	0	
9-13 Suju	0	
10-12 Dogog	0	
11-A1 Dalcheon		Section in HRBR, 1971
12-A2 Ganhyeon		Rough section measured on reconnaissance
Nakdong River		
13-35 Bonghwa		Section in study report, 1962
14-43 Imha	0	
15-36 Chibo	0	Rough section for downstream alternative site
16-51 Hamyang	0	Rough section for upstream alternative site
17-53 Dogsan	0	
Geum River		
18-62 Yongdam		Surveyed map, 1962
19-63 Sutong		Section in study report, 1962
20-64 Myeongcheon	0	
21-69 Simcheon	0	
Seoumjin River		
22-77 Jeokseong	0	
23-82 Juam	0	
24-A4 No. 2 Boseonggang		Rough section measured on reconnaissance

4.2 Geological Survey

The geological maps on the scales of 1:250,000 and 1:50,000, and the ones attached to some reports were collected and utilized for field reconnaissance.

The geological reconnaissance was carried out for all 24 dams and power station sites including their alternative sites. Based on the reconnaissance, the surface geological maps were made. The assumed rock line was drawn on the river cross section along the center line of each dam to estimate excavation quantity of dam foundation.

Further, the possibility of dam construction was examined; layout of power station was studied; the earth and rock materials were surveyed; accessibility to the site was examined; and efflux of sand from the basin was investigated on reconnaissance bases.

The results of these geological survey are briefly described for each dam in this main report, and are shown in detail in Appendix II "Geological Survey Report".

4.3 Hydrologic Study

The hydrologic study of this investigation was made based on the available data given in the "Report on Potential Hydropower", "Report on Comprehensive Survey of Rivers" and others. The rainfall data were examined to determine basic hydrologic data which suit the objective of the study.

(1) Annual average run-off

The proposed dam sites have already been investigated in the past and monthly run-off for more than 10 years have been calculated and made available in a number of reports. In particular, the "Report on Potential Hydropower" provides data for the same period for all of the project sites so that it was possible to determine the annual average run-off data of each site through reexamination taking into account of rainfall data during corresponding periods and basin conditions. For sites with similar rainfall and basin conditions, a standard gauging station was selected, based on which representative run-off of the group was determined.

(2) Monthly run-off

The monthly average run-off data for the longest available period at the standard gauging stations were utilized in this study.

(3) Natural firm discharge

The monthly average run-off data at the standard gauging stations were arranged in descending order and the discharge corresponding to 95% from the largest was taken as the natural firm discharges of those stations, which were proportioned to each catchment area to obtain the natural firm discharge at each site.

(4) Regulated firm discharge

Using the monthly run-off at the standard gauging station representing the group, a flow mass curve was drawn. In a case where there was a discontinuity in the run-off records caused by the Korean Disturbance, two separate mass curves were prepared. The minimum discharge obtained on the mass curve for each effective storage capacity was adopted as the regulated firm discharge, which was proportioned to each catchment area to obtain the regulated firm discharge of each site. (Evaporation and other losses from the reservoir were estimated and adjusted in Section 4.4)

(5) Design flood discharge

Design flood discharges were determined through reexaminations of those of the proposed dam sites given in existing reports and of the dam sites existing and under construction referring the Creager curves.

The existing flood hydrographs related to the proposed dam sites were analyzed and the results were applied to estimate flood duration hours of the dam sites. The simplified flood hydrographs combining the above with the design flood discharges determined above were utilized to calculate flood hydrographs.

(6) Evaporation

Evaporation data are given in Hydrologic Annual Report in Korea and other reports. Of the records available, the data of Chuncheon, Hwacheon and Andong which are relatively close to the proposed dam sites were utilized.

4.4 Reservoir and Dam

It was assumed that each dam would be constructed after the completion of dams now under construction and preparation and the sequence of dam construction was not considered in this study.

The power generating facilities were assumed to be provided to each dam in principle, however, dual-purposes dam for water supply and flood control was also studied on each site, to see if the provision of power facilities were advantageous or not.

Planning conditions of present study are as follows:

(1) Dam sites shown in "the Report on Potential Hydropower", "the Han River Basin Report" and other relevant reports were adopted to be surveyed in this first stage survey in principle. These are referred to as "the proposed dam sites" by the Government of ROK. But in the following cases, the alternative sites were selected.

a. In case the river gradient at the proposed dam site is quite steep and the alternative site could be found in its upper reaches: Hupyeong, Gujeol and Hamyang

b. In case the proposed dam site was found geologically unfavourable for dam construction: No. 2 Boseonggang.

c. In case the topography could not allow to construct a sufficiently high dam and the alternative site could be found in the lower reaches with a bigger storage capacity: Chibo

d. In case the alternative site could be found in the vicinity of the originally proposed site, the both of them were studied: Bamseonggol and Inje.

(2) The scale of dam, though it will be finally determined by the second stage survey, was studied roughly in the following manner:

The scale of dam was determined from the point of topographical and geological conditions. The location of local principal municipalities, of which submergence should be avoided, were considered as well. (Bamseonggol, Weolhak, Hongcheon, Panun, Dalcheon, Ganhyeon and Chibo). The scale of dam was also restricted by the location of the upper dam if any. (Inje, Dogog, Sutong and Myeongcheon)

In case it could be determined freely from these conditions, the scale of dam was determined based on economic study comparing four cases in which the effective capacity of reservoir (VE) was selected respectively at the level of 100%, 80%, 60% and 40% of mean annual run-off (Qy) at the dam site.

(3) The allotment of reservoir space was determined as follows:

a. The space of sand deposit was provided for a period of 100 years and was estimated based on the unit quantity of sand deposit shown below.

Dam site	Sand deposit $m^3/km^2/yr$
Pyeongchang, Panun, Hupyeong, Bamseonggol, Hamyang, Dogsan, Weolhak	700
Gujeol, Inje, Suju, Dogog, Bonghwa	600
Hongcheon, Dalcheon, Ganhyeon, Yongdam Sutong, Myeongcheon, Chibo	500
Imha, Simcheon, Jeokseong, Juam, No. 2 Boseonggang	400

b. In case of multipurpose dam with power facilities, the normal high water level (NHWL) and low water level (LWL) were set so that the effective storage capacity corresponding to the development scale could be provided between those water levels. The drawdown was set equivalent to 30% of the head between NHWL and tail water level. In case the elevation of the sand deposit was higher than the LWL determined by the above standard, the assumed elevation of sand deposit was taken as LWL.

The water supply for irrigation and M & I water use were integrated into one component in the study.

In case of dual-purpose dam without power facilities, LWL was set at the elevation of sand deposit and NHWL was lowered so that the effective storage capacity corresponding to the development scale could be set between those water levels.

c. The flood control volume was determined by the surcharge volume.

(4) Type of dam was determined based on map study and site reconnaissance.

(5) The foundation of dam was determined from rock surface marked on surveyed profile of dam site after site reconnaissance.

(6) The crest of dam was determined at the level of 5 meters higher than NHWL for each dam, as the flood control was studied by surcharge method. The depth of surcharge was determined at the level of 2 meters for fill type dam and 3 meters for concrete type dam. But for a few dams that may give a great flood control effect to the downstream area due to the fact that no dam is constructed downstream, the depth of surcharge was determined by an equivalent rainfall specifically assumed for each dam.

(7) The dam height was measured from the assumed rock surface to dam crest.

(8) The crest length of dam was measured on the surveyed river cross section.

(9) The fill dam was designed with crest width of 8 meters, and slope of 1:4.5 in total of upstream and downstream slopes.

(10) The concrete dam was designed with fundamental triangle section with slope of 1:0.9 in total of upstream and downstream slopes.

(11) The design flood for spillway was determined at the discharge equivalent to 200-year flood. The fixed ratio method was adopted for flood control.

(12) Evaporation and other losses from reservoir were estimated by the following formula.

$$\text{Loss} = AP\alpha - (AP-AE) = A\left\{E - P\ (1-\alpha)\right\}$$

Where, A = Reservoir surface area (m^2)

P = Average precipitation

α = Run-off coefficient out of reservoir surface area prior to dam construction

E = Evaporation from the reservoir surface (m)

In this study the value of E was taken at 70% of evaporation from the small-size pan (20 cm dia.) and α at 90% of the run-off coefficient at dam site out of the whole basin.

(13) Available firm discharge is the discharge that the evaporation and other losses are deducted from the regulated firm discharge mentioned in Section 4.3.

(14) Construction cost of the dam was estimated according to the items classified in Annex 1.

(15) Work quantity of the dam was calculated based on the surveyed profile and rough section measured on reconnaissance and formula shown in Annex 2.

(16) Unit construction cost was as tabulated in Annex 5. These costs included machinery cost.

(17) Construction cost included the necessary miscellaneous cost, preparatory works, general expenses, contingency and interest during construction, according to the Annex 1.

(18) Compensation cost was estimated based on the compensation survey by MOC.

(19) The reservoir and dam are the common facilities for multipurpose dam projects. The annual costs for these common facilities are calculated as a total of capital cost and OM & R cost by applying the following factors.

$$\text{Capital recovery factor} = \frac{i\ (1 + i)^n}{(1 + i)^n - 1}$$

Where i: interest ratio, 8% adopted

n: durable period, 50 years

OM & R cost is estimated at 0.5% of construction cost.

4.5 Hydro Power Generation

The facilities for hydropower generation were studied as exclusive use by the following standards.

(1) Layout of waterway (Type of hydropower station)

Not only dam type, but also dam-and-conduit type was adopted if advantageous for the site.

The reregulating bay was considered when it seemed to be needed.

The layout of waterway structures were surveyed in field reconnaissance and studied on the topographical maps on the scale of 1:25,000.

(2) The maximum discharge was determined at 24/5 = 4.8 times of firm discharge assuming 5 hours/day generation to meet peak demand.

(3) The rated effective head was determined by subtracting loss head from the gross head between TWL and the reservoir water level that was set at the level lower than HWL by 1/3 times of drawdown.

(4) Installed capacity

The combined efficiency of turbine and generator was selected at 88% for each power station. The installed capacity was calculated based on this efficiency, the maximum discharge and rated head. (8.65 x maximum discharge x rated head)

(5) Dependable peak power

The dependable peak power was calculated by the following F.P.C. formula.

$$Pd = 1/2(Pmin + Pi)$$

where Pd : dependable peak power
Pmin : power (kw) for the LWL
Pi : installed capacity (kw)

(6) Annual energy output

The annual energy output was calculated based on the discharge obtained by analysis of mass curve multiplied by energy output per cubic meters of the power station.

The increment of annual energy output accrued by the downstream power station was added in benefit calculation.

(7) Construction cost

The construction cost of waterway structures was calculated in the same way as that of dam i.e. estimated work quantity multiplied by unit construction cost.

The classification of work items, formula of work quantities and unit construction cost are shown in Annex 3, 4 and 5 respectively.

(8) The cost of power generating facilities was estimated based on the unit cost per kW as shown in Annex Fig. 2.

The cost consists of design, manufacturing, transportation and installation costs.

(9) The transmission line was considered to be connected to the nearest existing power station or substation. The cost of transmission line and extension of existing substation was estimated based on the cost data shown in Annex 6.

Cost of the flood forecasting system was included.

(10) Annual cost for hydropower generation was calculated as a sum of capital cost and OM & R cost (refer to the calculation of cost for reservoir and dam).

$$\text{Capital recovery factor} = \frac{i(1 + 1)^n}{(1 + 1)^{n-1}}$$

where i : interest rate = 8%

n : durable period = 50 years

OM & R cost : 2.5% of construction cost

(11) Annual benefit

In calculating the benefit accrued from hydropower generation, an alternative standard thermal power station, 300 MW (durable period: 30 years, interest rate : 10.3%) was assumed.

The unit benefit values of kW and kWh were calculated based on the above standard thermal power station.

The benefits were obtained from the unit values of kW and kWh multiplied respectively by dependable peak power and annual energy output which included the energy increase at the downstream power station.

KW and kWh values are as follows;

kW value : 38,820 Won/kW
kWh value: 9.475 Won/kWh

Analysis of the unit values is shown in Annex 7.

4.6 Water Supply

In carrying out the economic study, water supply for irrigation and M & I use were integrated into one component. The facilities for exclusive use of irrigation and M & I water were not considered in this study.

The annual increase of the guaranteed firm discharge of each dam was derived from the difference between the possible water supply volume in the drought year estimated for each proposed dam and the 95% drought discharge observed at the same site (equivalent to the possible water supply volume on the present conditions).

But in case the proposed dam is located upstream reaches of a large dam already constructed,/1 the annual increase of the guaranteed firm discharge of the proposed dam was derived from the balance of the discharge out of the downstream dam before and after construction of the proposed dam, considering the fact that the water of the proposed dam will be discharged, after being reregulated, from the downstream dam.

In calculating the unit benefit of water supply, the alternative dam exclusively used for water supply was assumed for each proposed dam site. The annual cost of the alternative dams were derived as a sum of capital cost and OM & R cost that were calculated based on the same formula as shown in the section 4.4.(19). Thus, the unit benefit of water supply for each basin was derived as the weighted average of the unit costs that were calculated by the above annual costs of the alternative dams divided by the annual increase of the guaranteed firm discharge brought by the proposed dams.

As a result, the unit benefit of water supply for each basin was obtained as shown below (refer to Annex 8).

/1 "The large dam already constructed" includes the following dams that are either completed already or under construction: Hwacheon, Soyangan, Chunju, Andong and Daecheon dams.

the Han river	:	8.56 w/m^3
the Nakdong river	:	6.52 "
the Geum river	:	5.85 "
the Seoumjing river	:	9.03 "

4.6.1 Municipal and Industrial Water

In the 1st stage survey, data on demand for M & I water is obtained from the "Report on Comprehensive Survey of Rivers in Korea".

4.6.2 Irrigation Water

In order to conceive an irrigation development plan in the basins under investigation, a long term forecast of the future demand of irrigation water is essential. The increase of the future water demand will be primarily brought by following three categories:

Category-A: Additional supply for the area now either partially irrigated or rainfed, where irrigation system will be improved to fully-irrigated level in the future,

Category-B: Supply for newly developed area, and

Category-C: Additional supply for improvement of current farming practices prevailing in this country.

In recent years, irrigation system in the partially-irrigated and the rainfed areas have been remarkably improved. According to the "Year Book of Agriculture and Forestry Statistics, 1976" published by the MOAF, the total hectareage of the fully-irrigated area amounts to some $1,065 \times 10^3$ ha which is equivalent to 84% of the whole paddy field ($1,276 \times 10^3$ ha) in this country. A sharp increase of additional water demand of the Category-A, therefore, will not be expected in future.

The self-sufficiency of staple food in this country has been attained in recent years. Domestic price of the staple food is so high, compared with the international price. Hence, the new reclamation of paddy field and upland will not be economically justified. The future increase of the irrigation water demand induced by the Category-B will not be anticipated too.

From the above viewpoint, the agricultural development inthis country has to place special emphasis on (i) the stability of its production and (ii) the vitalization of farmers economy. These two strategies will be attained through improvement of farming practices, relevant to the Category-C.

The stabilizations of land and labour productivities in agriculture, which are the basic components of the farming improvement, will be visualized by the improvement of infrastructures for agriculture. The land consolidation and upland irrigation are the prerequisites for the attainment of these strategies. These two works will effectively contribute to the agricultural development in the basins under investigation.

The irrigation water demanded by these works would be supplied from the dams proposed in this investigation. Almost all the dams for water resources development will be proposed at the main reaches of the relevant rivers. So, in order to irrigate the area expanding along the tributaries of the rivers, long irrigation canals, high-lift and large-scaled pumping units have to be installed. The irrigation development in the basins of tributaries will not be economically sound, as far as the irrigation water for these areas is dependent on the dams located at the main reaches of the rivers. The farm land extending along lower main reaches of the rivers, therefore, will be picked up for these works from economical viewpoint.

In "the Korean Agriculture", the authority concerned stipulated the targets that some 46% of total extent of paddy field all over the country would be consolidated by 1981. While, the attainable target in the basins under investigation are ranging from 40% to 80%, owing to the topographic and existing on-farm conditions in each basin. After the completion of the land consolidation works, the irrigation and drainage canal system on-farm level will be distinctly aligned and the drainage condition on-farm level will be remarkably improved. Therefore, the implementation of the land consolidation works will cause the substantial increase of water requirement on-farm level, due to such an alignment and an improvement. Judging from the past experiences of the land consolidation works implemented in Japan, some 25% increase of the water requirement is expected; about 20% from the well-drained condition on-farm level and 5% from the separate alignment of the relevant facilities.

On the other hand, some 15% increase of yield of rice will be anticipated after the completion of the consolidation works, due to the remarkable improvement of drainage condition on-farm level and the timely irrigation which will be conveniently practiced through the improvement of the on-farm facilities. An intensive and large scaled agricultural mechanization will be also realized by the implementation of the land consolidation works, such as enlargement of paddy plots, rearrangement of paddy field, land levelling and rehabilitation of farm road networks. Furthermore, about one third of farming labour force will be substantially curtailed through the mechanization. Considerable surplus labour will be shifted to a multifarming in the future.

The upland irrigation should also be developed at arable lands scattering along the main reaches of the rivers to effectively utilize the developed water resources at the series of dams. The water sources for the upland irrigation will also be dependent upon the proposed dams. The notable contribution of the upland irrigation to agriculture will basically comprises,

- i) sharp increase of the yield of upland crops, such as vegetables, fruits and other upland crops,
- ii) qualitative improvement of the crops, and
- iii) stable production of the crops.

These effects brought about by the upland irrigation will increase the marketability of the product and the expansion of upland cultivation in these basins in the long run. The water requirement of the upland irrigation in these basins is approximately estimated at 300 mm, on the basis of the meteorological and pedological data provided by the authority concerned.

Based on the basic concept as mentioned above, the development areas for the land consolidation and the upland irrigation in the basins under investigation are estimated on the topographic maps on a scale of 1:250,000 assuming the attainable ratios of land consolidations previously mentioned. The additional newly required irrigation water corresponding to the said development areas are approximately estimated as shown in Table 4.2.

As clarified in the table, the Geum river basin has the largest potentiality for the future demand of irrigation water, whereas the Seoumjin river the smallest.

Table 4-2 Development Areas and Demand for Irrigation Water

River Basin	Command Areas (ha)			Demand for Irrigation Water (10^6 m^3/year)		
	Paddy	Upland	Total	Paddy	Upland	Total
Han River (Northern)	12,040	8,220	20,260	33.23	35.51	68.74
" (Southern)	24,900	9,590	34,490	63.99	41.43	105.42
Nakdong River	35,120	14,080	49,200	110.28	67.02	117.30
Geum River	55,360	9,800	65,160	143.38	42.24	185.62
Seoumjin River	3,540	2,140	5,680	11.33	9.10	20.43

The detailed study on the irrigation plan in the respective basin is compiled in Appendices I-3. As a result of analysis, the justifiable expenditure for the irrigation purpose of multipurpose dam is estimated to range from 18 W/m^3 to 26 W/m^3 among the four basins.

4.7 Flood Control

4.7.1 General

(1) Problems in the study

The flood control effects of a dam are determined by such factors as characteristics of rainfall and the resulted flood hydrograph, design flood discharge and operational schemes of the dam, hydraulic characteristics of the river in the downstream reaches of the dam and topographical conditions of the surrounding areas of the dam.

Therefore, in the study of flood control effects of a dam, such preliminary studies as the existing hydraulic and hydrological survey and analyses, operational schemes of the dam group, land utilization of the downstream areas, and a nature of a flood damage may have to be studied as indispensable prerequisites.

The proposed twenty-four dam sites for the present study scatter over four major river basins and their hydrological and social conditions of the benefited areas differ each other.

On the other hand, to determine construction priority of the twenty-four dams, it is a criteria to evaluate flood control effects of the dams on an equalized basis, and to incorporate the respective dams into the comprehensive flood control schemes of the whole river systems.

In the first stage survey, the evaluation of the flood control effects was made in the manner described below taking into consideration the findings and the available data obtained in the field reconnaissance.

(2) Assumptions and prerequisites

The twenty-four dams are divided into two groups from the viewpoints of flood control effect, geographical and hydraulic characteristics: 1) the group of dams with flood control functions covering whole downstream reaches of the respective main rivers, and 2) the group of dams with flood control functions covering only a part of the downstream areas. Since the dams in the former group will require considerably large flood storage capacities in future, their flood control benefits are reasonably anticipated to reach as large as the justifiable expenditure of an alternative flood control dam. In case of the dams in the latter group, with a surcharge of 2 to 3 meters for the flood control laid on top of the water supply storage, it is considered that there will be the flood control benefits equivalent to the separable costs of flood control purpose of multipurpose dam.

Though such factors as hydrological and land utilization in the downstream areas, mechanisms of flood damage are not taken into consideration, the demand for flood control projects are ever increasing, because of such actual conditions of the country as a remarkable economic growth in recent years, changes in land utilization, urban concentration of population and assets, increase of damage potentials, stabilization of the national livelihood and reorganization of the national foundation.

Therefore, in this study, it is assumed that the flood control benefits equivalent to the dam construction costs can be expected.

4.7.2 Characteristics of Flood Damage

(1) Flood damage

The annual average of flood damage between 1967 and 1976 is W15,267 x 10^6 (in 1976 price). This is equivalent to 0.45 % of the GNP of the corresponding period. The damage amounting to 1.4 % of the GNP in 1969, about 1.0 % in 1970 and 1972 is reported. A heavy damage is observed in urban areas such as Seoul and Pusan.

In spite of the progress of the river improvement in recent years, there is an increasing tendency in inundation areas and death toll.

(2) Flood damage by river systems

The flood damage occurred in the four major river basins during the past ten years is almost equivalent to 50 % of that of the national total. Of the damage occurred in the four major river basins, 74 % had occurred in the Han and Naktong rivers.

The amount of flood damage is the heaviest in the Han river followed by the Naktong, the Geum and the Seoumjin rivers; the areas of inundation is the widest in the Naktong river followed by the Geum, the Han and the Seoumjin rivers.

Thus the Han river basin has been sufferred the heaviest flood damage. Its flood damage shows characteristics of urban flood represented by damage of public facilities, such as railway, road, bridge and building. In the three river basins other than the Han river, about 60 percent of the flood damage is occurred from agricultural damage.

4.7.3 Development of Flood Control Projects

(1) Flood damage of the respective river basins

a. Han river

As Seoul, the capital and political city, is located in the down-stream reaches, the effects of flood prevention of this districts including Seoul-Inchon industrial zone are of paramount importance.

Soyangang dam is now completed on the North Han river for flood control. On the South Han River, however, since no flood control dam has been constructed yet, flood damage is quite frequently reported.

b. Nakdong river

Along the main river course of the Nakdong river, farmland is spreading extensively, and about 50 % of the flood damage is somehow related to agriculture.

Along the mid-stream of the river, changes in land utilization (Gumi Industrial Estate) is observed. Topography of the river basin and alignment of the river channel call for construction of more flood control dams on the river, however, suitable dam sites for the flood control are hard to be found. The flood damage is increasing due to a rise of river bed caused by sediment load and inland water.

c. Geum river

The forestation along the river is rather poor, hence a flood flushes rapidly, and most of flood damage is concentrated in the downstream areas. Since the Daecheong dam under construction is located in the mid-stream of the main river, it is expected to bring on considerable effects of the flood control. Just like the Nakdong river, a damage caused by inland water is relatively high.

d. Seoumjin river

About 73 % and 13 % of the catchment area are mountainous areas and farmlands respectively. Population is the smallest among the four major river basins. It is an under-developed area. The areas suffering frequent flood damage can be seen in the mid- and downstream areas especially concentrated in the downstream of the No.2 Boseonggang dam.

(2) Existing flood control facilities of the respective river systems

In the national scale, the rate of progress of river improvement is only 28.8 % (as of October, 1977) of the proposed total improvement section of the rivers. The promotion of construction of large scale flood control projects is expected in the near future. Among the four major river basins, the rate of progress of the river improvement in the Han river is the lowest of 32.7 % in the section supervised directly by the Government.

(3) Flood control capacity of the dams of existing and under construction

The flood control storage of the dams - existing as well as under construction - are below 100 mm with regard to the equivalent precipitation with only exception of 185 mm of the Soyanggang dam. The national average precipitation equivalent to the flood control storage is 71.3 mm, and this shows flood control dams are still too few in number and too small in storage volume. More flood control dams may have to be constructed in the future.

4.7.4 Flood control effects of the 24-dams

Flood control projects are generally regarded extremely high in public interests, and construction of such projects are usually financed by domestic capitals. In line with the national policy, a substantially low interest rate is usually allowed for such projects and effects of flood control projects are all highly evaluated.

With regard to flood control in multipurpose dam projects, a justifiable expenditure constitutes an important factor, and the benefit-cost ratio is computed assuming an appropriate interest rate. According to Japanese practice, duration period of 80 years, interest rate of 4.5 %, and capital recovery factor of 0.0464 applied for evaluating a flood control project. Since in the current study, duration period of 50 years and interest rate on flood control at 8.0 % are considered, the capital recovery factor is nearly doubled to 0.08174. These factors should be re-considered in the following stages.

The flood control benefits are calculated in the present study based on the alternative justifiable expenditure method and the separable costs-remaining benefits method. It is recommended that the benefit-cost analysis of flood control of a dam will be carried out in an orthodox procedure at the time of the 2nd stage survey.

(1) Classification of dam group from the viewpoint of flood control

The 24 dams are classified as below owing to their location and alignments of the river channels.

a. Dam groups with flood control functions covering the downstream reaches of the main river channel

i) Han river: 3 dam groups, namely, Hongcheon, Ganhyeon and Dalcheon

ii) Nakdong river: 2 dam groups, namely, Imha and Chibo

b. Dam groups with flood control functions covering only a part of downstream areas of the dams. (Group of 19 dams other than group a.)

The above classification are based on such factors as location of the existing and proposed dams, flood protection areas in the downstreams of the dams, topography of the dam sites and alignments of the river channels and available survey data. Since the dams under the group (a) will require considerably large flood storage capacities in future, such benefit equivalent to justifiable expenditure of the alternative flood control dam is anticipated. For the dams under the group (b), a flood storage of 2 to 3 meters was surcharged on top of the design water supply and power generation storage in anticipation of the flood-control benefits equivalent to the separable costs. With regard to the dam group of (a) above, the separable costs are also computed for the purpose of reference.

(2) Annual expenditure for flood control in the group (a)

The alternative justifiable expenditure of flood control was computed on the five dams of the Han and Nakdong river basins referring to precipitation equivalent to the flood control storage of the existing dams, assuming 1) period of duration of flood control facilities at 50 years and 2) interest rate at 8 %. The computed annual expenditure is shown below.

Dam	River	Annual expenditure (10^6 W)
Hongcheon	Han	2,158
Dalcheon	"	1,868
Ganhyeon	"	1,260
Imha	Nakdong	1,915
Chibo	"	4,527

(3) Separable cost for flood control in the groups (a) and (b)

The separable cost were calculated on the 19 dams (group b) as well as on the 5 dams (group a). The results are shown below.

The surcharge level was determined at 2.0 meters for rockfill dams and 3.0 meters for concrete dams.

Dam	Annual Expenditure (10^6 W)
Bamseonggol	88
Hypyeong	45
Inje	66
Weolhak	74
Gujeol	78
Pyeongchang	84
Panun	29
Suju	35
Dogog	45
Bonghwa	35
Hamyang	36
Dogsan	57
Yongdam	48
Sutong	28
Myeongcheon	46
Simcheon	74
Jeokseong	55
Juam	131
No.2 Boseonggang	47
Hongcheon	131
Ganhyeon	34
Dalcheon	107
Imha	61
Chibo	141

5. OUTLINE OF MULTIPURPOSE DAM SCHEMES

5. OUTLINE OF MULTIPURPOSE DAM SCHEMES

The outline of the 24 multipurpose dam schemes is summarized in Table 5-1 and the cost estimate in Table 5-2, based on the study in accordance with the planning conditions stipulated in the Chapter 4.

The outline of each dam is attached in Annex 10.

Table 5-1 Principal Features of Long Term Multi-Purpose Dams

	Name of Dam (up)	V_E/Q_y	Catchment Area km²	Ann. Precipitation mm	Ann. Inflow $10^6 m^3$	Reservoir F.W.L. EL. m	H.W.L. EL. m	L.W.L. EL. m	Drawdown m	Reservoir Area (N.H.W.L.) km²	Gross Storage Capacity (N.H.W.L.) $10^6 m^3$	Effective Capacity $10^6 m^3$	Firm Discharge m³/sec	Flood Control Capacity $10^6 m^3$	Dam Type	Height x Crest Length m x m	Volume $10^3 m^3$	Design Flood Discharge m³/sec	Waterway Tunnel for Power D x L m x m	Powerstation Rated Head m	Max. Discharge m³/sec	Installed Capacity kw	Ann. Energy Output 10^6 kwh
1-32	Bamseonggol	58 %	582.7	1,350	525.5	302	300	264	36	11.8	400.6	303	12.66	19.8	R.F.	88x303	2775	5,400	5.2x 2,200	103.6	61.26	54,900	116.3
2-23	Hupyeong (up)	60	305	1,360	275.1	568.4	566.4	521.6	44.8	6.7	180,4	165,1	6.70	14.0	R.F.	88.4x327	2,960	3,830	4.1x11,500	195.2	32.4	54,700	118.5
3-22	Inje (up)	100	1,043.3	1,340	941	346	344	300.6	43.4	31	1,300	941	26.31	67.8	R.F.	125x362	5,206	7,200	6.9x 5,200	130.6	127.73	144,300	277.6
4-30	Weolhak	31	563.4	1,280	497.5	302	300	278.4	21.6	9.8	254	154.7	9.05	20.9	R.F.	81x357	3,330	5,310	———	63.4	43.95	24,100	64.8
5-A3	Hongcheon	60	1,473	1,430	1,333.2	123.5	120	99.3	20.7	49	1,314	799.3	30.40	202.5* (190.0)	C.G.	85x351	700	8,460	———	60.6	147.85	77,500	182.0
6-3	Gujeol (up)	60	100.8	1,210	83.9	744.5	742.5	717.9	24.6	4	57	50.3	2.03	9.0	R.F.	54.5x193	790	1,870	2.6x14,300	315.4	9.9	27,000	60.2
7-9	Pyeongchang	100	485.3	1,330	408.6	422	420	388.6	31.4	16.9	598.8	408.6	11.71	35.6	R.F.	102x424	5,570	4,570	5.1x 2,000	95.1	56.99	46,900	88.5
8-10	Panun	5	652	1,320	548.9	282	280	273.9	6.1	5.8	78.1	27.5	5.09	8.5	R.F.	48x285	1,090	5,310	3.7x 1,700	45.1	24.73	9,650	40.2
9-13	Suju	100	328.9	1,440	287.3	434	432	399	33	14.8	380	287.3	8.28	31.8	R.F.	107x483	6,300	3,720	4.5x 1,900	91.9	40.14	31,900	60.3
10-12	Dogog	33	492.6	1,420	430.3	327	325	301.5	23.5	8.3	213.3	141.5	9.16	16.2	R.F.	70x415	3,000	4,610	———	59.8	44.26	22,900	58.4
11-A1	Dalcheon	40	1,348	1,220	1,054.2	119.8	115.8	102.9	12.9	48.5	710	421.7	14.39	185.4* (138.5)	C.G.	56.8x313	300	6,980	———	37.3	71.52	23,100	66.7
12-A2	Ganhyeon	35	1,180	1,420	1,068	115.3	111.4	99.6	11.8	39	673	374	14.45	162.2* (130.7)	C.G.	48.4x264	192	7,670	———	34.7	70.98	21,300	63.6
13-35	Bonghwa	100	1,105	1,020	655.1	305.8	303.8	269.6	34.2	29.3	1,015	655.1	17.74	53.4	R.F.	128.8x302	5,920	6,360	———	100.4	86.62	75,200	149.4
14-43	Imha	100	1,230	1,040	729.2	193.5	192	169.8	22.2	48.8	1,055	729.2	19.60	84.9* (107.4)	R.F.	83x376	3,020	6,700	———	65	96.34	54,200	107.1
15-36	Chibo (down)	32	4,550	1,040	2,439	91.0	87.7	77.6	10.1	73.3	900	776	58.68	314.0* (380)	C.G.	48.7x579	476	11,780	———	29.6	285.41	73,100	164.8
16-51	Hamyang (up)	80	264	1,400	251.4	382.5	380.5	328.2	52.3	6.1	218	201.1	6.83	13.0	R.F.	95.5x402	3,780	3,290	4.1x 8,400	190.7	33.03	54,500	109.8
17-53	Dogsan	80	231	1,550	230.9	160.4	158.4	130.4	28	9.2	244	184.7	6.26	17.0	R.F.	77.4x371	2,880	3,280	4x 3,200	78.6	30.31	20,600	45.2
18-62	Yongdam	100	949	1,340	766.1	271.7	269.7	248.8	20.9	48.8	1,220	766.1	20.77	86.1	R.F.	79.7x465	3,460	5,920	———	61.3	101.53	53,800	106.5
19-63	Sutong	20	1,526	1,310	1,174.2	202	200	185	15	20.9	379	232.3	18.73	48.9	R.F.	62x246	1,580	7,390	———	44	90.69	34,500	105.4
20-64	Myeongcheon	34	2,003	1,260	1,503.4	152	150	136.5	13.5	53.5	910	507	28.42	105.6	R.F.	61x314	1,800	8,350	———	40	138.59	47,400	130.1
21-69	Simcheon	100	640.3	1,160	462.4	172.7	170.7	151	19.7	34.7	715	462.4	12.42	55.4	R.F.	76.7x327	2,810	4,870	———	57.8	61.25	30,600	60.2
22-77	Jeokseong	80	1,004 /1	1,390	187	135	133	116.2	16.8	13.7	240	149.6	5.01	27.0	R.F.	66x389	2,320	6,580	———	49.2	24.45	10,400	21
23-82	Juam	100	1,010 /2	1,410	709.3	126.5	124.5	106	18.5	61.3	1,100	709.3	19.79	124.5	R.F.	76.5x424	3,070	6,590	———	54	97.34	45,500	86.4
24-A4	Boseonggang (up)	40	457 /2	1,410	175.6	121	119	112.1	6.9	13.6	100.5	70.2	3.08	30.5	R.F.	25x239	270	4,430	———	20	18.30	3,170	7.9

Remarks: 1. Flood control capacity with asterisk is calculated based on equivalent rainfall
2. Dam type R.F. : Rockfill
C.G. : Concrete gravity

/1 Includes the catchment area, 763 km², of the Seoumjingan dam.
/2 Includes the catchment area, 275 km², of the No. 1 Boseonggang dam.

Table 5-2 Construction Cost of Long-Term Multipurpose Dams

Unit : 10^6 Won

	Name of Dam	V_E/Q_Y	Cost of Dam & Reservoir											Total Cost	Cost of Powerstation								Grand Total Cost
			Compen-sation	General Expense	Contin-gency	Interest during Const.	Sub-Total	Dam includ. Spillway	Prepara-tory	General Expense	Contin-gency	Interest during Const.	Sub-Total		Waterway includ. Regulating Pond	Power-station	Generating Facilities includ. Trans-mission	Prepa-ratory	General Expense	Contin-gency	Interest during Const.	Sub-Total	
1-32	Bamseonggol(up)	58%	3,900	468	874	503	5,745	7,903	79	958	1,788	1,030	11,758	17,503	1,861	391	5,240	21	902	1,683	969	11,067	28,570
2-23	Hupyeong (up)	60	1,800	216	403	232	2,651	7,725	77	936	1,748	1,007	11,493	14,144	4,891	315	6,038	51	1,355	2,530	1,457	16,637	30,781
3-22	Inje (up)	100	8,270	992	1,852	1,423	12,537	13,775	138	1,670	3,117	2,394	21,094	33,631	6,408	851	10,406	70	2,128	3,973	3,051	26,887	60,518
4-30	Weolhak	31	5,750	690	1,288	742	8,470	8,570	86	1,039	1,959	1,128	12,782	21,252	269	227	4,468	4	596	1,113	641	7,318	28,570
5-A3	Hongcheon	60	12,720	1,526	2,849	1,641	18,736	15,850	158	1,921	3,586	2,065	23,580	42,316	756	616	9,418	11	1,324	2,471	1,423	16,248	58,564
6-3	Gujeol (up)	60	3,170	380	710	545	4,805	2,585	26	311	584	449	3,955	8,760	2,648	146	3,342	27	740	1,381	1,060	9,344	18,104
7-9	Pyeongchang	100	8,350	1,002	1,870	1,077	12,299	12,552	126	1,521	2,840	1,636	18,675	30,974	1,840	363	5,053	21	873	1,630	939	10,719	41,693
8-10	Panun	5	3,790	455	849	489	5,583	3,900	39	473	882	508	5,802	11,385	730	118	2,672	8	423	790	455	5,196	16,581
9-13	Suju	100	4,000	480	896	688	6,064	13,556	136	1,643	3,067	2,355	20,757	26,821	1,198	255	4,037	13	660	1,233	947	8,343	35,164
10-12	Dogog	33	2,500	300	560	323	3,683	7,530	75	913	1,704	981	11,203	14,886	516	220	4,318	6	607	1,133	653	7,453	22,339
11-A1	Dalcheon	40	12,250	1,470	2,744	1,580	18,044	7,980	80	967	1,850	1,040	11,872	29,916	313	276	6,150	5	809	1,511	870	9,934	39,850
12-A2	Ganhyeon	35	9,380	1,126	2,101	1,210	13,817	4,460	45	541	1,009	581	6,636	20,453	1,347* 278	247	6,936	4	896	1,672	963	12,343	32,796
13-35	Bonghwa	100	3,610	433	809	621	5,473	14,526	145	1,761	3,286	2,524	22,242	27,715	747	522	6,832	11	973	1,817	1,395	12,297	40,012
14-43	Imha	100	13,400	1,608	3,002	1,729	19,739	8,663	87	1,050	1,960	1,129	12,889	32,628	1,175* 506	453	6,893	8	943	1,761	1,014	12,753	45,381
15-36	Chibo (down)	32	34,100	4,092	7,638	4,400	50,230	10,100	101	1,224	2,285	1,316	15,026	65,256	1,747* 986	778	15,604	15	2,086	3,894	2,242	27,352	92,608
16-51	Hamyang (up)	80	4,500	540	1,008	774	6,822	8,960	90	1,086	2,027	1,557	13,720	20,542	3,821	317	5,757	40	1,192	2,225	1,709	15,061	35,603
17-53	Dogsan	80	5,580	670	1,250	720	8,220	7,040	70	853	1,593	917	10,473	18,693	1,454	185	3,260	15	590	1,101	634	7,239	25,932
18-62	Yongdam	100	16,600	1,992	3,718	2,142	24,452	9,066	91	1,099	2,051	1,181	13,488	37,940	1,457	460	8,136	17	1,208	2,256	1,299	14,833	52,773
19-63	Sutong	20	8,050	966	1,803	1,039	11,858	5,703	57	691	1,290	743	8,484	20,342	375	350	7,372	6	972	1,815	1,045	11,935	32,277
20-64	Myeongcheon	34	20,680	2,482	4,632	2,668	30,462	6,330	63	767	1,432	825	9,417	39,879	518	477	10,461	8	1,376	2,568	1,479	16,887	56,766
21-69	Simcheon	100	17,680	2,122	3,960	2,281	26,043	7,667	77	929	1,735	999	11,407	37,450	572	292	5,660	7	784	1,463	843	9,621	47,071
22-77	Jeokseong	80	6,260	751	1,402	808	9,221	6,935	69	840	1,569	904	10,317	19,538	310	121	2,724	4	379	708	408	4,654	24,192
23-82	Juam	100	32,100	3,852	7,190	4,142	47,284	8,674	87	1,051	1,962	1,130	12,904	60,188	984	405	7,792	12	1,103	2,059	1,186	13,541	73,729
24-A4	Boseonggang(up)	40	5,560	667	1,245	478	7,950	1,753	18	213	397	152	2,533	10,483	224	63	1,922	2	265	495	190	3,161	13,644

* Cost of regulating pond

6. COMPARATIVE STUDY OF MULTIPURPOSE DAM SCHEMES

6. COMPARATIVE STUDY OF MULTIPURPOSE DAM SCHEMES

Annual benefits and benefit-cost analysis of the 24 multipurpose dam schemes are tabulated in Tables 6-1 and 6-2, which indicate some index for economic comparison. Based on the result of the study and consideration on urgency of development of water resources of the respective basins, ten schemes mentioned in the Summary and Conclusion are derived.

Table 6-1 Annual Benefit of Long-Term Multipurpose Dams

Name of Dam		V_E/Q_Y	Power & Energy Benefit					Benefit of Water Supply					Benefit of Flood Control			Total Benefit
			Installed Capacity	Ann. Energy Output	kW Benefit	kWh Benefit	Annual Benefit	Increment of Ann. Suppliable Water	Decrease due to Existing Dam	Net Increment	Unit Benefit	Ann. Benefit	Surcharge Depth	Surcharge Capacity	Ann. Benefit	
			Pi kW	10^6 kWh/y	10^6W @38820	10^6W @9.475	10^6W	$10^6m^3/y$	$10^6m^3/y$	$10^6m^3/y$	W/m^3	10^6W	m	10^6m^3	10^6W	10^6W
1-32	Bamseonggol(up)	58%	54,900	116.3	1,870	1,144	3,014	326.0	-3.4	322.6	8.56	2,761	2.0	19.8	88	5,863
2-23	Hupyeong(up)	60	54,700	118.5	1,945	1,138	3,083	173.1	-144.4	28.7	8.56	246	2.0	14.0	45	3,374
3-22	Inje(up)	100	144,300	277.6	4,944	2,809	7,753	699.1	-539.6	159.5	8.56	1,365	2.0	67.8	66	9,184
4-30	Weolhak	31	24,100	64.8	823	635	1,458	216.3	-190	26.3	8.56	225	2.0	20.9	74	1,757
5-A3	Hongcheon	60	77,500	182.0	2,646	2,096	4,742	798.5	—	798.5	8.56	6,835	3.5	202.5* (190.0)	2,158 (131)	13,735 (11,708)
6-3	Gujeol(up)	60	27,000	60.2	1,012	571	1,583	52.5	-23.4	29.1	8.56	249	2.0	9.0	78	1,910
7-9	Pyeongchang	100	46,900	88.5	1,608	890	2,498	314.3	-112.4	201.9	8.56	1,728	2.0	35.6	84	4,310
8-10	Panun	5	9,650	40.2	355	389	744	87.1	-72.4	14.7	8.56	126	2.0	8.5	29	899
9-13	Suju	100	31,900	60.3	1,082	580	1,662	222.1	-79.2	142.9	8.56	1,223	2.0	31.8	35	2,920
10-12	Dogog	33	22,900	58.4	767	562	1,329	231.0	-148.1	82.9	8.56	710	2.0	16.2	45	2,084
11-A1	Dalcheon	40	23,100	66.7	787	706	1,493	403.5	—	403.5	8.56	3,454	4.0	185.4* (138.5)	1,868 (107)	6,815 (5,054)
12-A2	Ganhyeon	35	21,300	63.6	727	674	1,401	405.7	—	405.7	8.56	3,473	3.9	162.3* (130.7)	1,260 (34)	6,134 (4,908)
13-35	Bonghwa	100	75,200	149.4	2,568	1,555	4,123	535.1	-395.8	139.3	6.52	908	2.0	53.4	35	5,066
14-43	Imha	100	54,200	107.1	1,851	1,014	2,865	590.9	—	590.9	6.52	3,853	1.5	84.9* (107.4)	1,915 (61)	8,633 (6,779)
15-36	Chibo(down)	32	73,100	164.8	2,498	1,561	4,059	965.7	—	965.7	6.52	6,296	3.3	314.0* (380.0)	4,527 (141)	14,882 (10,496)
16-51	Hamyang(up)	80	54,500	109.8	1,907	1,072	2,979	184.4	—	184.4	6.52	1,202	2.0	13.0	36	4,217
17-53	Dogsan	80	20,600	45.2	699	458	1,157	169.0	—	169.0	6.52	1,102	2.0	17.0	57	2,316
18-62	Yongdam	100	53,800	106.5	1,838	1,107	2,945	550.5	-54.6	495.9	5.85	2,901	2.0	86.1	48	5,894
19-63	Sutong	20	34,500	105.4	1,178	1,033	2,211	430.6	-123.6	307.0	5.85	1,796	2.0	48.9	28	4,035
20-64	Myeongcheon	34	47,400	130.1	1,618	1,332	2,950	691.5	-21.5	670.0	5.85	3,920	2.0	105.6	46	6,916
21-69	Simcheon	100	30,600	60.2	1,045	600	1,645	328.7	-33.4	295.3	5.85	1,728	2.0	55.4	74	3,447
22-77	Jeokseong	80	10,400	21	355	199	554	134.4	—	134.4	9.03	1,214	2.0	27.0	55	1,823
23-82	Juam	100	45,500	86.4	1,553	819	2,372	534.4	—	534.4	9.03	4,826	2.0	124.5	131	7,329
24-A4	Boseonggang(up)	40	3,170	7.9	108	75	183	94.0	—	94.0	9.03	849	2.0	30.5	47	1,079
	Total		1,067,220	2,345.3												

Remarks: Figures with asterisk in surcharge capacity is calculated based on equivalent rainfall

Table 6-2 Benefit Cost Analysis of Long-Term Multipurpose Dams

Unit : 10^6 Won

	Name of Dam	V_E/Q_Y (up)	Dam & Reservoir						Power Facilities				Ann. Cost	Benefit										
														Power			Power & Water Supply				Power, Water Supply & Flood Control			
			Compen-sation Cost	Const. Cost	Total	Ann. Capital Cost (3)x 0.08174	OMR (2)x 0.005	Total Cost	Const. Cost	Ann. Capital Cost (7)x 0.08174	OMR (7)x 0.025	Total Cost	C	Benefit	B/C	B-C	Benefit of Water Supply	Sub-Total B	B/C	B-C	Benefit of Flood Control	Sub-Total B	B/C	B-C
			(1)	(2)	(3) =(1)+(2)	(4)	(5)	(6) =(4)+(5)	(7)	(8)	(9)	(10) =(8)+(9)	(11) =(6)+(10)	(12)	(13) =(12)/(11)	(14) =(12)-(11)	(15)	(16) =(12)+(15)	(17) =(16)/(11)	(18) =(16)-(11)	(19)	(20) =(12)+(15)+(19)	(21) =(20)/(11)	(22) =(20)-(11)
1-32	Bamseonggol	58%	5,745	11,758	17,503	1,431	59	1,490	11,067	904	277	1,181	2,671	3,014	1.13	343	2,761	5,775	2.16	3,104	88	5,863	2.20	3,192
2-23	Hupyeong(up)	60	2,651	11,493	14,144	1,156	57	1,213	16,637	1,360	416	1,776	2,989	3,083	1.03	94	246	3,329	1.11	340	45	3,374	1.13	385
3-22	Inje (up)	100	12,537	21,094	33,631	2,749	105	2,854	26,887	2,198	672	2,870	5,724	7,754	1.35	2,030	1,365	9,119	1.59	3,395	66	9,185	1.60	3,461
4-30	Weolhak	31	8,470	12,782	21,252	1,737	64	1,801	7,318	598	183	781	2,582	1,458	0.56	-1,124	225	1,683	0.65	-899	74	1,757	0.68	-825
5-A3	Hongcheon	60	18,736	23,580	42,316	3,459	118	3,577	16,248	1,328	406	1,734	5,311	4,742	0.89	-569	6,835	11,577	2.18	6,266	(131) 2,158	(11,708) 13,735	(2.20) 2.59	(6,397) 8,424
6-3	Gujeol(up)	60	4,805	3,955	8,760	716	20	736	9,344	764	233	997	1,733	1,583	0.91	-150	249	1,832	1.06	99	78	1,910	1.10	177
7-9	Pyeongchang	100	12,299	18,675	30,974	2,532	93	2,625	10,719	876	268	1,144	3,769	2,498	0.66	-1,271	1,728	4,226	1.12	457	84	4,310	1.14	541
8-10	Panun	6	5,583	5,802	11,385	931	29	960	5,196	425	130	555	1,515	744	0.49	-771	126	870	0.57	-645	29	899	0.59	-616
9-13	Suju	100	6,064	20,757	26,821	2,192	104	2,296	8,343	682	209	891	3,187	1,662	0.52	-1,525	1,223	2,885	0.90	-302	35	2,920	0.92	-267
10-12	Dogog	33	3,683	11,203	14,886	1,217	56	1,273	7,453	609	187	796	2,069	1,329	0.64	-740	710	2,039	0.98	-30	45	2,084	1.01	15
11-A1	Dalcheon	40	18,044	11,872	29,916	2,445	60	2,505	9,934	812	248	1,060	3,565	1,493	0.42	-2,072	3,454	4,947	1.39	1,382	(107) 1,868	(5,054) 6,615	(1.42) 1.91	(1,489) 3,250
12-A2	Ganhyeon	35	13,817	6,636	20,453	1,672	33	1,705	12,343	1,009	308	1,317	3,022	1,401	0.46	-1,621	3,473	4,874	1.61	1,852	(34) 1,260	(4,908) 6,134	(1.62) 2.03	(1,886) 3,112
13-35	Bonghwa	100	5,473	22,242	27,715	2,266	111	2,377	12,297	1,005	308	1,313	3,690	4,123	1.12	433	908	5,031	1.36	1,341	35	5,066	1.37	1,376
14-43	Imha	100	19,739	12,889	32,628	2,667	65	2,732	12,753	1,042	319	1,361	4,093	2,865	0.70	-1,228	3,853	6,718	1.64	2,625	(61) 1,915	(6,779) 8,633	(1.66) 2.11	(2,686) 4,540
15-36	Chibo (down)	32	50,230	15,026	65,256	5,334	75	5,409	27,352	2,236	684	2,920	8,329	4,059	0.49	-4,270	6,296	10,355	1.24	2,026	(141) 4,527	(10,496) 14,882	(1.26) 1.79	(2,167) 6,553
16-51	Hamyang(up)	80	6,822	13,720	20,542	1,679	69	1,748	15,061	1,231	377	1,608	3,356	2,979	0.89	-377	1,202	4,181	1.24	825	36	4,217	1.26	861
17-53	Dogsan	80	8,220	10,473	18,693	1,528	52	1,580	7,239	592	181	773	2,353	1,157	0.49	-1,196	1,102	2,259	0.96	-94	57	2,316	0.98	-37
18-62	Yongdam	100	24,452	13,488	37,940	3,101	67	3,168	14,833	1,212	371	1,583	4,751	2,945	0.62	-1,806	2,901	5,846	1.23	1,095	48	5,894	1.24	1,143
19-63	Sutong	20	11,858	8,484	20,342	1,663	42	1,705	11,935	976	298	1,274	2,979	2,211	0.74	-768	1,796	4,007	1.34	1,028	28	4,035	1.35	1,056
20-64	Myeongcheon	34	30,462	9,417	39,879	3,260	47	3,307	16,887	1,381	422	1,803	5,110	2,950	0.58	-2,160	3,920	6,870	1.34	1,760	46	6,916	1.35	1,806
21-69	Simcheon	100	26,043	11,407	37,450	3,061	57	3,118	9,621	786	240	1,027	4,145	1,645	0.40	-2,500	1,728	3,373	0.81	-772	74	3,447	0.83	-698
22-77	Jeokseong	80	9,221	10,317	19,538	1,597	52	1,649	4,654	381	116	497	2,146	554	0.26	-1,592	1,214	1,768	0.82	-378	55	1,823	0.85	-323
23-82	Juam	100	47,284	12,904	60,188	4,920	65	4,985	13,541	1,107	338	1,445	6,430	2,372	0.37	-4,058	4,826	7,198	1.12	768	131	7,329	1.14	899
24-A4	Boseonggang (up)	40	7,950	2,533	10,483	857	13	870	3,161	258	79	337	1,207	183	0.15	-1,024	849	1,032	0.86	-175	47	1,079	0.89	-128

7. RECOMMENDATIONS

7. RECOMMENDATIONS

The scope of the second stage survey is as attached in the Annex 9.

The following data are needed for the second stage survey to increase the accuracy of survey for the 10 selected long-term multipurpose dam schemes.

(1) Topographical survey

a. All the plans (scale 1:1,000 to 1:5,000) are required for 10 dam sites (including alternative dam sites), excluding some already available.

b. The permanent B.M. at each dam site is required to be installed for all the dam sites above described, excluding some already installed.

c. The installation of center line logs along the provisional center line of dam is required.

d. For the sites where the head for power generation is to be obtained by a headrace or tailrace tunnel, the preparation of river profile is required based on field survey.

e. For the tunnel type power station, the plan (scale 1:1,000 to 1:5,000) along the provisional center line of penstock is to be prepared based on field survey.

f. The general plan in and around the power station (scale 1:1,000 to 1:5,000) is to be prepared by survey including the location of B.M.

The detailed scope of survey works will be determined based on the discussion made between the MOC and the second stage survey team.

(2) Compensation survey

a. Supplemental survey of compensation for the selected dam sites; the survey of large towns is to be made independently.

b. The survey of length of highway, main local road and railway to be submerged in the reservoir, if any.

c. The survey of market prices to estimate the increase of compensation cost.

(3) Geological survey

a. Drilling investigation

Three bore holes along dam axis are required, and their location and depth are shown on the geological map.

b. Permeability test

The survey of permeability coefficient or Lugeon's value by pressing pure water with hydrostatic pressure of about 1.5 times of water pressure caused by HWL for every 5 meters after reaching hard rock.

c. Seismic exploration

The seismic exploration is to be made in principle at each dam site.

The detailed scope of geological survey works is to be determined based on the discussion made between the MOC and survey team, taking into account of tepography and dam type.

(4) Hydrological survey

a. The arrangement of stage-discharge records at the gauging stations related to the proposed dam sites (including the periodical discharge measurement).

It is desirable, if possible, to install the self gauging station at each proposed dam site.

b. The records of reservoir water level, inflow and outflow, and operation of existing power station.

c. The records of water pumped-up at major pumping stations (for M & I and irrigation water supply use) in each basin.

d. The data on storm rainfall (daily and hourly) during flood period for each basin.

e. The data on stage and discharge during flood periods for major stage-discharge gauging stations.

f. The data on hourly stage and discharge of existing dams during flood periods.

g. The data on discharge and density of salty water observed at the lowest intake site of each river basin during drought period.

(5) Municipal and industrial water

a. The data on intake facilities of M & I water in big cities or industrial complexes in each basin and the records of water supply.

b. The data on public works planned during the Fourth Five-year Plan period. (mainly the location of intake, its facilities and design-intake-discharge).

c. The forecast of water demand and the development concept after the Fourth Five-year Plan.

(6) Irrigation water

a. Required data for irrigation development

a.1 The existing irrigation areas that are located along the rivers under investigation.

a.2 The irrigable areas along the rivers under investigation which are to be provided with water by the dams proposed in this survey.

a.3 The irrigable areas located in other basins which are to be provided with water by diversion from the dams proposed in this survey.

b. The above data should contain the following items, if possible.

b.1 Present conditions of irrigation and drainage (i.e. general conditions, irrigation & drainage system, command area, irrigation method, irrigation practice, water management, water rights, etc.)

b.2 Data on inventory of the facilities.

b.3 Current situation of land consolidation work (i.e. implemented hectareage, construction method & cost, on-farm arrangement, etc.)

b.4 Data on soil and land use.

b.5 Data on cropping pattern, cropyield, farming practice, agricultural mechanization, crop diversification,production cost, farm inputs & outputs, etc.

b.6 Data on farm economy.

(7) Flood control

a. Data related to flood damage

a.1 The records of inundation at the maximum floods for each basin (area, stage, duration, etc.), if possible.

a.2 The data on areas of habitual flood and attributable causes for each basin.

b. Data related to the present status of each river

b.1 The data on longitudinal and cross sections along the related area on the downstream of each river.

b.2 The data on discharge capacity of flood for each river.

b.3 The data on the observed flood discharges and flood traces for each river, if available.

c. Data related to the improvement of each river.