3. Examination of the Storage Dam Plans

Based on the data and information provided by DSİ and the results of field survey carried out by the JICA Study Team, the above mentioned storage dam plans, except the Kiraz dam, of which site is topographically not attractive, have been examined mainly based on the hydrological and topographical conditions, and the results of the examination are mentioned in Annex G and summarized below.

Items	Uladı	Ödemiş	Beydağ	Ergenli	Aktaş	Burgaz
Catchment area (km^2)	66.0	64.6	444.0	97.2	58.7	91.2
Dam type	earthfill	earthfill	earthfill	earthfill	earthfill	earthfill
Dam height (m)	83.0	25.0	95.0	93.0	80.5	115.0
Dam length (m)	505.0	840.0	788.5	805.0	271.0	415.0
Dam volume (MCM)	5.70	0.26	9.00	6.85	1.60	7.02
N. R. C. (MCM)	41.70	- 0.02	241.3	61.78	16.72	68.90
Net Irrigation Area (ha)	2,150	0	10,200	3,150	850	3,300

Name of Dam	Birgi	Bucak	Akyurt	Eğridere	Sarılar	Pirinçci
Catchment area (km^2)	12.6	18.0	24.2	21.8	30.9	51.3
Dam type *	earthfill	earthfill	facing type	earthfill	earthfill	earthfill
Dam height (m)	70.0	74.0	41.0	70.0	119.5	70.5
Dam length (m)	280.0	1,080	1,250	410	1,150	725.5
Dam volume (MCM)	2.10	5.60	1.38	2.44	17.80	3.44
N. R. C. (MCM)	0.42	9.20	8.48	2.16	30.01	5.23
Net Irrigation Area (ha)	20	330	300	80	1,000	180

(Note) : The net irrigation area was estimated for the cropping intensity of 140 %.
*: Selection of dam type is detailed in Paragraph (3) hereof.

The above-examined dam plans except the Ödemiş, Birgi and Eğridere dam plans, which have less storage capacities and are definitely less economical, have been further examined from the economic viewpoint as shown in Table G.1. According to the results shown in this table, five dam plans: Uladı, Beydağ, Ergenli, Aktaş and Burgaz dam plans, would be economically justifiable.

After knowing the economic viability of the dam plans, the following preliminary economic evaluations have been made for the irrigation projects which will use irrigation water to be released from the above five storage dams (Annex K).

Name of Project	Irrigation Area	Cost			Annual Net Benefit	EIRR-1	EIRR-2
		Construction	Replacement	Annual O&M			
	(ha)	(TL billion)	(TL billion)	(TL billion)	(TL billion)	(%)	(%)
Uladı	2,150	2,077.8	315.1	9.5	210.5	6.6	7.6
Beydağ	10,200	5,512.9	1,494.9	45.0	1,189.5	13.7	14.8
Ergenli	3,150	2,651.0	461.6	13.9	304.1	7.5	8.4
Aktaş	850	667.9	124.6	3.8	103.5	10.4	11.6
Burgaz	3,300	2,754.8	483.6	14.6	319.3	7.6	8.5

(Note): EIRR - 1 : In the case of surface water development only.
EIRR - 2 : In the case of conjunctive use of surface water and groundwater

According to the above table, the Beydağ Project shows the highest economic internal rate of return (EIRR), followed by the Aktaş, Ergenli Project or Burgaz Projects and lastly by the Uladı Project in case that the irrigation is made only by the surface water developed through the dam construction. The economic viability of these five projects has been assessed based on the criteria applied in the Irrigation Master Plan prepared by the World Bank (IBRD) in 1991, which defined that a project with EIRR of more than 8.0% would be economically feasible. As a result, it may be concluded that the Beydağ and Aktaş Projects are feasible, showing EIRR of 13.7% and 10.4%, respectively. For the irrigation development plan to be formulated under the present master plan study, however, it is intended to use both surface water and groundwater based on the concept of conjunctive use of these waters. Following this concept, EIRR was re-calculated for each project after adding the irrigation area to be irrigated by conjunctively using the surface water and groundwater, and the calculated results are shown also in the above table as EIRR-2. The results indicate that the four projects except the Uladı Project are economically justifiable under the present economic condition in Turkey.

Following the above study results, the four project areas of Beydağ, Aktaş, Ergenli and Burgaz will be taken up in this master plan study and further detailed study will be made below.

4. Selection of Dam Type

4.1 Conceivable Dam Types

The Küçük Menderes river basin is widely covered with erosive micaschist rocks. Due to this geological conditions, the river sections at most of dam sites are shaped by wider river beds and gently sloped abutments in both banks. Considering these topographical and geological conditions, the following 6 popular types of dams are studied for their construction.

(i) Earth Dam

From the topographical and geological viewpoints, there is no difficulty for the construction of earthfill dam in this river basin. The metamorphic rocks such as micaschists, phillite and mica-quartz schists, which are widely distributed around dam sites and also easily obtained from the various foundation excavations, are intended to be used as the main earthfill materials. Since these materials are relatively soft and poor durability, their engineering properties should be improved to the maximum practicable extent by compaction, moisture control and/or special processing, and will be used as the rolled earthfill.

The limiting factor for the construction of this dam type is only the poor availability of good impervious earth core materials. In this case, it should first be tried to find the decomposed terrigenous sediments of Neogene which is the mixture of clay, silt, sand and gravel with medium plasticity of good quality as impervious materials. In case of non-availability of such materials in the vicinity, the second solution should be to use the decomposed metamorphic soft rocks such as micaschist, mica-quartz schist and phyllite as the impervious material by accelerating further decomposition through stockpiling and moisture control, and designing a thick pervious core zone.

The decomposed soft rocks originally have little fines (clay and silt) with little or no plasticity, but it can be effectively used as an impervious core material as shown in the various examples shown in Table G.2, and the paper on "Development of New Core Material in Zone Fill Dam Use of Decomposed Granite in Andong Dam" prepared for the 12th Congress of Large Dam organized by the International Commission on Large Dams is attached hereto as Attachment for further detailed information.

In order to avoid pipings at the contact portions with the foundation, contact clay of miduum to high plasticity should be placed in the core trench for a thickness of about 1.0 m. Judging from the availability of the construction materials in this river basin, the center-cored zone type earthfill dam is recommendable as shown in Figure G.2.

(ii) Rockfill Dam

The topographical and geological conditions in the river basin as a whole allow the construction of this type of dam, but due to the non availability of suitable hard rock material within an economical distance, this type of dam would be very costly and not recommendable except the Beydag dam which is now in the stage of construction.

(iii) Concrete Dam

For the construction of concrete dams, the availability of concrete aggregates and the shearing strength of the foundation rock are the decisive factors. According to the geological map and the result of the reconnaissance survey conducted by JICA Study Team, there is no quarry site for coarse aggregates with a maximum size of 150 mm in the river basin. Moreover, the shearing strength of the foundation rock is estimated at 10 ~ 15 kg/cm^2 at most dam sites, though dams with a height of 50 m require a shearing strength of 15 kg/cm^2 and those with a height of 100 m require a strength of 28 kg/cm^2. Based on these required conditions, the type is considered not suitable for all the proposed dam sites.

(iv) Roller Compacted Concrete (RCC) Dam

For the same reason as mentioned for the concrete dam type, the adoption of RCD type is also not recommendable for all the proposed dam sites.

(v) Concrete/Asphalt Facing Type Dam

Concrete/sphalt facing is usually provided on the upstream face of rockfill dam to prevent seepage through the dam body. If concrete/asphalt facing is placed on earthfill dam, it will be damaged, because the dam embankment may deform and settled due to water pressure in the reservoir and its own weight. Since the rockfill dam type is not proposed as mentioned above, this concrete/asphalt facing type dam is out of consideration.

(vi) Asphalt Center-cored Fill Dam

In case that good impervious core materials are not available within an economical distance, asphalt concrete is used as the internal core material, though there are not many instances of high dams for the reason that the maintenance method has not been well established. Table G.3 shows the lsit of the asphalt center-cored fill dams in the world.

The typical cross section of asphalt center-cored fill dam is illustrated in Figure G.2. This core material consists of 6.0 % of asphalt, 11.9% of filler, 29.2 % of fine aggregates, and 52.9 % of coarse aggregates.

4.2 Conclusion

As explained above, the dam types applicable to this river basin would be the earthfill type and the asphalt center-cored fill type. A comparison of the construction cost has been made between these two types, taking the example of the Burgaz dam. The estimated results are as shown in Table G.4 and summarized below.

(i) Earthfill dam with micaschist core zone

- Impervious zone	TL 244,353 million
- Semi-pervious zones	TL 1,095,116 million
- Contact clay	TL 1,534 million
- Filter	TL 22,780 million
- Drain	TL 3,619 million
- Riprap	TL 23,741 million
Total	TL 1,391,143 million

(ii) Asphalt center-cored Fill Dam

- Impervious zone	TL 224,762 million
- Semi-pervious zones	TL 1,239,233 million
- Filter	TL 22,780 million
- Drain	TL 4,976 million
- Riprap	TL 23,741 million
Total	TL 1,515,492 million

The result of the cost comparison showed that, the construction cost for the asphalt center cored fill dam is slightly higher than that of the earthfill dam with micaschist core zone. Moreover, considering the difficulty of quality control and future repair in the case of the asphalt cored type, the micaschist cored type is recommended to be adopted for the Küçük Menderes river basin.

Table-G.1 Examination of Respective Dam Development Plans

Name of Dam	Dam Embankment Volume (m3)	Net Reservoir Capacity		Construction Cost		Engineering Remarks	Judgement
		Total (m3)	per m3 of D.E.V. (m3)	Total (TL billion)	per 1m3 of N.R.C. (TL)		
Uladı	5,700,000	41,700,000	7.32	1654.0	39,664	The slope stability of right bank side, just upstream of the dam site, and hydrological properties of the arete at the right abutment should be investigated.	Economically justifiable
Beydağ	9,000,000	241,300,000	26.81	3165.0	13,116	The cut-off treatment and workability of very thick alluvial deposit should be studied.	Economically justifiable
Ergenli	6,850,000	61,780,000	9.02	1962.0	31,758	The treatment of the hot spring located at the dam site should be studied.	Economically justifiable
Aktaş	1,600,000	16,720,000	10.45	482.0	28,828	Bearing strength and permeability of the sediments distributed in the left bank side should be checked.	Econimically justifiable
Burgaz	7,020,000	68,900,000	9.81	2001.0	29,042		Economically justifiable
Bucak	5,600,000	9,200,000	1.64	1451.4	157,761	The construction of the cut-off will be difficult because of fan deposit. Furthermore, there will occur a plenty of sedimentation from the erosion and transportation of fan deposit.	Econimically not justifiable
Akyurt	1,380,000	8,480,000	6.14	1039.7	122,606	A detailed investigation will be required fto check the existence of caverties in lime stone. In addition, hydrological properties of the arete of right abutment should be investigated.	Economically not justifiable
Sarılar	17,800,000	30,000,000	1.69	4592.7	153,090	The existence of hard rock basement at river bed should be confirmed.	Economically not justifiable
Prinçci	3,440,000	5,230,000	1.52	891.7	170,497		Economically not justifiable

Table-G.2 List of Fill Type Dams with Core Material of Non-Plasticity to Low Plasticity Material and Decomposed Rock in Japan

Name of Dam	Year of Completion	Location (Prefecture)	Dam Height (m)	Crest Length (m)	Volume Content (1000 m³)	Type of Material	Soil Classi-fication	Plasticity Index (%)
Hirose	1974	Yamanashi	75.0	255.0	1,400	Decomposed Granite	SM, ML	N.P
Fukuji	1974	Okinawa	91.7	260.0	1,622	-	CL~ML ML~SM	7~15
Taisetsu	1975	Hokkaido	86.5	440.0	3,875	Andesite origin deposits	Se	10
Nabaru	1976	Hiroshima	85.5	305.0	2,213	Decomposed Granite	SM, ML	N.P.
Myojin	1976	Hiroshima	88.5	402.0	3,268	Decomposed Granite	SM, ML	N.P.
Seto	1978	Nara	110.5	342.8	3,740	Decomposed Shale & Sandstone	-	-
Terauchi	1979	Fukuoka	83.0	420.0	3,000	-	SC, SM	9~14
Takase	1979	Nagano	176.0	362.0	11,590	Decomposed Granite & Mudflow	-	N.P.
Izarigawa	1980	Hokkaido	45.5	270.0	647	-	SM	N.P.
Inamura	1982	Kochi	88.0	352.0	3,100	Decomposed Greenschist	GM	11~13
Shitoki	1983	Fukushima	83.5	300.0	2,512	Decomposed Crystalline schist	-	-
Tokachi	1984	Hokkaido	84.3	443.0	3,715	Decomposed slate	SM	11.8
Itsuwa	1985	Kumamoto	37.1	173.0	223	Decomposed Shale & Sandstone	MH~SC	-
Tenzan	1986	Saga	69.0	380.0	1,640	Decomposed Crystalline schist	-	-

Table-G.3 List of Asphalt Center-Cored Dams in the World

Name of Dams	Year of Constriction	Country	Storage Volume (mil. m³)	Dam Height (m)	Slope of Asphalt Core	Thickness of Asphalt Core (cm)
Vale de Gelo	1949	Portugal	63.0	45.0	1 : 0.75	100 - 110
Henne	1954/55	W. Germany	39.0	58.0	1 : 0.6	100
Kleine Dhunn	1961/62	W. Germany	7.3	35.0	1 : 0	70 / 60 / 50
Bigge	1961/63	W. Germany	172.0	52.0	1 : 0.58	100
Lastioulles	1970	France	12.0	30.0	-	100
Wiehl	1969/71	W. Germany	31.5	53.0	1 : 0	60 / 50 / 40
High Island West Dam	73/77	Hongkong	273.0	96.0	1 : 0 1 : 0.235	120 / 80 60 (double core)
High Island East Dam	73/78	Hongkong	273.0	105.0	1 : 0 1 : 0.235	120 / 80 60 (double core)
Laguna de los Cristales	1978/77	Chile		31.0	1 : 0	60
Wehobach	1978	W. Germany		53.0	1 : 0	100
Finstertal	78/80	Austria	60.0	100.0 max135	1 : 0.4	70 / 80 / 60
Wegget	1979/80	U.K.	67.0	56.0	1 : 1	70 / 80
Kleine Kinzig	1978/81	W. Germany		68.0	1 : 0	70 / 50
Große Dhunn-Talsperre	1979/80	W. Germany	75.0	63.0	1 : 0 1 : 0.25	60
Sulby	1979/80	U.K.		36,0	1 : 0	76
Pla de Soulcco	1980	France	29.0	67.0 core10	1 : 0	60
Vestredals-Damm	1980	Norway	37.0	32.0	1 : 0	50
Katlavatn-Damm	1980	Norway	10.0	35.0	1 : 0	50
Kleine Kinzig	1981/82	W. Germany	13.0	70.0	1 : 0	70 / 50
Storvatn	1985/87	Norway		90.0	1 : 0.2	80 / 50
Dorpe-Vordamm/Wupper	1985	W. Germany	10.6	16.2	1 : 0	60
Wupper	1986	W. Germany	25.9	39	1 : 0 1 : 0.25	60 40(double core)
Rottach	1987/88	W. Germany	25.0	38.0	1 : 0	60
Doguchanskaya	1988	U.S.S.R.		79.0	1 : 0	120 / 60
Telnanskaya	1988	U.S.S.R.		140.0	1 : 0	140 / 50
Irganalskaya	1988	U.S.S.R.		100.0	1 : 0	130 / 60
Queen's Valley	1989/90	U.K.		34.0		60
Feistritz	1989/90	Austria	16.2	88.0	1 : 0	70 / 60 / 50
Hintermuhr	1990/91	Austria	14.2	40.0	1 : 0	70 / 60
Schnalwesser	1991/92	E. Germany	210.0	74.0	1 : 0.1	60

Table G.4 Construction Cost by Dam Type (1/2)

(Earthfill Dam with Micaschist Core Zone)

	Unit	Quantity	Price (TL/unit)	Cost (TL million)	Remarks
1. Mica Schist for Impevious Zone					
(1) Excavation of Mica Shist	cu. m	832,600	75,564	62,915	
(2) Transportation to Stockyard	cu. m	999,120	86,148	86,072	Volume = (1) x 1.20
(3) Transportation to Dam Site	cu. m	999,120	86,148	86,072	Volume = (1) x 1.20
(4) Filling and Compaction	cu. m	999,120	9,302	9,294	102.3 cu. m/hr.
Sub-total				244,353	
2. Material for Semi-pervious Zones					
(1) Excavation of Material	cu. m	6,174,000	75,564	466,532	
(2) Transportation to Dam Site	cu. m	6,791,400	86,148	585,066	Volume = (1) x 1.10
(3) Filling and Compaction	cu. m	6,791,400	6,408	43,518	148.5 cu.m/hr.
Sub-total				1,095,116	
3. Contact Clay					
(1) Excavation of Material	cu. m	13,000	25,337	329	
(2) Transportation to Dam Site	cu. m	13,000	86,148	1,120	
(3) Compaction	cu. m	13,000	6,537	85	102.3 cu. m/hr.
Sub-total				1,534	
4. Filter (t = 3.0 m x 2, A = 32,650 sq. m)					
(1) Excavation of Material	cu. m	195,900	25,337	4,964	
(2) Transportation to Dam Site	cu. m	205,695	86,148	17,720	Volume =(1) x 1.05
(3) Compaction	cu. m	205,695	468	96	102.3 cu. m/hr.
Sub-total				22,780	
5. Drain (Lu = 80 m, Ld = 80 m, n = 12 nos. A = 15.63 sq. m)					
(1) Excavation of Material	cu. m	30,010	25,337	760	
(2) Transportation to Dam Site	cu. m	33,011	86,148	2,844	Volume = (1) x 1.10
(3) Compaction	cu. m	33,011	468	15	102.3 cu. m/hr.
Sub-total				3,619	
6. Riprap (t = 2.5 m, A = 32,650 sq. m)					
(1) Excavation of Material	cu. m	81,625	25,337	2,068	
(2) Transportation to Dam Site	cu. m	85,706	86,148	7,383	Volume = (1) x 1.05
(3) Spreading	cu. m	85,706	166,731	14,290	102.3 cu. m/hr.
Sub-total				23,741	
7. Grand Total				1,391,143	
(US$ equivalent				$27,823 x 1,000)	

Table G.4 Construction Cost by Dam Type (2/2)

(Asphalt Center Cored Fill Dam)

	Unit	Quantity	Price (TL/unit)	Cost (TL million)	Remarks
1. Core Material for Impervious Zone					
(1) Asphalt Cement	cu. m	19,600	10,208,960	200,096	2.44 ton/cu. m
(2) Transportation to Dam Site	cu. m	19,600	800,549	15,691	Volume = (1) x 1.05
(3) Filling (Compaction by Machine)	cu. m	19,600	21,383	419	44.5 cu. m/hr
(4) Filling (Compaction by Manual)	cu. m	19,600	68,681	1,346	
(5) Base Concrete	cu. m	6,700	990,000	6,633	
(5) Transportation of concrete to Dam Site	cu. m	6,700	86,148	577	
Sub-total				224,762	
2. Material for Semi-pervious Zones					
(1) Excavation fo Material	cu. m	6,986,500	75,564	527,928	
(2) Transportation to Dam Site	cu. m	7,685,150	86,148	662,060	Volume = (1) x 1.10
(3) Filling & Compaction	cu. m	7,685,150	6,408	49,245	148.5 cu. m/hr
Sub-total				1,239,233	
3. Filter (t = 3.0 m x 2, A = 32,650 sq. m)					
(1) Excavation of Material	cu. m	195,900	25,337	4,964	
(2) Transportation to Dam Site	cu. m	205,695	86,148	17,720	Volume = (1) x 1.05
(3) Compaction	cu. m	205,695	468	96	102.3 cu. m/hr.
Sub-total				22,780	
4. Drain (Lu = 110 m, Ld = 110 m, n = 12 nos. A = 15.63 sq. m)					
(1) Excavation of Material	cu. m	41,263	25,337	1,045	
(2) Transportation to Dam Site	cu. m	45,389	86,148	3,910	Volume = (1) x 1.10
(3) Compaction	cu. m	45,389	468	21	102.3 cu. m/hr.
Sub-total				4,976	
5. Riprap (t = 2.5 m, A = 32,650 sq. m)					
(1) Excavation of Material	cu. m	81,625	25,337	2,068	
(2) Transportation to Dam Site	cu. m	85,706	86,148	7,383	Volume = (1) x 1.05
(3) Spreading	cu. m	85,706	166,731	14,290	
Sub-total				23,741	
6. Grand Total				1,515,492	
(US$ equivalent				$30,310 x 1,000)	

FIGURES

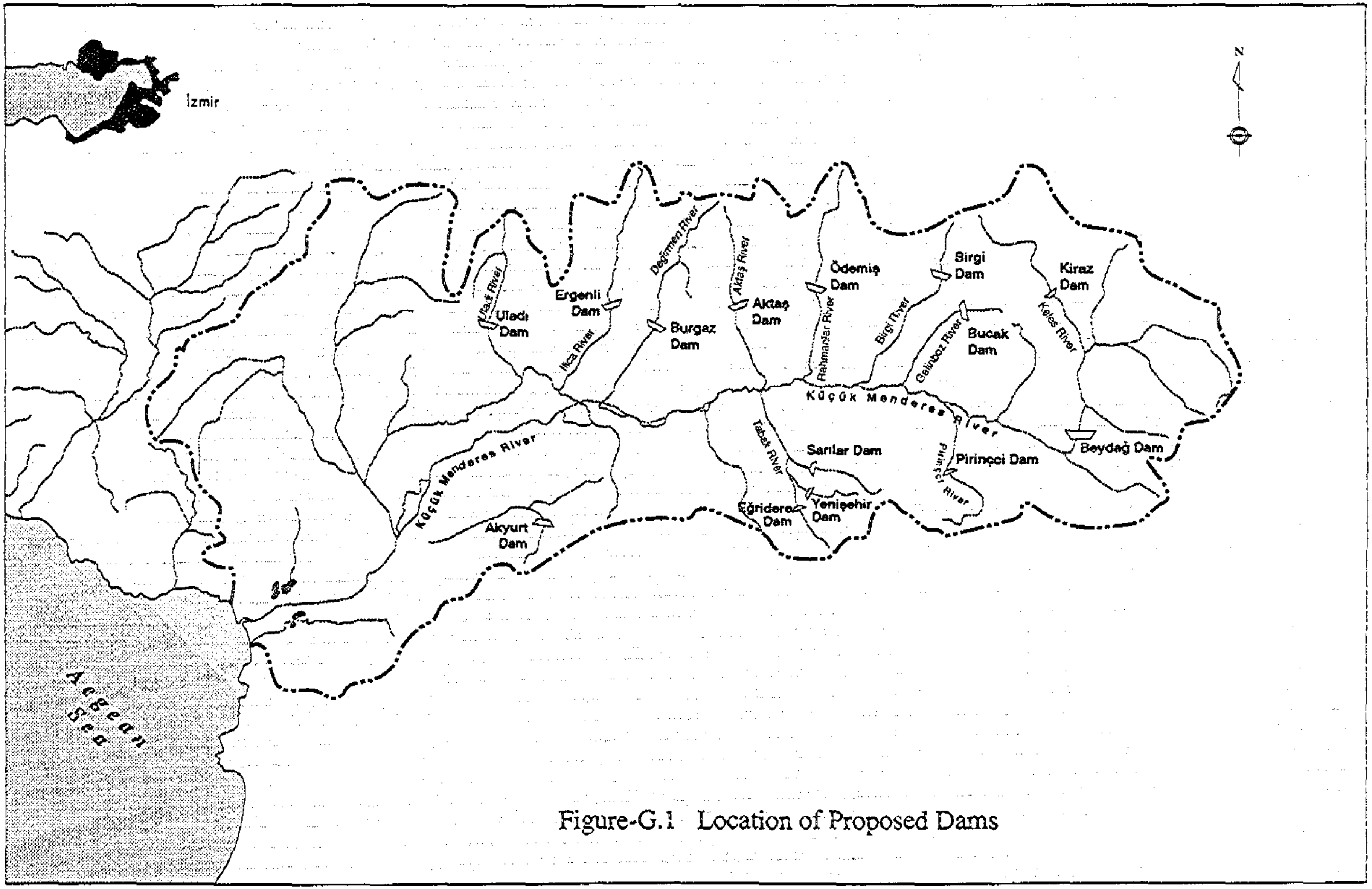
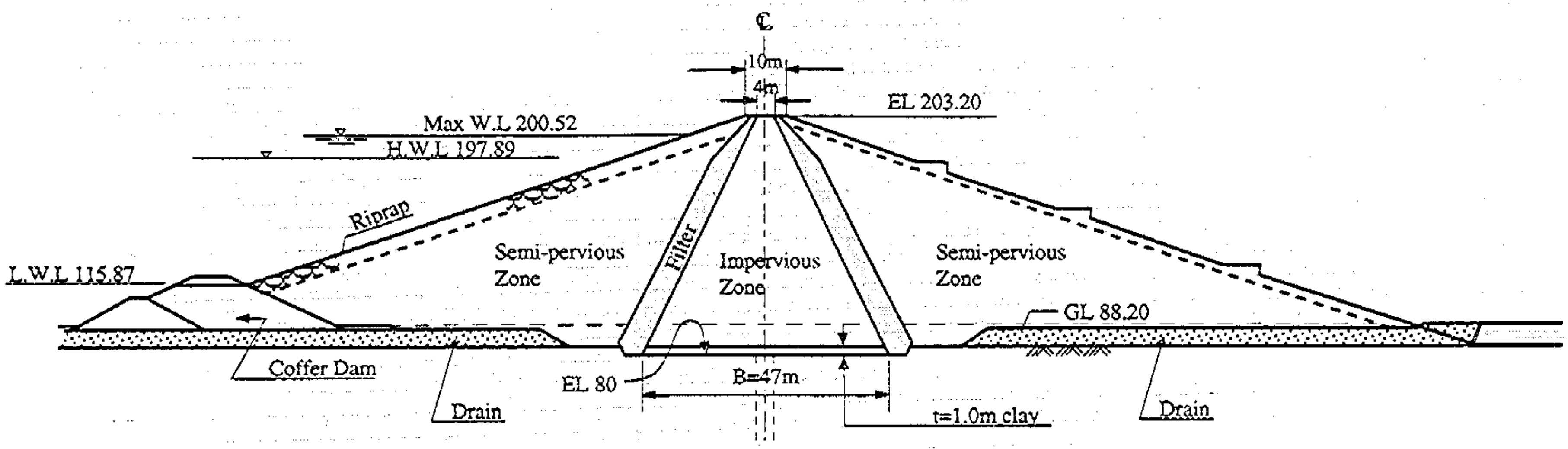
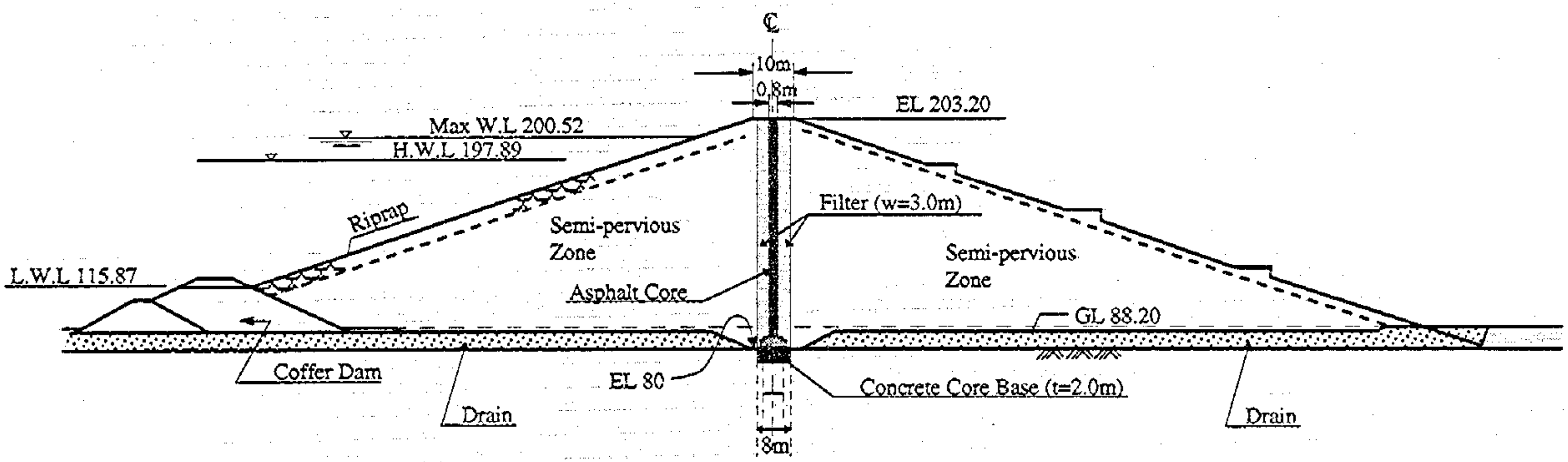


Figure-G.1 Location of Proposed Dams



(a) Earth Fill Dam



(b) Asphalt Center-Cored Fill Dam

Figure-G.2 Cross Section of Dams

ATTACHMENT

Commission Internationale
des Grands Barrages

Douzième Congrès
des Grands Barrages
Mexico, 1976

Q. 44
R. 38

DEVELOPMENT OF NEW CORE MATERIAL IN ZONE FILL DAM USE OF DECOMPOSED GRANITE IN ANDONG DAM (*)

Andong Dam Construction Office,
Industrial Sites and Water Resources
Development Corporation

KOREA

1. INTRODUCTION

Andong dam multipurpose development project was commenced in 1971 as a part of overall water resources development plan of Nakdong river basin which is the second largest one located in south-east part of Korean Peninsular with 23, 852 km^2 of catchment area and 525 km of river length. The project will be completed by end of 1976. The dam is located about 340 km upstream from the estuary (Fig. 1).

Total embankment volume of Andong dam is 4,041,000 m^3 and the type of the dam was designed as a zone fill type dam with central core taking into account construction materials available around the dam site. It was originally designed to use impervious clay of good quality as a core material which can be obtained from 12 km upstream area; however, expensive cost for the construction of access road and transporting the clay material forced us to find an alternative measure. So an investigation was performed to find the possibility of using decomposed granite as a core material which is widely distributed around the dam site and also can be obtained from the various foundation excavations under the expectation of cost reduction. The result from a series of laboratory test revealed that the decomposed granite can be effectively used as an impervious core material by an application of accelerating further decomposition on this material

(*) *Utilisation d'un nouveau matériau de noyau dans un barrage en remblai zoné. Utilisation de granit décomposé au barrage Andong.*

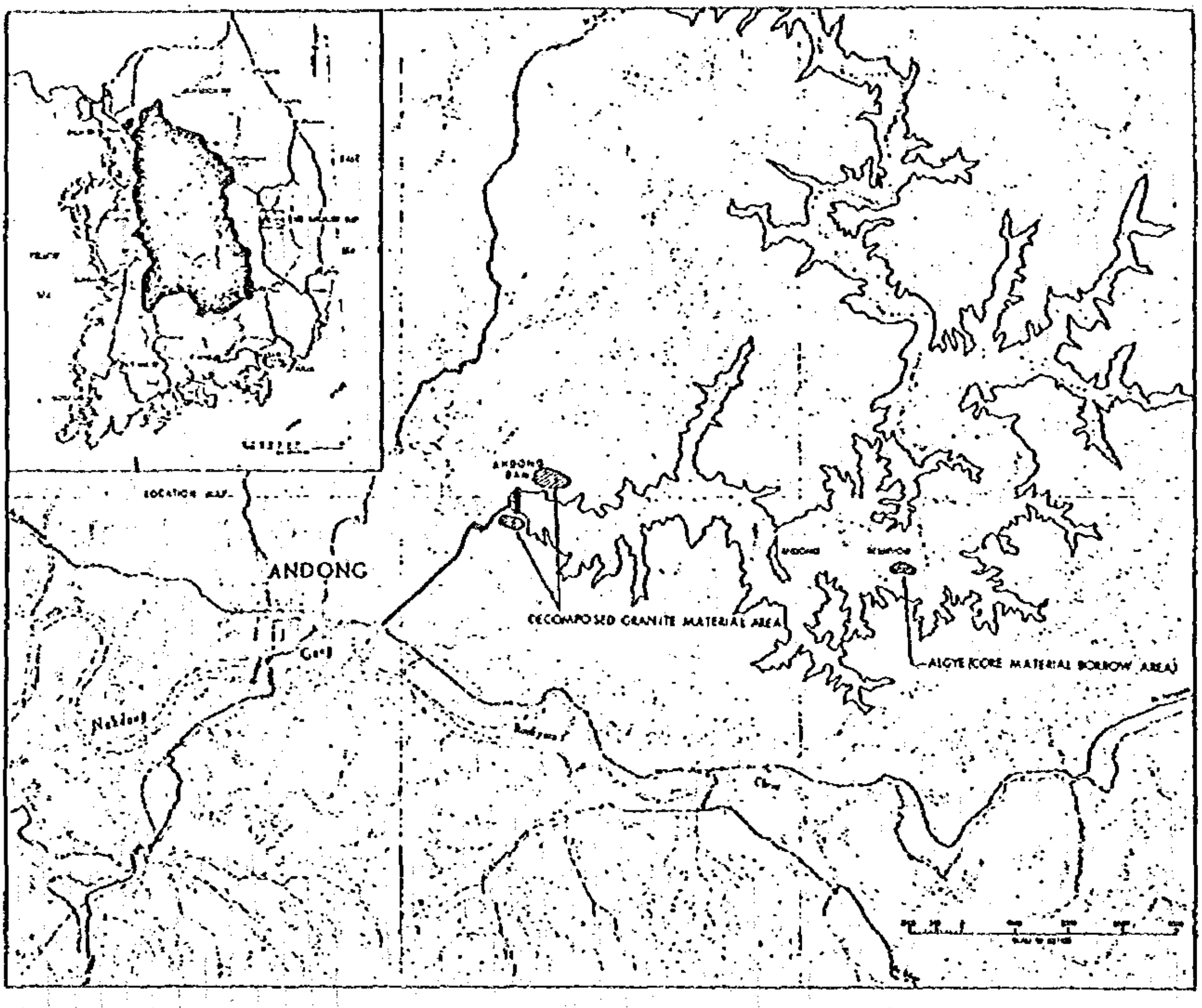


Fig. 1

Locality map.
Carte.

and of controlling the moisture content to be determined. And it was expected to reduce the construction cost of 700,000 U.S. $ which is almost 13 % of dam construction cost.

Because of the decomposed granite has no plasticity, a great caution should be paid on the initial core embankment in right on foundation rock. So the embankment initiated by clay with higher plasticity than 12 % upto 100 cm in layer depth and the decomposed granite was used thereafter.

In accordance with the result of various tests for quality control of dam embankment to 22 m out of dam height 83 m, the dry density, degree of compactness and permeability show the values of 1.971 g/cm^3, 100.7 %

Photo 1
Construction work of Andong dam.
Construction du barrage de Andong.

and 4×10^{-8} cm/s respectively and these values are running above the design criteria.

For further information, the general description of Andong dam is as follows (Fig. 2).

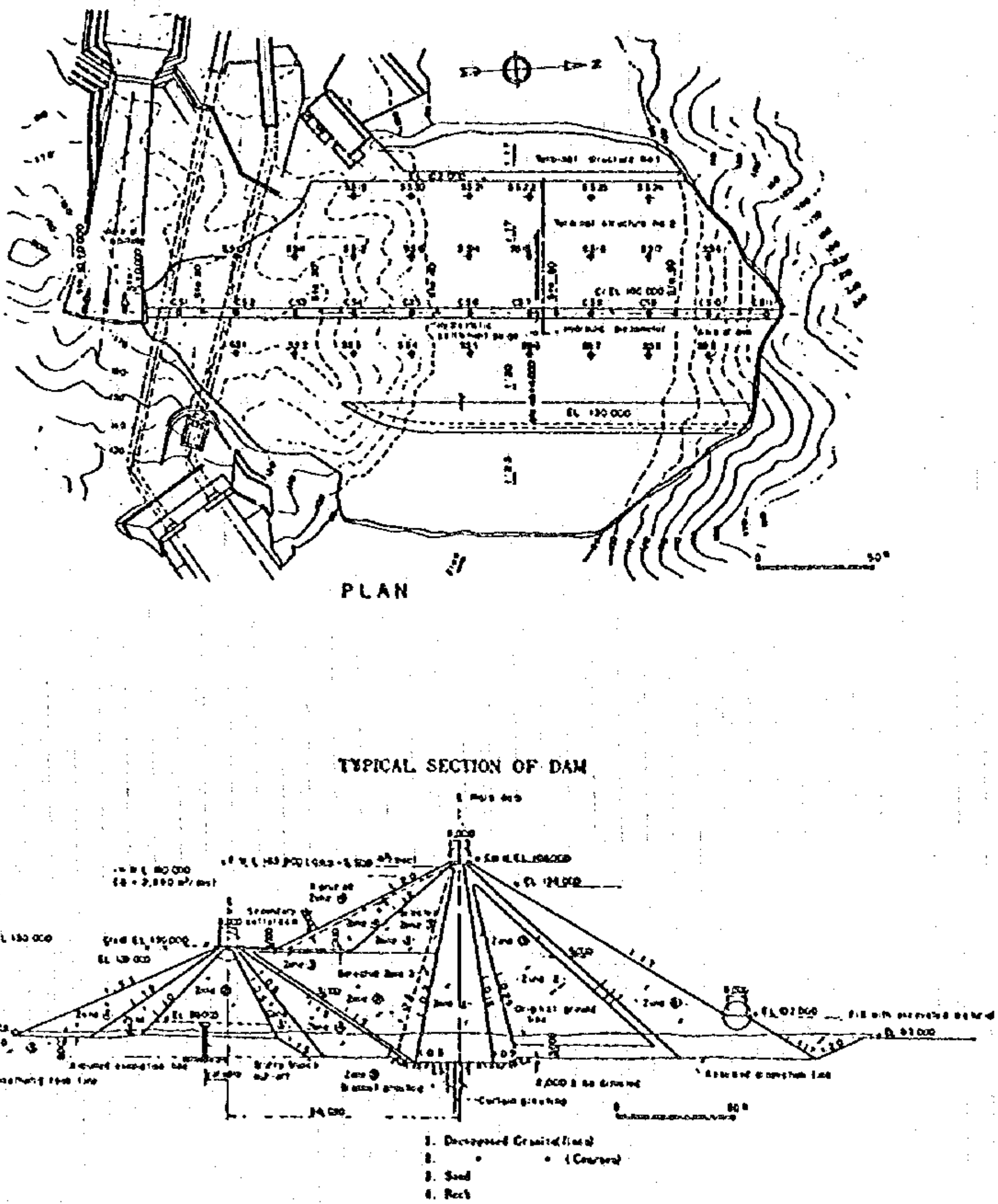


Fig. 2

Plan of dam. Power station and appurtenant.

Plan du barrage, de la centrale et des ouvrages auxiliaires.

Reservoir.

Surface area	51,5 km²
Gross storage capacity	1,248 × 10⁶ m³
Effective storage capacity	1,000 × 10⁶ m³
Normal high water level	El. 160 m
Low water level	El. 130 m

Dam.

Height	83 m (from foundation)
Crest length	542 m
Volume	4,041,000 m³
Zone 1 (Core material)	451,000 m³
Zone 2 (Decomposed granite)	1,356,000 m³
Zone 3 (Sand and gravel)	876,000 m³
Zone 4 (Rock)	1,352,000 m³

Spillway.

Gate W 14 m × H 9.7 m × 4 sets (Radial gate)
Design outflow 5,350 m³/s

Power plan

Turbine : Deriaz type, reversible pump turbine
Installing capacity : 45 MW × 2 sets

2. TEST ON CORE MATERIAL

a) PRELIMINARY INVESTIGATION.

In order to substitute the decomposed granite to core material, the preliminary investigations were performed to survey the total amount of decomposed granite available and to find out its physical characteristics through the measurement of specific gravity and sieve analysis. The test samples were collected by hand auger at each 1 m below from selected points. The tests revealed that the decomposed granite around the dam site were fine enough to pass through No. 4 sieve mostly and 7-15 % of the soil passed through No. 200 sieve. Also it showed the specific gravity is 2.68-2.72 g/cm³.

It means further decomposition would be occurred in considerably short period of time by weathering. For the convenience of laboratory test on permeability and compaction, the soil was classified in 3 items according to the extent of decomposition :

i) highly weathered : No. 200 sieve pass, above 10 %;
ii) moderately weathered : No. 200 sieve pass, 8-10 %;
iii) slightly weathered : No. 200 sieve pass, below 8 %.

It was observed in the laboratory that average maximum dry density and optimum moisture content were 1.86 g/cm³ and 13 % respectively when the soil sample was compacted 25 times by rammer, and of 1.97 g/cm³ and 11 % when 75 times compaction was applied. It means that the increase of compaction energy causes an increase of maximum dry density but decrease of the optimum moisture content. On the other hand, permeability reached to the less value than 1×10^{-5} cm/s in most case when the 75 times rammer compaction was applied to the soil of which moisture content was little higher than the optimum moisture content.

Conclusion resulted from these tests that the highly and moderatly weathered granite could be safely used as a core material for the zone fill dam and amount of these weathered granite was estimated to 700,000 m³ around the dam site which exceeds required amount of 500,000 m³ for core embankment.

And also, to check the variation of weathering in decomposed granite according to the time procedure, sieve analysis tests had been performed for 8 months by one week interval for each sampled soil from selected depth. But no more increase of fine particles passing through No. 200 seive which would be greatly effected to a leakage was appeared.

b) LABORATORY TEST.

i) Physical test .

The physical properties of undisturbed soil samples were as follows :

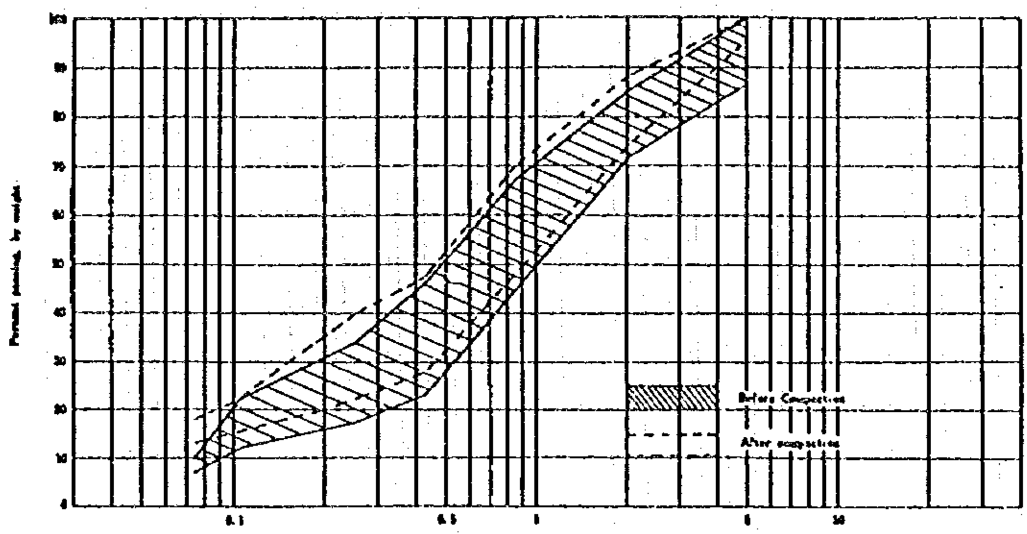
Specific gravity	2.68-2.72
Moisture content	7.3-8.9 %
Amount passing No. 200 sieve	7.0-15 %
Uniformity coefficient	22
Coefficient of curvature	2

The soil used for embankment test was of non-plasticity and well graded and classified as S.M. by Unified Soil Classification Method (Fig. 3).

ii) Compaction and permeability test :

The permeability is affected by a progressive crushing of soil particles during the embankment works. Considering this effect, two different soil samples were collected after the adjustment of passing rate of No. 200 sieve.

One was the soil with 17 % of passing rate of No. 200 sieve and the other with 21 %. Figure 4 shows the results of compaction and permeability test. From this Figure 4, the smallest permeability coefficient occurred near the optimum moisture content in case of soil with 17 % of passing rate, while it occurs at 2 % higher than the optimum moisture content in case of soil with 21 % of passing rate. Also the variation of permeability according to the time procedure was observed as in Figure 5 when the tests were performed for 48 hours after the soil samples had been saturated



Grain Size (mm)

Fig. 3

Grain size distribution for embankment material.

Granulométrie du remblai.

for 24 hours. No significant change in permeability was observed from these two different soil samples which behaved as an impervious barrier for 72 hours' testing period.

Permeability of alluvial sand varied according to it's void ratio, while that of the decomposed granite has a direct relationship with the characteristic of soil particles. In other words, permeability of decomposed granite is greatly varied in accordance with the degree of decomposition and the amount of primary mineral. Generally, permeability coefficient is decreased in case soil contains mica or hornblende because of their expansion in the water. It is considered that the result of the above mentioned test was also caused by this expansion.

iii) Relation between amount of fine particles and soil also affects the permeability. To check this relation, an artificial variation in the amount of fine particles was applied to soil samples from compacted decomposed granite in the field. The moisture contents were fixed at the value of O.M.C. + 2 % and O.M.C. — 1 %.

An apparent decreasing trend in permeability was noticed when the amount of fine particles passing No. 200 sieve and little wetter side than O.M.C. (Fig. 6).

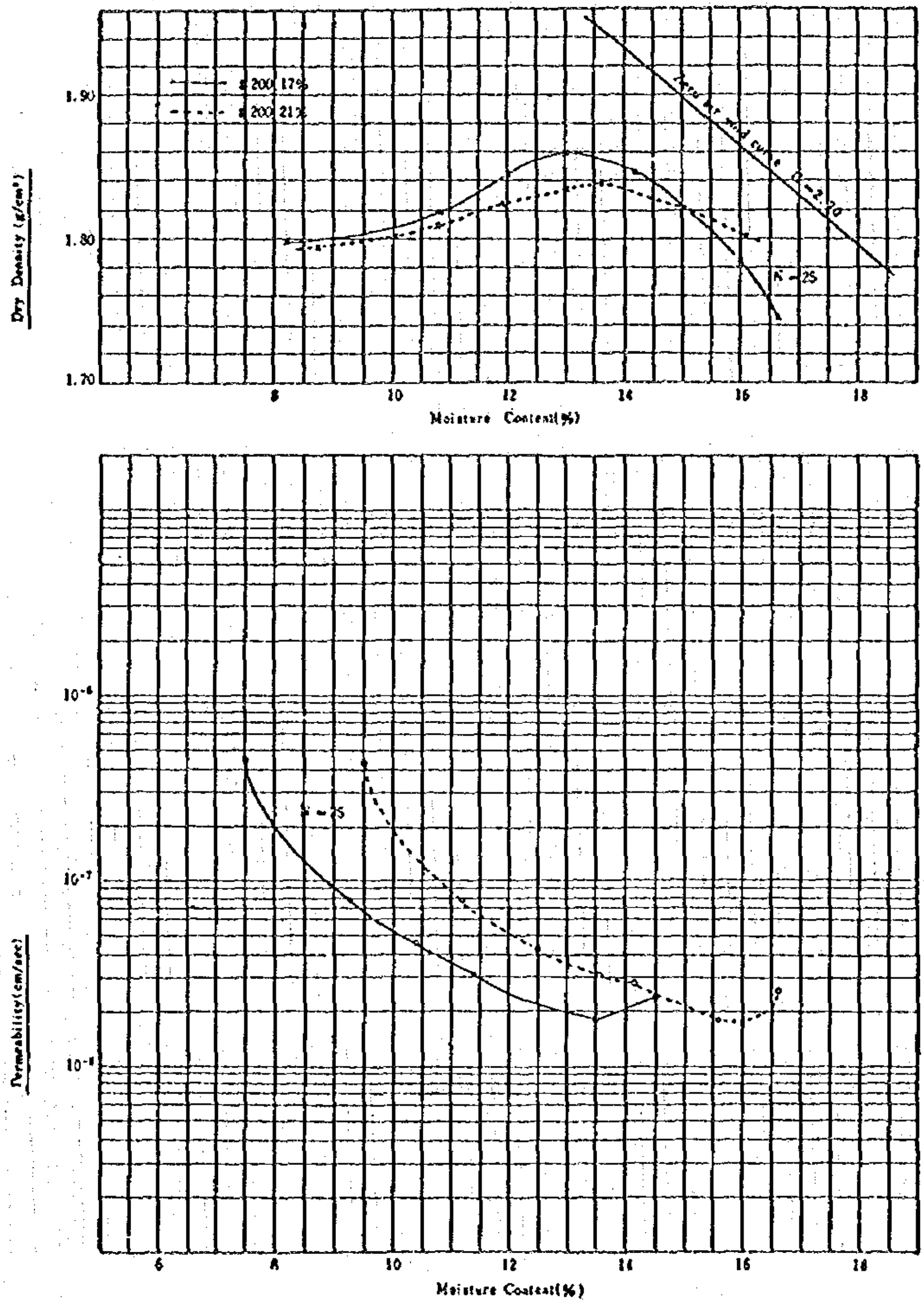


Fig. 4

Results of compaction and permeability test.

Résultat des essais de compactage et de perméabilité.

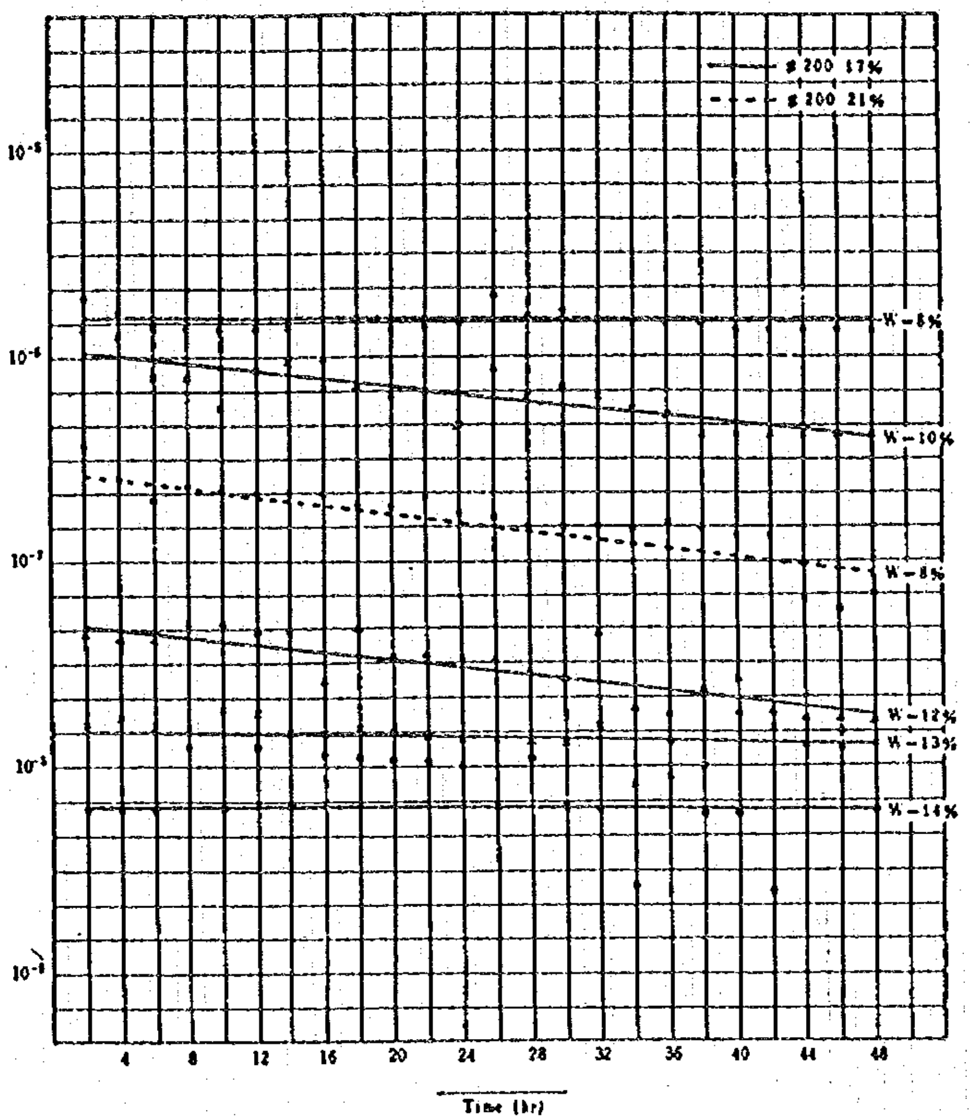


Fig. 5

Time-permeability.
Relation temps-perméabilité.

iv) Shearing stress.

The tri-axial compression tests were conducted under the conditions of unconsolidated undrained (U.U.), consolidated undrained (C.U.) and consolidated drained (C.D.). By the results of measurements, the value of internal friction and cohesive force were 32-35° and 0.1-0.45 kg/cm² with U.U. condition. With C.U. condition, they were 39° and 0.35 kg/cm² and 37-38° and 0.35-0.59 kg/cm² with C.D. condition respectively. Decrease in shearing stress was expected when the amount of fine particles were

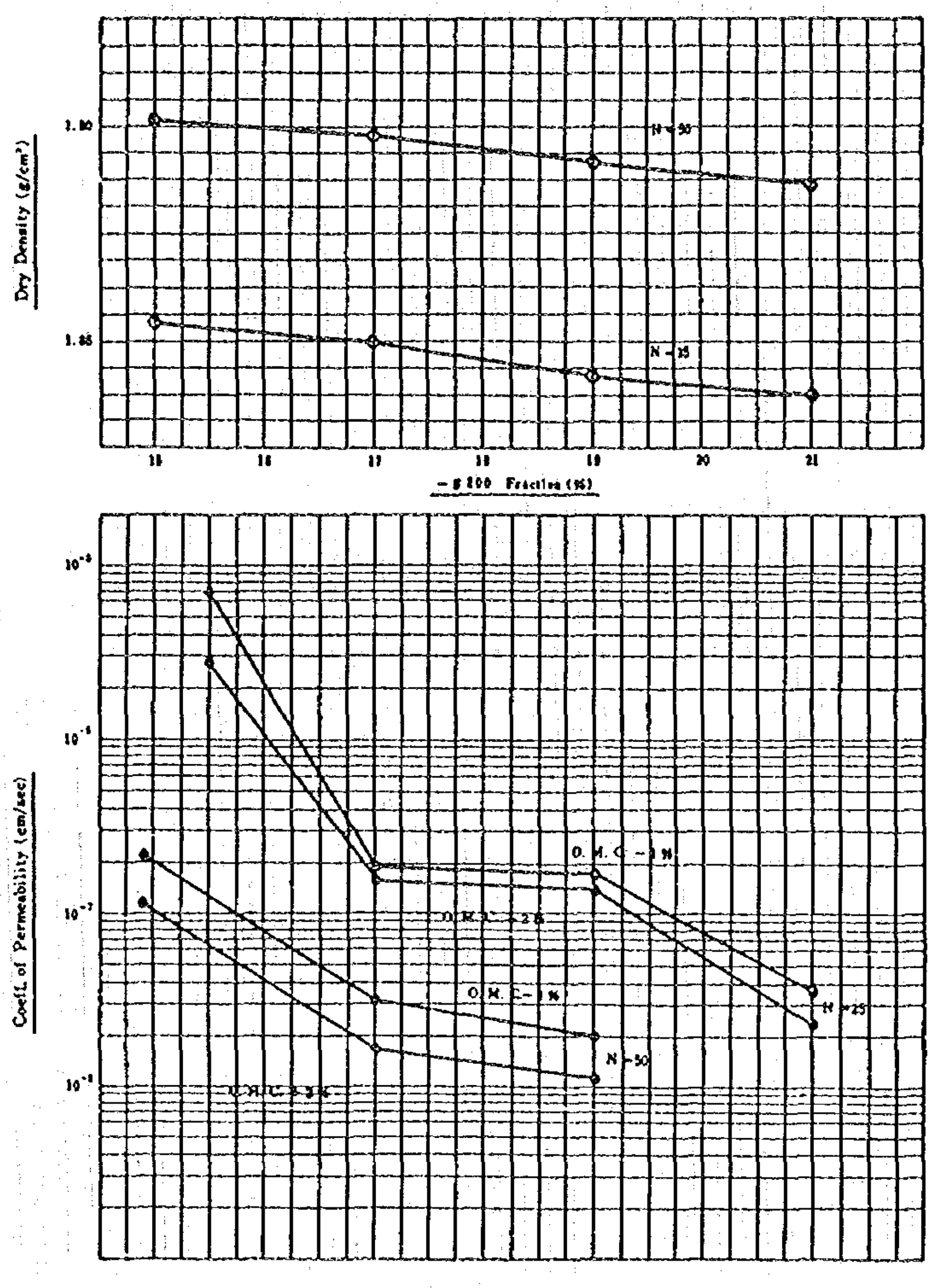


Fig. 6

Correlation of dry density, permeability and — # 200 fraction.

Corrélation entre la densité sèche, la perméabilité et la fraction passant au tamis 200.

increased. However, no apparent change was observed in shearing stress. On the other hand, the shearing stress increased profoundly as expected when the dry density was artificially increased.

c) FIELD TEST ON EMBANKMENT.

i) Field test.

Fiels test was conducted from March 1973 to June 1973 to determine the embankment method and construction specification since the conclusion was made to substitute the decomposed granite to the core material. Eleven different embankment tests were performed by combining compacting equipment, moisture content, and number of roller passing (Table 1). Field tests of density and permeability were performed using the soil samples collected after the 3, 6, and 9 passes roller compaction were completed.

Field density test was carried out according to the Korea Standard Field Density Test (Sand Replacement Method) and U.S.B.R. equation was applied to determine the permeability through the field test. The equation was :

$$K_f = \frac{Q}{2\pi H^2}\left(2.3 \log_{10}\left\{\frac{H}{\gamma}\sqrt{1+(H/\gamma)^2}\right\} - 1\right).$$

TABLE 1

Criteria of field embankment test.

Test embankment (No.)	Compaction equipment.	Moisture content (%)	Layer thickness (cm)	No. of passing	Embanked material
1	Vibrating roller	10-12	20	3, 6, 9	Stock riled material
2	Vibrating roller	10-12	30	3, 6, 9	Natural condition
3	Vibrating roller	8-12	20	3, 6, 9	Stock piled material
4	Vibrating roller	12-14	20	3, 6, 9	Stock piled material
5	Tire roller	10-12	20	3, 6, 9	Stock piled material
6	Tire roller	10-12	30	3, 6, 9	Stock piled material
7	Tamping roller	10-12	20	3, 6, 9	Stock piled material
8	Tamping roller	10-12	30	3, 6, 9	Stock piled material
9	Tamping roller	10-12	40	3, 6, 9	Stock piled material
10	Tamping roller	8-10	20	3, 6, 9	Stock piled material
11	Tamping roller	12-14	20	3, 6, 9	Stock piled material

ii) Analysis of test results.

Figures 7 and 8 and Table 2 show the results of the test carried in the field.

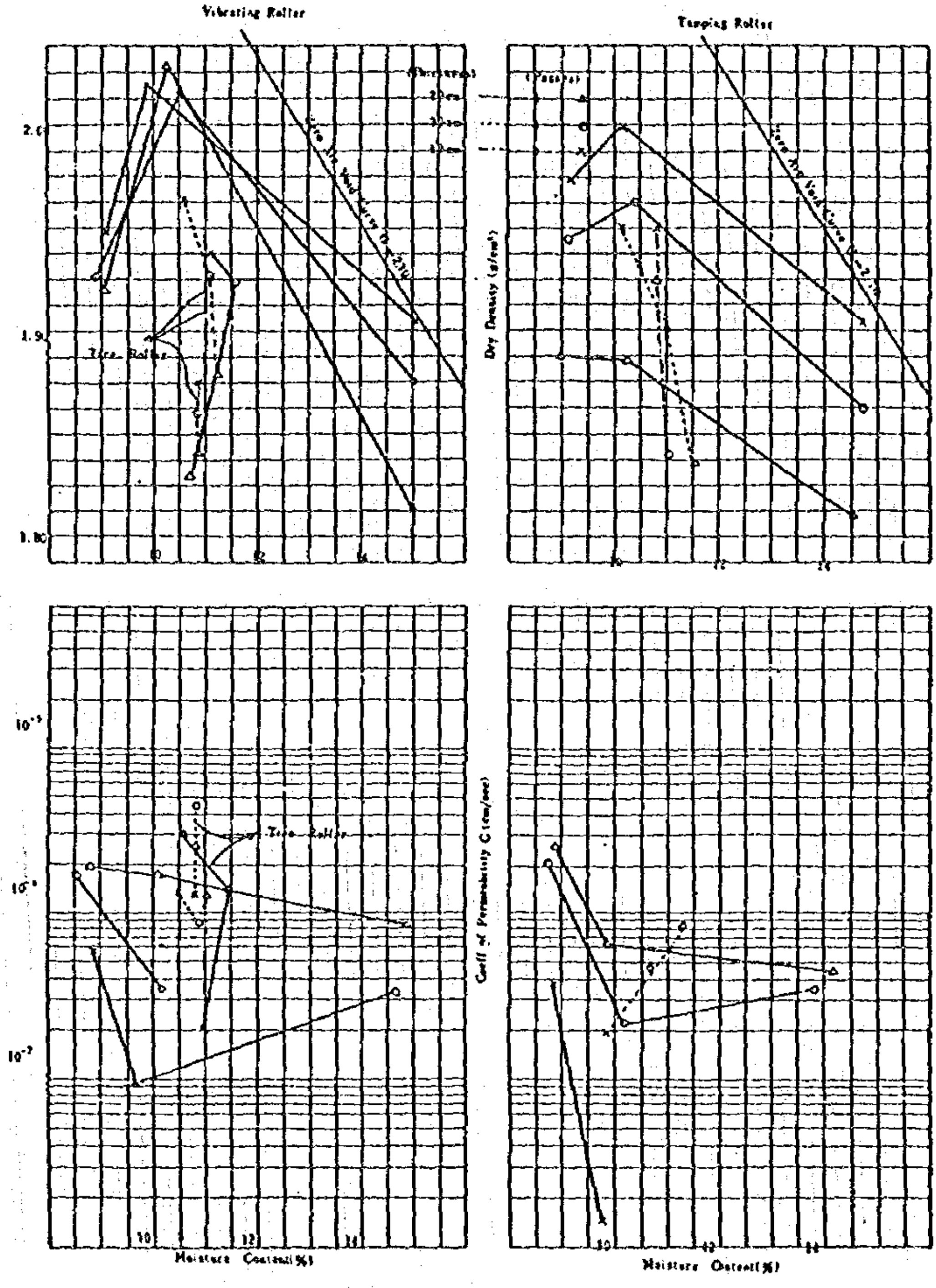


Fig. 7

Moisture content-dry density-permeability relationship.

Relation entre la teneur en eau, la densité sèche et la perméabilité.

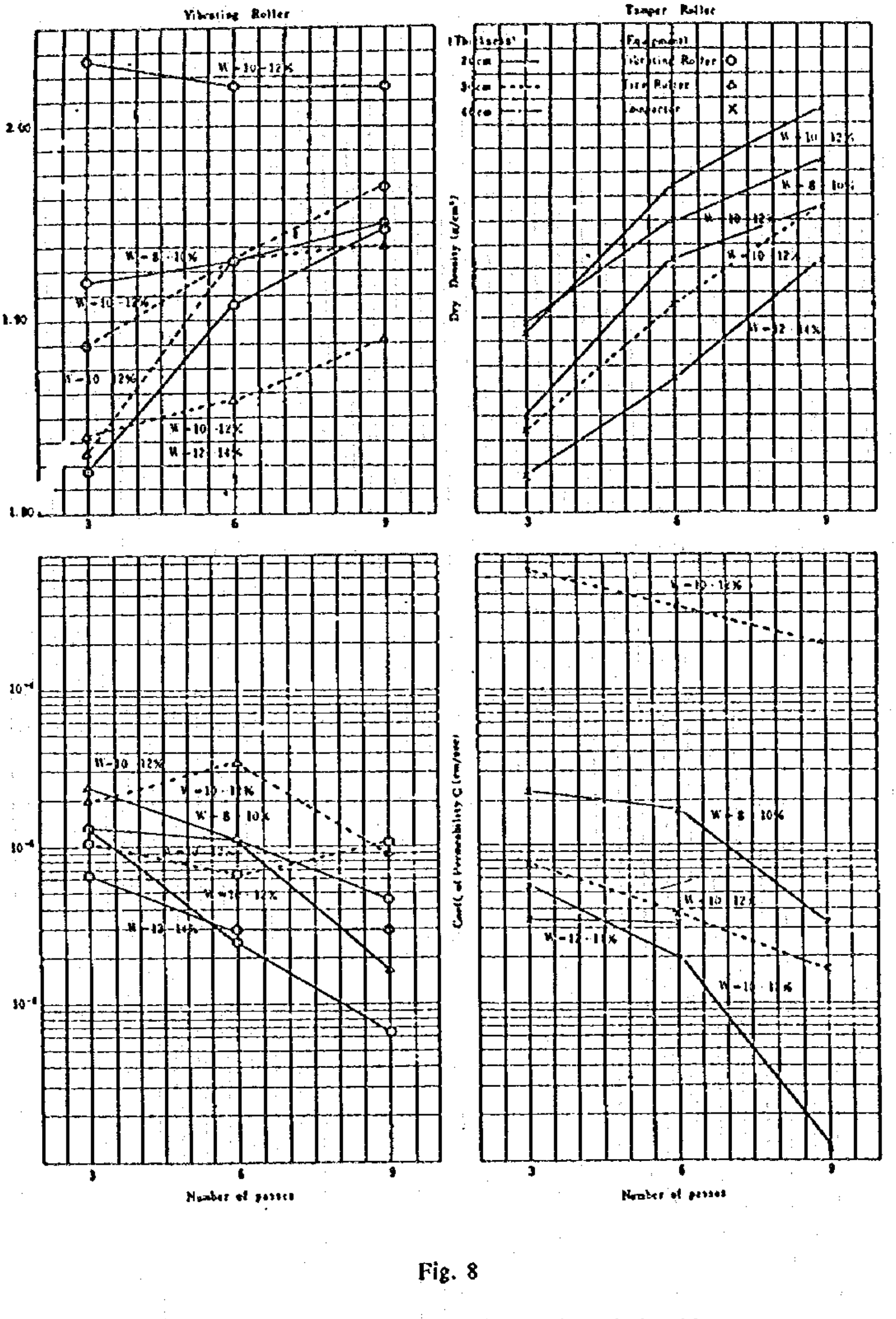


Fig. 8

No. of passing-dry density-permeability relationship.

Relation entre le nombre de passages de rouleaux, la densité sèche et la perméabilité.

TABLE 2

Result of field embankment test.

Passing No. / Result / Testing No.	3		6		9	
	Dry density (g/cm^3)	Permea-bility (cm/s)	Dry density (g/cm^3)	Permea-bility (cm/s)	Dry density (g/cm^3)	Permea-bility (cm/s)
1	2.03	1.3×10^{-6}	2.02	2.4×10^{-6}	2.02	6.8×10^{-7}
2	1.88	1.1×10^{-5}	1.93	6.4×10^{-6}	1.97	1.1×10^{-5}
3	1.92	1.4×10^{-5}	1.93	1.2×10^{-5}	1.95	4.2×10^{-6}
4	1.82	6.7×10^{-6}	1.91	2.8×10^{-6}	1.95	2.9×10^{-6}
5	1.83	2.2×10^{-5}	1.93	1.1×10^{-5}	1.94	1.5×10^{-6}
6	1.84	2.0×10^{-5}	1.86	3.3×10^{-5}	1.88	9.5×10^{-6}
7	1.89	5.3×10^{-6}	1.97	1.9×10^{-6}	2.01	1.2×10^{-7}
8	1.84	7.9×10^{-6}	1.91	3.1×10^{-6}	1.96	1.7×10^{-6}
9	1.85	5.2×10^{-6}	1.93	3.4×10^{-6}	1.96	1.9×10^{-6}
10	1.89	2.1×10^{-5}	1.95	1.8×10^{-6}	1.98	3.1×10^{-6}
11	1.82	3.6×10^{-6}	1.87	3.1×10^{-6}	1.93	2.8×10^{-6}

Moisture content-dry density-permeability-relationship.

As illustrated in Table 1, the test embankment 1, 3 and 4 were compacted by vibrating roller, and test embankment 10, and 11 by tamping roller. In both cases, the maximum dry density and smallest permeability occurred near the moisture content of 10 %. In other moisture content, dry density decreased and permeability increased. Thus, optimum values of permeability and compaction frequency were obtained when moisture content was lying on between 10-12 %.

Layer thickness-dry density-permeability relationship.

The result of compaction of 20 cm layer thickness was found to be more satisfactorily than of 30 cm layer thickness. Also the smaller value of permeability could be obtained in 20 cm layer thickness than of 30 cm.

Compaction equipment-dry density-permeability relationship.

Three types of compacting equipments were used for various test embankment. The tire roller was found to be the least effective among three types of rollers tested and vibrating roller and tamping roller gave virtually same effects of dry density and permeability when the soil was compacted 9 times. For the low passing frequency of roller, the tamping roller gave better results on dry density and permeability than vibrating roller.

This may be caused by better crushing effect of tamping roller than vibrating roller. It can be concluded that tamping roller should be used for the compaction of core material.

Number of passing-dry density-permeability relationship.

Based on analysis from the above test, the optimum passing frequency of the roller was 6 passes for one layer, however, 8 passing frequency is adopted for the construction specification considering safety.

Increasing rate of fine particles during construction procedures.

It was already mentioned that the amount of fine particles increases during the construction procedures of zone fill dam. For the analysis of this phenomenon, soil samples were taken at different stages of construction, as :

1) Natural condition at the borrow area.
2) Stock piled material before modification of moisture content.
3) Stock piled material after modification of moisture content.
4) Before compaction by roller.
5) After compaction by roller.

The result of the analysis is shown in Table 3 which reveals that the amount of fine particles (Passing No. 200 sieve) in natural state was about 8 % and it increased to 10-12.5 % when the moisture content was controlled by spreading water. After the soil spreading at the construction area by bulldozer, the value increased upto 12-14.5 %. Further increase of fine particle was observed when the compaction was completed and the value was 15.3-17.5 %. This results also confirm that tamping roller is more effective in reducing the permeability by crushing soil.

3. SUITABILITY OF DECOMPOSED GRANITE AS A CORE MATERIAL

Even though the shearing stress and internal friction by triaxial compression test (U.U. test) were greater than those of clay, the possibility of weakness of dam still exists when the dam is completely submerged and saturated, it is no problem since the safety of the zone fill dam greatly depends on the pervious material which orotects the core material.

The permeabiliy of the core material can be reduced below 1×10^{-5} cm/s, which is the design standard, by modifying the moisture content and compacting 20 cm layer thickness by vibrating roller or tamping roller passing more than 6 times.

Based on the above results, it is concluded that the decomposed granite can be safely used for the core material.

TABLE 3

Increase of fine particles according to construction procedures.

Test embankment	Borrow area		Stock pile				Embankment area				Remarks
			Before water spread		After water spread		Before compaction		After compaction		
(No.)	Water content (%)	— # 200 (%)	Water content (%)	— # 200 (%)	Water content (%)	— # 200 (%)	Water content (%)	— # 200 (%)	Water content (%)	— # 200 (%)	(%)
1	7.9	8.2	7.9	8.6	10.1	11.4	10.0	14.4	10.0	16.5	
2	7.9	8.2					11.0	14.1	10.9	16.7	
3	8.9	9.6	8.6	9.7	9.9	12.6	9.3	14.6	8.8	16.3	
4	7.5	7.8	10.7	12.6	14.8	12.6	14.8	14.2	14.9	15.8	
5	8.9	8.0	8.9	8.3	11.6	10.7	10.7	12.6	11.1	15.3	
6	8.3	7.9	8.4	8.6	11.6	9.8	10.8	12.3	10.8	15.3	
7	8.9	8.0	8.9	8.3	11.0	12.5	10.8	14.4	10.1	17.5	
8	8.9	8.0	8.9	8.3	11.7	11.0	11.0	13.6	10.8	17.4	
9	7.5	7.8	7.5	7.8	11.5	10.1	11.3	10.7	10.7	12.6	
10	7.3	7.7	7.6	8.1	10.2	11.1	9.1	12.3	8.9	16.4	
11	7.6	8.2	7.6	8.3	14.7	12.0	14.5	12.7	14.7	16.8	

4. DETERMINATION OF CONSTRUCTION SPECIFICATION

i) Moisture content.

The moisture content of core material should lie on between O.M.C. — 1 % and O.M.C. + 2 % since it gives lowest permeabiliiy coefficient.

ii) Layer thickness.

The layer thickness for compaction is determined not greater than 20 cm by considering the length of tamping roller foot and safety of the dam.

iii) Compacting equipment.

The tamping roller is determined to be used because :

a) It accelerates crushing of soil to fine particles and

b) It has the advantage of faster compaction.

iv) Passing frequency.

The 6 passes of roller on 20 cm layer gives values of 1.97 g/cm^3 in dry density, 1.4×10^{-6} cm/s in permeability and 10-12 % in moisture content which are the design standards, but for the sake of safety, passing frequency of roller is determined to be 8 times.

v) Core material.

The excavated decomposed granite should be treated to satisfy the requirements for the core material before being used as a core material. The content of fine material passing No. 200 sieve should exceed 17 % of total amount of soil and the moisture content of soil should lie on between — 1 % and 2 % from O.M.C.

This can be accomplished by spreading water on the soil and piling soil for the unified mixing before carring to the dam site.

SUMMARY

The decomposed granite deposited around Andong multipurpose dam site has the specific gravity of 2.70 and contains 7-15 % of fine particle passing No. 200 sieve. This highly weathered soil in under S.M. class by Unified Soil Classification Method and accomodates 7.3-8.9 % of moisture. The soil is well graded with uniformity coefficient of 22.

The soil in site does not meet the requirements for the core material. The moisture content should be increased to near O.M.C. and the amount of fine particle should not be less than 17 % after compaction. However, this can be done by piling up the excavated soil and mixing them by bulldozer with spreading water.

During the construction of the dam up to 22 m out of total 83 m, it was found that the treated decomposed granite which is behaving very well as a core material satisfies all the requirements. The test shows the

dry density of 1.971 g/cm³, compaction degree of 100.7 %, field moisture content of 9.8 %, O.M.C. of 10.1 %, permeability of 4×10^{-6} cm/s-3×10^{-7} cm/s, and the amount of fine particles passing No. 200 sieve of 17 %. It is also advantageous for the construction that the moisture content can be simply increased by spreading water since the moisture content before treatment is below the O.M.C.

RÉSUMÉ

Le granit décomposé en dépôt autour du barrage à buts multiples de Andong a une densité de 2,7 et contient 7 à 15 % de particules fines passant au tamis 200. Ce sol très altéré appartient à la classe S.M. (méthode de classification des sols unifiée) et son humidité est de 7,3 à 9 %. Sa granulométrie est régulière avec un coefficient d'uniformité de 22.

Le sol en place n'est pas convenable à la construction d'un noyau. Il faudrait augmenter la teneur en eau au voisinage de l'optimum et sa teneur en particules fines ne devrait pas être inférieure à 17 % après compactage. Toutefois, il est possible d'atteindre ce résultat en entassant le sol excavé et en le triturant au bulldozer en l'arrosant. Pendant la construction du barrage, sur les 22 premiers mètres de la hauteur totale (83 m), on a constaté que le granit décomposé ainsi traité se comporte très bien comme matériau de noyau et qu'il satisfait à toutes les prescriptions.

Les essais montrent que la densité sèche est de 1,971 g/cm³, le degré de compactage 100,7 %, la teneur en eau de 9,8 %, la teneur en eau optimale de 10,1 %, la perméabilité variant de 4×10^{-6} cm/s à 3×10^{-7} cm/s avec un pourcentage de particules fines passant au tamis 200 de 17 %. Il est également avantageux pour la construction que la teneur en eau puisse être facilement augmentée par arrosage puisque la teneur en eau naturelle est inférieure à l'optimum.

ANNEX H

IRRIGATION AND DRAINAGE

ANNEX II

IRRIGATION AND DRAINAGE

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ANNEX H

IRRIGATION AND DRAINAGE

1 Basic Conditions for Irrigation Development

1.1 Proposed Irrigation Method

Modernized irrigation methods, such as sprinkler irrigation and drip irrigation, should be widely introduced under this Project, in order to save irrigation water effectively. Irrigation method can be selected among the modernized irrigation methods in consideration of crop, equipment applying for cultivation and farmers' intention.

The present surface irrigation method will be applied continuously for winter crops and olive. The modernized irrigation methods will be introduced with first priority for steep areas and high permeable areas.

1.2 Irrigation Water Requirement

(1) Estimation of Reference Evapo-transpiration (ETo)

Three methods, (Pan Evaporation), Blaney-Criddle and Modified Penman can be used for estimating of ETo in this Study, considering the availability of necessary meteorological data in and around the Study Basin. Considering some instructive studies on methodology for estimation of evapo-transpiration applied in world-wide recently, the Penman-Monteith Equation has been recognized to show the very convincing result under varying climatic conditions. Though this method will get reliable result, it was not applied in the Study due to scarce of sufficient parameter especially crop coefficient.

As the three meteorological stations, Ödemiş, Tire and Bayındır have almost complete meteorological data required for applying those three methods, ETo values were estimated by the three methods at the three stations. The result of estimated ETo is shown in Tables H-1~H-3 and summarized below.

Meteorological Station	(Pan Evaporation)	Blaney-Criddle FAO mth.	Blaney-Criddle Turkey mth.	Modified Penman
Ödemiş	(1,068.3)	1,187.5	*1,326.4*	1,271.6
Tire	(1,112.5)	1,199.3	*1,340.6*	1,313.3
Bayındır	(1,169.2)	1,242.5	*1,407.5*	1,350.3

FAO and Turkish applications were used in the Blaney-Criddle method. In the estimation by FAO application, the order of ETo values among the three methods is as follows:

Pan Evaporation < Blaney-Criddle < Modified Penman

The Blaney-Criddle method was selected for estimation of ETo in this Study, because this method gave the mean value among the three, and its application has been authorized in appliance in Turkey long time ago. Furthermore, Turkish application of the Blaney-Criddle method is preferred to the FAO application due to good suitability in Turkey. Difference between the FAO application and the Turkish application is as follows:

FAO application: $ETcrop=K_c x ETo=K_c x C x F=K_c x C x [P x (0.46T+8.13)]$

Turkish application: $ETcrop=K_c' x ETo'=K_c' x K_t x F=K_c' x (0.031T+0.24) x [P x (0.46T+8.13)]$

While F values in both applications are equivalent, C and K_c differ from K_t and K_c', respectively. In this Study, the Turkish application which had been tested for a long time in Turkey, was adopted.

(2) Crop Coefficient

The water requirement for each crop can be estimated by multiplying ETo by the Crop coefficient (K_c) of the respective crop. As to K_c, the values authorized in Turkey were utilized in this Study.

(3) Effective Rainfall

Effective rainfall for cultivation was calculated monthly, referring to the relation between monthly rainfall and monthly effective rainfall formulated through a long experience, as shown below.

(mm)

Monthly rainfall	0.0	25.0	50.0	75.0	100.0	125.0	150.0	175.0	-
Monthly eff.rainfall	0.0	25.0	46.0	67.0	84.0	96.0	102.0	104.0	104.0

As actual effective rainfall varies corresponding by to daily rainfall, such method handled monthly gives outlines of the actual effective rainfall. However, they are allowable for easy calculation of effective rainfall, because it is impracticable to consider all factors such as daily rainfall, topographic and soil conditions. Accordingly, the above-mentioned relation curve was utilized in this Study.

(4) Present Irrigation Water Requirement

Considering the irrigation conditions mentioned above, the present irrigation water requirement was calculated in accordance with the present cropping pattern. The present annual average water requirement for crops was calculated at 560.4 mm. The results are presented in Table H-4 and summarized below:

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Present Water Requirement	0.2	0.5	5.6	22.1	63.1	108.0	130.4	137.7	71.8	18.1	2.5	0.4

Note: An irrigation efficiency of 0.6 is applied for all crops. Irrigation water for olive is assumed to account for 40% of the total calculated value, taking into consideration the present situation.

1.3 Proposed Irrigation System

The proposed irrigation system will consist of main canals for conveying irrigation water, distributaries, on-farm facilities, and so on. The main canal will generally be a pipeline. Closed conduits will be used for construction of secondary canals branching off from the main canals. At the head of each tertiary canal, a booster pumping station will be built in order to provide necessary pressure for sprinkler irrigation. The booster pump will be installed in a bypass conduit so that water can flow by gravity when surface irrigation is applied. The sprinkler and drip irrigation equipment should be of removable type, because it should be removed when not needed.

1.4 Conjunctive Use of Surface Water and Groundwater

The construction of the proposed dams would enable to substitute surface water for groundwater as a water supply source. However, it is impossible to completely eliminate the groundwater use in the Study Basin, due to limited number of suitable dam sites as mentioned in Section 2.2.4 in the Main Report. Incidentally, some of the existing irrigation systems utilizing groundwater with reliable facilities, such as cooperatives, are advantageous and should be maintained as long as their pumping yield within the allowable limit.

Therefore, as a policy for future groundwater use, cooperatives and advantageous fields for groundwater use located within the irrigation areas by the proposed surface water will continue to use groundwater for irrigation. Such cooperatives and fields are expected to obtain the same irrigation benefits through the application of the same proposed irrigation methods after renovation of existing irrigation systems.

2 Irrigation Development Plan for the Beydağ Dam

(1) Command Area

The Beydağ dam will command an agricultural area extending from the eastern edge of the alluvial plain to Ödemiş town. The area will be bounded on the north and south by the main canals which will be aligned on both sides of the Küçük Menderes river. The water level of the canals should be so designed as to have sufficient head of water conveyance when the lowest water level of the Beydağ reservoir is at EL.182.55 m. The western part should be bounded by an existing tributary, which will be selected so as to have an equivalent command area irrigable by storage water of the proposed Beydağ reservoir.

(2) Irrigation Water Requirement in the Proposed Plan

The irrigation water requirement in the proposed plan was calculated taking into consideration the proposed cropping calendar which was prepared based on the present soil and land use conditions. Necessary factors used in the calculation of water requirement were derived from values under the present condition. Irrigation efficiencies for surface irrigation, sprinkler and drip are adopted on the bases of the DSİ criteria as shown below.

Irrigation method	Conveyance efficiency	Application efficiency	Whole efficiency	Remarks
Surface	0.98	0.59*	0.58	Pipeline system
Sprinkler	0.98	0.80	0.78	Pipeline system
Drip	0.98	1.00	0.98	Pipeline system

*: Application efficiency for the surface irrigation method was calculated as a weighted mean for respective soil types, considering the soil condition that sandy loam(efficiency;0.60) extends in 98% of the Project Area, and remaining Area is covered by Sandy(efficiency;0.50).

The annual average irrigation requirement was calculated at 617.8 mm (See Table H-5), and its monthly apportionment is as follows:

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Beydağ dam	0.2	0.3	2.1	10.9	67.8	113.6	122.4	163.6	97.8	34.0	4.9	0.3	617.8

Note: An overall irrigation efficiency of 0.78 is applied assuming adopting areas for each irrigation method based upon proposed cropping calendar. Each irrigation efficiency for the surface irrigation, sprinkler and drip irrigation method, is 0.58, 0.78 and 0.98 respectively. (0.78 = 0.58 x 0.5/1.4 + 0.78 x 0.4/1.4 + 0.98 x 0.5/1.4)

(3) Command Area by Surface Water

The area to be supplied with surface water developed by the Beydağ dam was determined through a dam operation study, applying the unit water requirement estimated above. The following conditions were assumed in the dam operation study:

Study term: 33 years from 1961 to 1993, corresponding to the period of available runoff discharge data of the Beydağ river

Runoff data: Runoff discharge data of the Beydağ river at the dam site having a catchment area of 445 km2 (See Annex A)

Dam reservoir: Adopting dimensions decided in previous feasibility study (F/S). The total water volume: 248.275 MCM at EL 221.18 m, including a dead water volume of 6.66 MCM

Evaporation: Evaporation from the reservoir surface is derived from analysed data (See Annex A)

Drinking water supply: Not considered

The command area should be irrigable having water shortage of less than 15% of the water requirement in the most severe cycle (an event on the dam operation recurring from a full water stage to another full water stage is counted as one cycle or one time) during the dam operation study term, which was appraised at around 15 times probability of failure.

Firstly, dam operation calculation was carried out assuming 4 irrigable areas of 6,000, 8,000, 10,000, and 12,000 ha. And then, calculation on return times probability of failure for each case was conducted. The result of the calculation of necessary dam capacity is tabulated below:

(MCM)

Return times probability	6,000ha	8,000ha	10,000ha	12,000ha
2	39.31	56.09	78.43	109.83
5	51.88	77.27	117.77	172.43
10	65.88	100.87	161.58	242.16
20	83.47	130.52	216.64	329.78
30	100.35	158.97	269.45	413.83
40	116.90	186.86	321.25	496.26
50	122.19	195.78	337.81	522.62
60	126.50	203.05	351.31	544.10
100	138.56	223.37	389.04	604.14

Based on the above result, the irrigation area of the proposed Beydağ reservoir of 248.275 MCM was assumed to be between 10,000 ha and 12,000 ha. Using this temporary value, a dam operation study based on the planned dimensions of the reservoir was carried out in order to decide the net irrigation area with 15% water shortage in the most severe operation cycle. As a result, the net irrigation area was calculated to be 10,200 ha (See Figure H-1).

(4) Proposed Ground Water Use in the Project Area

The net irrigation area of the Beydağ dam reservoir is 10,200 ha (12,050 ha in gross, with a conversion factor of 0.846). As the command area of the proposed irrigation system including fields to be irrigated continuously by groundwater will be around 20% of the total groundwater basin area, the available volume of groundwater will also be 20% of the total volume of groundwater in the whole basin. Of the total groundwater volume of 160 MCM in the whole basin, 32.5 MCM will be appropriated for irrigation in the proposed area.

Area to be irrigated by groundwater in the Project Area is corresponding to the available groundwater, which is totaling 5,200 ha (6,150 ha in gross, with a conversion factor of 0.846) including 700 ha of 6 cooperatives. The groundwater irrigation areas will be provided with modern irrigation systems same as in the surface water irrigation areas. The proposed total irrigation area thus becomes 15,400 ha (18,200 ha in gross).

3 Irrigation Development Plan for the Aktaş Dam

(1) Command Area

The command area of the Aktaş dam will be a cultivation field located in the western part of Ödemiş town, extending from the gorge of the Aktaş river to the Küçük Menderes river. The area will be bounded on the north by the main canal, of which elevation was planned to be around 150 m where water flows down through the proposed diversion canal from the lowest water level of the Aktaş reservoir at EL.328.0 m. The western and eastern parts should be bounded by an existing tributary, which will be selected so as to have an equivalent command area irrigable by storage water of the proposed Aktaş reservoir.

(2) Irrigation Water Requirement in the Proposed Plan

The irrigation water requirement in the proposed plan was calculated taking into consideration the proposed cropping calendar which was prepared based on the present soil and land use conditions. Necessary factors used in the calculation of water requirement were derived from values under the present condition. The annual average irrigation requirement was calculated at 606.1 mm (See Table H-6), and its monthly apportionment is as follows:

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Aktaş dam	0.3	0.4	4.1	17.1	61.2	97.6	117.1	164.5	99.7	37.0	6.7	0.5	606.1

Note: An overall irrigation efficiency of 0.78 is applied assuming adopting areas for each irrigation method based upon proposed cropping calendar. Each irrigation efficiency for the surface irrigation, sprinkler and drip irigation method, is 0.58, 0.78 and 0.98 respectively.

(3) Command Area by Surface Water

The area to be irrigated by surface water developed by the Aktaş dam was determined through a dam operation study, applying the unit water requirement estimated above. The following conditions were assumed in the dam operation study:

Study term:	29 years from 1965 to 1993, corresponding to the period of available runoff discharge data of the Aktaş river
Runoff data:	Runoff discharge data of the Aktaş river at the dam site having a catchment area of 58.7 km^2 (See Annex A)
Dam reservoir:	Adopting dimensions decided in previous F/S. Total water volume: 17.312 MCM at El.372.0 m, which including a volume water dead of 0.59 MCM
Evaporation:	Evaporation from reservoir surface is derived from analyzed data (See Annex A)
Drinking water supply:	Supplying an incremental volume of 2.4 MCM to cover water demand of Ödemiş in 2020, plus conveyance losses of 10% of such net demand.

The command area should be irrigable having water shortage of less than 15% of the water requirement in the most severe cycle (an event on the dam operation recurring from a full water stage to another full water stage is counted as one cycle or one time) during the dam operation study term, which was appraised at around 15 times probability of failure.

Firstly, dam operation calculation was carried out assuming 4 irrigable areas of 600, 800, 1,000, and 1,200 ha. And then, calculation on return times probability of failure for each case was conducted. The result of the calculation of necessary dam capacity is tabulated below:

				(MCM)
Return times probability	600ha	800ha	1,000ha	1,200ha
2	4.39	5.79	7.72	9.94
3	5.37	7.70	11.08	15.20
5	6.47	9.82	14.84	21.07
10	7.85	12.49	19.55	28.43
20	9.17	15.05	24.07	35.50
30	9.93	16.52	26.67	39.56
40	10.47	17.55	28.51	42.43
50	10.89	18.36	29.93	44.64
60	11.22	19.01	31.08	46.45
100	12.17	20.84	34.31	51.49

According to the above result, the irrigation area of the proposed Aktaş reservoir of 16.722 MCM would be between 800 ha and 1,000 ha. Using this temporary value, a dam operation study based on the planned dimension of the reservoir was carried out in order to decide the net irrigation area with 15% water shortage in the severest operation cycle. The net irrigation area was calculated to be 850 ha (See Figure H-2).

(4) Selection of Scheme for Each Purpose of Water Use

If the Project is formulated as a multi-purpose scheme combining irrigation water supply and drinking water supply, the irrigation area will be 850 ha (1,000 ha in gross, with a conversion factor of 0.846) as mentioned above. The project cost should be allocated to the component of drinking water supply. For the single-purpose scheme for drinking water supply only, the reservoir was planned to have a total volume of 6.41 MCM including a dead volume of 0.59 MCM, based on the results of the dam operation study at the same dam site.

The single-purpose scheme for irrigation water supply will benefit 1,310 ha (1,550 ha in gross), which is 154% of the beneficiary area of the multi-purpose scheme. While the difference in beneficiary areas between the two schemes is rather significant, the drinking water supply scheme must be combined with the irrigation scheme due to no alternative water source excepting the Aktaş river. For this reason, this dam Project should be a multi-purpose one for both irrigation and drinking water supply.

(5) Proposed Groundwater Use in the Project Area

The area to be irrigated by groundwater in the Project Area is corresponding to available groundwater of 2.7 MCM, which will be 450 ha (530 ha in gross, with a conversion factor of 0.846) including 350 ha of 2 cooperatives. The groundwater irrigation areas will be provided with modern irrigation systems same as in the surface water irrigation areas. The proposed total irrigation area thus becomes 1,300 ha (1,530 ha in gross).

(6) Irrigation System

Irrigation water will be diverted from the proposed dam and conveyed to an irrigation system through a diversion canal. The irrigation system will be mainly composed of 2 main canals, as shown in Figure H-6. The left main canal will have a length of 3.0 km and a discharge capacity of 0.34 m^3/sec. at its head, while the right main canal will have a length of 4.0 km and a discharge capacity of 0.15 m^3/sec.

4 Irrigation Development Plan for Burgaz Dam

(1) Command Area

The command area of the Burgaz dam will be a cultivation field located in the eastern part of Bayındır town, extending from the gorge of the Degirmen river to the Küçük Menderes river. The area will be adjacent to the command area of the Ergenli dam on the west and bounded on the north by the main canal, of which elevation was set at around 100 m to have sufficient head for water conveyance when the lowest water level of the Burgaz reservoir is at EL.115.87 m. On the south and west, it will be bounded by the Küçük Menderes river and Degirmen river, respectively.

(2) Irrigation Water Requirement in the Proposed Plan

The irrigation water requirement in the proposed plan was calculated taking into consideration the proposed cropping calendar which was prepared based on the present soil and land use conditions. Necessary factors used in the calculation of water requirement were derived from values under the present condition. The annual average irrigation requirement was calculated at 638.8 mm (See Table H-7), and its monthly apportionment is as follows:

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Burgaz dam	0.2	0.4	3.9	15.9	65.0	117.8	140.4	168.5	95.5	28.8	2.2	0.3	638.8

Note: An overall irrigation efficiency of 0.78 is applied assuming adopting areas for each irrigation method based upon proposed cropping calendar. Each irrigation efficiency for the surface irrigation, sprinkler and drip irrigation method, is 0.58, 0.78 and 0.98 respectively.

(3) Command Area by Surface Water

The area to be irrigated by surface water developed by the Burgaz dam was determined through a dam operation study, applying the unit water requirement estimated above. The following conditions were assumed in the dam operation study:

Study term:	29 years from 1965 to 1993, corresponding to the period of runoff discharge data of the Degirmen river
Runoff data:	Runoff discharge data of Degirmen river at the dam site having catchment area of 91.0 km^2 (See Annex A)
Dam reservoir:	Adopting dimensions decided in the previous master plan study (M/S). Total water volume: 70.0 MCM at EL.197.89 m, which including a water volume dead of 1.14 MCM
Evaporation:	Evaporation from reservoir surface is derived from analyzed data (See Annex A)
Drinking water supply:	Not considered

The command area should be irrigable having water shortage of less than 15% of the water requirement in the most severe cycle (an event on the dam operation recurring from a full water stage to another full water stage is counted as one cycle or one time) during the dam operation study term, which was appraised at around 15 times probability of failure.

Firstly, dam operation calculation was carried out assuming 4 irrigable areas of 2,000, 2,500, 3,000, and 3,500 ha. And then, calculation on return times probability of failure for each case was conducted. The result of the calculation of necessary dam capacity is tabulated below:

				(MCM)
Return times probability	2,000ha	2,500ha	3,000ha	3,500ha
2	9.91	13.72	19.40	28.59
3	12.63	18.74	29.19	45.85
5	15.66	24.33	40.08	65.08
10	19.46	31.35	53.77	89.22
20	23.11	38.09	66.91	112.39
30	25.21	41.96	74.46	125.71
40	26.69	44.70	79.79	135.11
50	27.84	46.81	83.90	142.37
60	28.77	48.53	87.26	148.29
100	31.38	53.34	96.64	164.84

Based on the above result, the irrigation area for the proposed Burgaz reservoir of 68.86 MCM was assumed to be between 3,000 ha and 3,500 ha. Using this temporary value, a dam operation study based on the planned dimensions of reservoir was carried out in order to decide the net irrigation area with 15% water shortage in the severest operation cycle. The net irrigation area was estimated at 3,300 ha (Figure H-3).

(4) Proposed Groundwater Use in the Project Area

The area to be irrigated by groundwater in the Project Area is corresponding to available groundwater of 10.2 MCM, which will be 1,600 ha (1,890 ha in gross, with a conversion factor of 0.846) including 750 ha of 5 cooperatives. The groundwater irrigation areas will be provided with modern irrigation systems same as in the surface water irrigation areas. The proposed total irrigation area thus becomes 4,900 ha (5,790 ha in gross).

(5) Irrigation System

The irrigation system will mainly consist of 2 main canals, as shown in Figure H-6. The left main canal will have a length of 8.0 km and a discharge capacity of 1.24 m^3/sec. at its head, while the right main canal will have a length of 6.0 km and a discharge capacity of 0.67 m^3/sec.

5 Irrigation Development Plan for Ergenli Dam

(1) Command Area

The command area of the Ergenli dam will be a cultivation field located in the south-eastern part of Bayındır town, extending on the right bank of the Mica river from its gorge to the Küçük Menderes river. On the east, the command area will be adjacent to the command area of the Burgaz dam. It will be bounded on the north by the main canal, of which elevation was set at 100 m to have sufficient head for water conveyance when the lowest water level of the Burgaz reservoir is at EL.134.5 m. The Küçük Menderes river will form the southern boundary of the area.

(2) Irrigation Water Requirement in the Proposed Plan

The irrigation water requirement in the proposed plan was calculated taking into consideration the proposed cropping calendar which was prepared based on the present soil and land use conditions. Necessary factors used in the calculation of water requirement were derived from values under the present condition. The annual average irrigation requirement was calculated at 638.8 mm (See Table H-7), and its monthly apportionment is as follows:

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Ergenli dam	0.2	0.4	3.9	15.9	65.0	117.8	140.4	168.5	95.5	28.8	2.2	0.3	638.8

Note: An overall irrigation efficiency of 0.78 is applied assuming adopting areas for each irrigation method based upon proposed cropping calendar. Each irrigation efficiency for the surface irrigation, sprinkler and drip irrigation method, is 0.58, 0.78 and 0.98 respectively.

(3) Command Area by Surface Water

The area to be irrigated by surface water developed by the Ergenli dam was determined through a dam operation study, applying the unit water requirement estimated above. The following conditions were assumed in the dam operation study:

Study term:	29 years from 1965 to 1993, corresponding to the period of runoff discharge data of the Mica river
Runoff data:	Runoff discharge data of Mica river at the dam site having a catchment area of 98.0 km^2 (See Annex A)
Dam reservoir:	Adopting dimensions of decided in previous M/S. Total water volume: 63.0 MCM at EL.191.97 m, including volume a dead volume of 1.22 MCM
Evaporation:	Evaporation from reservoir surface is derived from analyzed data (See Annex A)
Drinking water supply:	Supplying an incremental volume of 0.55 MCM to cover the drinking water demand of Bayındır in 2020, plus conveyance losses of 10% of such net demand

The command area should be irrigable having water shortage of less than 15% of the water requirement in the most severe cycle (an event on the dam operation recurring from a full water stage to another full water stage is counted as one cycle or one time) during the dam operation study term, which was appraised at around 15 times probability of failure.

Firstly, dam operation calculation was carried out assuming 4 irrigable areas of 2,000, 2,500, 3,000, and 3,500 ha. And then, calculation on return times probability of failure for each case was conducted. The result of the calculation of necessary dam capacity is tabulated below:

Return times probability	2,000ha	2,500ha	3,000ha	3,500ha (MCM)
2	9.88	13.62	19.18	28.07
3	12.52	18.58	28.43	44.64
5	15.45	24.09	38.74	63.10
10	19.15	31.03	51.70	86.30
20	22.69	37.68	64.13	108.55
30	24.73	41.50	71.28	121.35
40	26.16	44.20	76.32	130.37
50	27.27	46.28	80.21	137.35
60	28.18	47.98	83.39	143.04
100	30.71	52.73	92.27	158.93

Based on the above result, the irrigation area for the proposed Ergenli reservoir of 61.78 MCM was assumed to be between 3,000 ha and 3,500 ha. Using this temporary value, a dam operation study based on the planned dimensions of reservoir was carried out in order to decide the net irrigation area with 15% water shortage in the severest operation cycle. The net irrigation area was estimated at 3,150 ha (See Figure H-4).

(4) Selection of Scheme for Each Purpose of Water Use

If the Project is formulated as multi-purpose scheme combing irrigation water supply and drinking water supply, the irrigation area will be 3,150 ha (3,720 ha in gross, with a conversion factor of 0.846) as mentioned above.

The drinking water supply scheme shall be combined with the irrigation scheme because there is no alternative water source except the Mica river, and there would no significant negative effect for such a combination due to the small share of water for drinking purpose (less than 3% of the irrigation water volume).

The cost allocation should be carried out using alternative cost of drinking water supply. The single-purpose scheme for drinking water supply will not require the construction of a dam and reservoir but only a diversion weir at the same dam site. The diversion weir is proposed to be of concrete fixed type, equipped with gates, and having a total length of 270 m.

(5) Proposed Groundwater Use in the Project Area

The area to be irrigated by groundwater in the Project Area is corresponding to available groundwater of 9.6 MCM, which will be 1,500 ha (1,770 ha in gross, with a conversion factor of 0.846) including 280 ha of 1 cooperative. The groundwater irrigation areas will be provided with modern irrigation systems same as in the surface water irrigation areas. The proposed total irrigation area thus becomes 4,650 ha (5,490 ha in gross).

(6) Irrigation System

Irrigation water will be diverted from the dam site and conveyed to the irrigation system through a diversion canal of concrete flume type. The major facility of the irrigation system is the right main canal aligned upstream of Bayındır town as shown in Figure H-6. The main canal will have a length of 10.0 km and a discharge capacity of 1.83 c.m.s.

6 Irrigation Development Plan for the Uladı Dam

(1) Command Area

The command area of the Uladi dam will be a cultivation field located in the western part of Bayındır town, extending mainly on the right bank of the Uladi river from the dam site to the Küçük Menderes river. The eastern part of the command area will be adjacent to the command area of the Ergenli dam. The area will be bounded on the north by the main canal, of which elevation was set at around 85 m to have sufficient head for water conveyance the lowest water level of the Uladi reservoir is at EL.92.0 m. The southern boundary of the area will be the Küçük Menderes river.

(2) Irrigation Water Requirement in the Proposed Plan

The irrigation water requirement in the proposed plan was calculated taking into consideration the proposed cropping calendar which was prepared based on the present soil and land use conditions. Necessary factors used in the calculation of water requirement were derived from values under the present condition. The annual average irrigation requirement was calculated at 638.8 mm (See Table H-7), and its monthly apportionment is as follows:

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Uladi dam	0.2	0.4	3.9	15.9	65.0	117.8	140.4	168.5	95.5	28.8	2.2	0.3	638.8

Note: An overall irrigation efficiency of 0.78 is applied assuming adopting areas for each irrigation method based upon proposed cropping calendar. Each irrigation efficiency for the surface irrigation, sprinkler and drip irrigation method, is 0.58, 0.78 and 0.98 respectively.

(3) Command Area by Surface Water

The area to be irrigated by surface water developed by the Uladi dam was determined through a dam operation study, applying the unit water requirement estimated above. The following conditions were assumed in the dam operation study:

Study term:	29 years from 1965 to 1993, corresponding to the period of available runoff discharge data of Uladi river
Runoff data:	Runoff discharge data of the Uladi river at the dam site having a catchment area of 66.0 km^2 (See Annex A)
Dam reservoir:	Referring to the dimensions decided in previous M/S. Total water volume: 42.7 MCM at EL.148.50 m, including a dead volume of 0.99 MCM
Evaporation:	Evaporation from reservoir surface is delivered from an analyzed data (See Annex A)
Drinking water supply:	Not considered

The command area should be irrigable having water shortage of less than 15% of the water requirement in the most severe cycle (an event on the dam operation recurring from a full water stage to another full water stage is counted as one cycle or one time) during the dam operation study term, which was appraised at around 15 times probability of failure.

Firstly, dam operation calculation was carried out assuming 4 irrigable areas of 1,750, 2,000, 2,250, and 2,500 ha. And then, calculation of probability of failure for each case was conducted. The result of the calculation of necessary dam capacity is tabulated below:

Return times probability	1,750ha	2,000ha	2,250ha	2,500ha
				(MCM)
2	9.46	11.86	14.86	20.26
3	12.83	17.03	22.46	32.26
5	16.58	22.79	30.92	45.62
10	21.29	30.03	41.56	62.42
20	25.81	36.97	51.76	78.53
30	28.41	40.97	57.63	87.79
40	30.25	43.78	61.77	94.33
50	31.66	45.96	64.97	99.38
60	32.82	47.74	67.58	103.50
100	36.05	52.70	74.87	115.00

Based on the above result, the irrigation area for the proposed Ergenli reservoir of 41.71 MCM was assumed to be between 2,000 ha and 2,250 ha. Using this temporary value, a dam operation study based on the planned dimensions of reservoir was carried out in order to decide the net irrigation area with 15% water shortage in the severest operation cycle. The net irrigation area was estimated at 2,150 ha (See Figure H-5).

(4) Proposed Groundwater Use in the Project Area

The area to be irrigated by groundwater in the Project Area is corresponding to available groundwater of 6.7 MCM, which will be 1,050 ha (1,250 ha in gross, with a conversion factor of 0.846) including 1,000 ha of 9 cooperatives. The groundwater irrigation areas will be provided with modern irrigation systems same as in the surface water irrigation areas. The proposed total irrigation area thus becomes 3,200 ha (3,790 ha in gross).

(5) Irrigation System

The major facilities of the irrigation system will be the right main canal aligned on the right bank of the Uladi river, as shown in Figure II-6. The right main canal will have a length of 6.6 km and a discharge capacity of 1.28 m^3/sec. A small portion located on the left bank of the river will be supplied with water by a lateral canal branched off from the main canal.

7 Conclusion on the Irrigation Development Plan

Positive effects of the proposed 5 dams mentioned above are schematically illustrated in Figure H-6. The direct beneficiary areas will include: (i) the areas to be irrigated by surface water from the proposed dam reservoirs, and (ii) the areas of existing cooperatives and private farmlands to be continuously irrigated by groundwater within each dam command area. The total direct beneficiary area is shown below:

(Unit:ha)

Project Name	Irrigation by Surface-water		Irrigation by Ground-water		Total Area		Available Ground-water
	Net	Gross	Net	Gross	Net	Gross	
Beydağ	10,200	(12,050)	5,200	(6,150)	15,400	(18,200)	32.5MCM
Aktaş	850	(1,000)	450	(530)	1,300	(1,53)	2.7MCM
Burgaz	3,300	(3,900)	1,600	(1,890)	4,900	(5,790)	10.2MCM
Erganli	3,150	(3,720)	1,500	(1,770)	4,650	(5,490)	9.6MCM
Uladi	2,150	(2,540)	1,050	(1,250)	3,200	(3,790)	6.7MCM

8. Irrigation Method

The furrow irrigation method has been practiced in most of the Project Area, and border and basin irrigation methods have also been practiced in a very limited area, especially for tree crops.

As to the furrow irrigation practice, a ready-made 3" PVC pipe having several outlets has been widely used, which can easily be connected to an existing well. The furrow direction and length are decided so as to reach water sufficiently to the end of the furrow without wasting much water.

Five sample areas of 25 ha each were selected in the field survey to identify the actual situations of the furrow length and farm plot size. The furrow length and farm plot area were measured in the sample areas on the topographic maps with a scale of 1:5,000, and the measured results were checked in the fields. According to the result of this survey, farmers generally take direction of furrow in parallel with contour lines in a steep area, and not in parallel with contour lines in a flat area. The results of the measurement of furrow length and farm plot size are summarized as follows:

Length of Furrow of the Farmland in the Project Area (m)

Item	Sample1	Sample 2	Sample 3	Sample 4	Sample 5	Overall
Landgradient	1/186	1/260	1/200	1/116	1/173	
Average	74.83	87.00	73.13	111.10	113.14	86.56
Mode	95.00	75.00	80.00	120.00	150.00	80.00
Max.	140.00	160.00	160.00	270.00	180.00	270.00
Min.	38.00	35.00	22.00	20.00	30.00	20.00
St.deviation	26.82	27.16	31.92	64.15	47.20	46.19

Farm Plot Size in the Project Area (ha)

Item	Sample1	Sample 2	Sample 3	Sample 4	Sample 5	Overall
Average	0.72	0.84	1.05	0.95	1.02	0.91
Mode	1.04	0.24	0.25	1.50	0.48	0.48
Max.	2.09	2.08	3.30	4.03	2.86	4.03
Min.	0.12	0.21	0.10	0.08	0.16	0.08
St.deviation	0.45	0.44	0.99	0.72	0.74	0.70

The distribution of the measured results are shown in Figure-H.7 and Figure-H.8 respectively.

9 Field Experiment for Irrigation Conducted during the Field Survey

9.1 General Description

(1) Outline of the Experiment

Improvement of irrigation efficiency is the most highlighted aspect for the development of area with limited water resources. Irrigation water losses consist of three categories, namely, conveyance loss, operation loss and application loss. The application loss which is a major element of the irrigation efficiency can be improved by adoption of several modern irrigation methods such as sprinkler and drip irrigation. Even for surface irrigation method, it is possible to improve irrigation efficiency through improvement on water management.

The field experiment for irrigation in the Study has been conducted for the purpose of confirming adaptability of modern irrigation methods, and improving of surface irrigation method to be widely extended in the Study Area.

As explained in the Inception Report on the Study of the Küçük Menderes River Basin Irrigation Project, purposes of the irrigation experiment are as follows:

- to quantify irrigation water requirements,
- to test irrigation efficiency of each irrigation method,
- to investigate salinization due to irrigation, if possible,
- to collect meteorological data for estimation of irrigation water requirements,
- to calculate actual Et, if possible, and
- to investigate the relation between irrigation method and crop yield, if possible.

In order to obtain useful result for these purposes, the experiment field was prepared and the experiment has been carried out.

(2) Experimental Field

Prior to arrival of the Study Team in Turkey in January 1995, DSİ secured approximately 5.0 ha of the experimental field in Konaklı, Ödemiş, and drilled one well having 116 meter depth. The experimental field is located at N38°8'06", E27°59'26" in the south-east part of the Project Area.

As mentioned in the Inception Report of the Study, three kinds of irrigation methods, namely, sprinkler, drip and surface irrigation, have been applied in the field experiment. Necessary equipment for the irrigation experiment were supplied by JICA Study Team, and DSİ was installed them following the layout plan prepared by the Study Team as shown in Figure H-9. Experimental Field-I locating in the southern side of the highway is a main experimental space. Experimental Field-II locating in the northern side of the highway is a supplemental experimental field, in which the furrow irrigation method was applied.

(3) Specification of Provided Irrigation Equipment

(a) Sprinkler Irrigation

Irrigation area:	0.5	ha
Field available soil moisture:	40.0	mm
Daily water consumption:	6.7	mm/day
Irrigation interval:	6.0	days
Applied crop:	vegetable, watermelon, cotton etc.	
Sprinkler specification:		
- Nozzle diameter;	5.2 x 3.2	mm
- Applied pressure;	3.0	ATM
- Spreading diameter;	29.0	m
- Spreading discharge;	40.0	l/min
- Interval of laterals;	20.0	m
- Interval of sprinkler;	14.0	m
- Numbers of sets;	18	sets
- Spreading intensity;	8.7	mm/hr

Irrigation discharge for the plot:

$40^{l/min} \times 18^{sets} / 0.8 = 900.0^{l/min} = 15.0^{l/sec}$

Irrigation hours:

$40.0 \times 10^{-3\,m} \times 5{,}000^{m2} / 15.0^{l/sec} \times 10^{-3} / 3{,}600 = 3.7$ hour

(b) Drip Irrigation

Irrigation area:	0.5	ha
Field available soil moisture:	40.0	mm
Daily water consumption:	6.7	mm/day
Irrigation interval:	6.0	days
Applied crop:	vegetable, watermelon etc.	
Drip specification:		
- Diameter of drip tube;	16.0	mm
- Applied pressure;	1.0	ATM
- Spreading discharge;	0.15	l/min/m
- Interval of tubes;	2.0	m
- Interval of emitter;	0.5	m
- Total length of drip tube;	2,400	m

Irrigation discharge for the plot:

$0.15^{\,l/min/m} \times 2{,}400^{\,m} / 1.0 = 360.0^{\,l/min} = 6.0^{\,l/sec}$

Irrigation hours:

$40.0 \times 10^{-3\,m} \times 5{,}000^{\,m2} / 6.0^{\,l/sec} \times 10^{-3} / 3{,}600 = 9.3$ hour

(c) Furrow Irrigation

Irrigation area:	0.5	ha
Field available soil moisture:	40.0	mm
Daily water consumption:	6.7	mm/day
Irrigation interval:	6.0	days
Applied crop:	vegetable, watermelon, cotton etc.	
Discharge at inlet:	20.0	l/sec

Irrigation hours:

$40.0 \times 10^{-3\,m} \times 5{,}000^{\,m2} / 20.0^{\,l/sec} \times 10^{-3} / 3{,}600 / 0.6 = 4.6$ hour

(d) Border Irrigation

Irrigation area:	0.6	ha
Field available soil moisture:	40.0	mm
Daily water consumption:	6.7	mm/day
Irrigation interval:	6.0	days
Applied crop:	vegetable, watermelon, cotton etc.	
Discharge at inlet:	20.0	l/sec

Irrigation hours:

$40.0 \times 10^{-3\,m} \times 6{,}000^{\,m2} / 20.0^{\,l/sec} \times 10^{-3} / 3{,}600 / 0.6 = 5.6$ hour

(e) Specification of Pump

Irrigation water shall be supplied by the well drilled by DSI by using a sub-merged pump installed following this specification.

Irrigation water will be supplied to each irrigation plot rotationally. The specification of the pump should be decided so as to be able to supply water to each plot in the required quantity and pressure.

Type of pump:	Submerged type (with motor)
Diameter of pump:	150 mm
Diameter of conduit:	100 mm
Lifted head for well:	50.0 m
Required power of pump:	30.0 Hp (the highest required power among each method as follows)

for sprinkler-- $13.32 \times 0.015^{\,m3/sec} \times 85^{\,m} \times (1+0.15) / 0.65 = \underline{30.0\ Hp}$

for drip------ $13.32 \times 0.006^{\,m3/sec} \times 65^{\,m} \times (1+0.15) / 0.65 = 9.2$ Hp

for furrow--- $13.32 \times 0.020^{\,m3/sec} \times 60^{\,m} \times (1+0.15) / 0.65 = 28.3$ Hp for border--- 13.32 x 0.020 $^{m3/sec}$ x 60 ^{m} x (1+0.15) / 0.65 = 28.3 Hp

9.2 Soil Analysis on the Experiment Field

Soil in each irrigation plot of the experimental field was sampled at depth of 30 cm, 60 cm and 90 cm, and analyzed for the items of grain size distribution, real specific gravity, available soil water between field capacity and wilting point. Infiltration test was conducted at eight (8) sites in and around the experimental field. Result of the soil analysis is shown in Table H-8.

9.3 Schedule of Experiment

The JICA Study Team has carried out field survey at the site twice; in winter and summer. In the first field survey in winter from January to March in 1995, the Study Team completed selection, procurement, installation and test-run of irrigation equipment on the experiment, and necessary preparation work for the commencement of the experiment was completed. Soil analysis in the field was also conducted within the said period, and the result of soil analysis was available by May 1995.

During absence of the JICA Study Team after terminating the first field survey, DSİ continued the irrigation experiment in line with the guideline of the experiment discussed between the Study Team and DSİ. Every irrigation method was examined in the experimental plot, in which watermelon and cantaloupe were planted. DSİ has made experiment, cultivating crop, operating irrigation facilities, observing soil water by tensiometers and recording meteorological data. In July 1995, the crops cultivated in the experimental field were harvested.

On August 24, 1995, the Study Team arrived at Izmir to carry out the second field survey. The Study Team has analyzed experimental data collected by DSİ during the absence of the Study Team, and prepared the future experimental schedule.

9.4 Result of the Experiment during Summer season in 1995

(1) General

Production of the crops harvested in the experimental field was rather lower than the production in the average of farmers. Such low productivity was caused by inadequate cultivation and/or poor field conditions, not due to inferiority of irrigation methods applied in the experiment. It must be emphasized that the purpose of this irrigation experiment is not to obtain high production in the experimental field but to obtain useful data and information for the use of study on the modern irrigation methods to be introduced to the area. In viewpoint of this purpose of the experiment, fruitful and important data have been collected by this experiment since establishment of the experimental field.

During absence of Study Team, DSİ conducted the experiment applying watermelon in line with guideline of irrigation experiment as attached in Attachment.

(2) Execution of the Irrigation Experiment

(a) General

Irrigation has been practiced in the experimental field, planting watermelon in the Experimental Field-I located in the southern part, cantaloupe in the Experimental Field-II located in the northern part. The conditions of cultivation in the experimental fields are as follows:

Farm plot	Irrigation method	Date of planting	Date of irrigation started	Date of harvesting
I - 1	Drip	May 5, 1995	May 31, 1995	July 4, 1995
I - 2	Sprinkler	May 6, 1995	May 31, 1995	July 7, 1995
I - 3	Furrow(special)	May 6, 1995	June 1, 1995	July 13, 1995
I - 4	Border	May 12, 1995	June 1, 1995	July 13, 1995
II	Furrow	May 12, 1995	May 27, 1995	-

Irrigation was started after more than three weeks from planting, due to taking time for re-setting of irrigation facilities including pipeline. Such delay of irrigation seems to be the cause of low production of crop.

Meteorological data observed in Konaklı station established by the Study Team are shown in table below. According to these data, effective rainfall was negligible during the irrigation period, due to scarce rainfall.

Month	Rainfall	Evaporation	Temperature			Relative humidity
			Max.	Min.	Average	
	(mm)	(mm)	(°C)			(%)
April	49.6	131.1	-	-	-	-
May	23.8	252.7	-	-	-	-
June	0.0	352.1	-	-	-	-
July	0.0	353.0	35.6	18.0	26.6	48.7
August	24.2	295.4	35.1	15.2	25.5	54.6

(b) Drip Irrigation Experiment

During the irrigation period, tensiometers had been gauged everyday at the center of the plots at three depths of soil of 20 cm, 40 cm and 60 cm as shown in Attachment. The observed the values were converted to the values of soil moisture content using the result of the soil analysis conducted by the Study Team. The transition of the converted values of the soil moisture content at each depth are shown in the figure shown in Attachment.

The above figures show the fact that soil is supplied with water at every depth with practices of irrigation. No delay of soaking below layer was found. Irrigation water reached to lower layer within a day of irrigation. However, in case of applying drip irrigation method, the difference of soil moisture between the upper soil layer and the lower layer is conspicuous in comparison with such difference observed through other irrigation methods. From this result, the drip irrigation method seems to enable to supply water effectively to the upper soil layer.

A good correlation between irrigation intensity and increment of soil moisture content is not recognized in the above figures. The reason for it is due to difference of growing stage of crop, or difference of measuring site of tensiometer. Some tendencies on the decreasing rate of soil moisture have been recognized as follows:

i) The reducing rate of soil moisture becomes higher as the progress of crop growth stage.

ii) When the soil layer is deeper, the reducing rate of soil moisture becomes lower.

iii) For the same soil layer depth, the reducing rate of soil moisture becomes higher when the moisture value itself is higher.

During the irrigation period, frequent irrigation was given in consideration of characteristic of the drip irrigation method. However, it is recognized that a certain irrigation interval can be taken depending upon soil texture. Assuming the soil moisture is available for crop between 10 cbr to 100 cbr, at least 10-days irrigation interval seems to be allowable in the experimental field.

(c) Sprinkler Irrigation Experiment

During the irrigation period, tensiometers had been gauged everyday at the center of the plot at three depth of soil of 20 cm, 40 cm and 60 cm as shown in Attachment same as in the case of drip irrigation. The transition of soil moisture content at each depth is shown in the figure shown in Attachment.

Sprinkling intensity has been set at 8.7 mm/hr. Infiltration rate in the experimental field has been equated as $I\ (mm/hr) = 41.02 \times T^{-0.427}$. According to the result of infiltration characteristic of soil, the infiltration rate will decrease to less than 8.0 mm/hr after 45 minutes from the start of sprinkling. When the sprinkling intensity exceeds infiltration rate of soil, excess water of such difference is retained on the surface of soil. During the experiment, inundation was partly found in the sprinkler plot. From this reason, it is concluded that the relation between the infiltration rate characteristic and drainage condition must be taken into consideration when the sprinkler irrigation is introduced. Furthermore, it is noted that the soil should not be compacted much by heavy equipment before planting.

The figure shown in Attachment shows the fact that soil is supplied with water at every depth with practices of irrigation. No delay of soaking below layer was found. Irrigation water reached to the lower layer within a day of irrigation. Difference of soil moisture between the upper soil layer and the lower layer is small in comparison with such difference observed when applying the drip irrigation method. Good correlation between the irrigation intensity and the increment of soil moisture content is not recognized in the figure. The reason for it is due to the difference of growing stage of crop, or difference of the measuring site of tensiometer. The same tendency as that in the case of drip irrigation was recognized for the decreasing rate of soil moisture as follows:

i) The reducing rate of soil moisture becomes higher as the progress of crop growth stage.

ii) When the soil layer is deeper, the reducing rate of soil moisture becomes lower.

iii) For the same soil layer depth, the reducing rate of soil moisture becomes higher when the moisture value itself is higher.

During the irrigation period, several days irrigation interval was given. It is recognized that a long irrigation interval can be taken depending upon soil. Assuming the soil moisture is available for crop between 10 cbr to 100 cbr, at least 10-days irrigation interval seems to be allowable same as in the case of drip irrigation.

(d) Surface Irrigation Experiment

Border irrigation and furrow irrigation methods were practiced in the experimental field in order to compare the test results of the border and furrow irrigation methods with those of modern irrigation methods. During irrigation period, tensiometers had been gauged everyday at the center of the plot at three depth of soil of 20 cm, 40 cm and 60 cm as mentioned in Attachment. The transition of converted values of soil moisture content at each depth are shown in the figure in Attachment.

The gradient of field is as steep as around 1/100. Due to this steepness of field, the irrigation water ran fast. As water reached immediately to the end of the field, the upper portion was not given sufficient water, while the lower portion was inundated. By these problems, production in these farm plots was relatively low. From this fact, it is concluded that the direction of furrow and border should be carefully given so as to obtain moderate gradient less than 1/200, and the length of furrow and border should be properly decided in consideration of infiltration characteristic.

The figures in Attachment shows the fact that soil is supplied with water at every depth with practices of irrigation. No delay of soaking the lower layer was found. Irrigation water reached to the lower layer within a day of irrigation. Good correlation between the irrigation intensity and the increment of soil moisture content is not recognized in the figures. The reason for it is due to the difference of growing stage of crop, or the difference of measuring site of tensiometer. The same tendency as in the case of other irrigation methods have been recognized for the decreasing rate of soil moisture.

During the irrigation period, frequent irrigation was given in consideration of characteristic of the irrigation method. However, it is recognized that a certain irrigation interval can be taken depending upon soil in the experimental field. Assuming the soil moisture is available for crop between 10 cbr to 100 cbr, more than 10-days irrigation interval seems to be allowable same as in the case of other irrigation methods.

9.5 Conclusion and Recommendation

The volume of irrigation water supplied during the experiment for each irrigation method is summarized in the following table.

Farm plot	Area (m2)	Irrigation water (m3)	Depth of irrigation water (mm)	Remarks
I - 1	5,000	862.6	172.5	
I - 2	5,000	1,112.7	222.5	Surplus water was provided.
I - 3	5,000	*781.7*	*156.3*	Insufficient water was supplied.
I - 4	6,000	*991.7*	*165.2*	Insufficient water was supplied.
II	25,000	7,294.6	291.8	

Net water requirement of fresh fruits is estimated at 166 mm applying the modified Blaney-Criddle method. In case of the drip irrigation method, 96.2% of the field application efficiency (166/172.5) is obtained by the measured water volume of irrigation. For sprinkler irrigation, irrigated water was in excess compared with an adequate water requirement. Furthermore, supply of water was stopped insufficiently in case of the surface irrigation method in the plots I - 3 and I - 4, due to the occurrence of water puddle at the edge of the plot.

From these experimental results, following conclusion were tentatively obtained.

(i) Drip irrigation method is much applicable to the Study Area. Therefore, it is recommended to introduce this method to this area, in consideration of the cost performance and planting crop.

(ii) Sprinkler irrigation method can be applied if sprinkling intensity is set smaller than infiltration rate of soil. An agronomist insisted that moistening atmosphere through sprinkling water must be harmful for crop in viewpoint of plant-pathology. However, it can not be considered harmful, because water is not given continuously but at 6 ~ 10 days interval. If necessary, a special experiment on such field should be conducted.

(iii) As for the adoption of surface irrigation method, the gradient of furrow or border is the most important factor, besides percolation rate of soil. Direction of furrow or border must be taken so as to give a moderate velocity of water. And applicable length of furrow is restricted by infiltrating characteristic of soil.

(iv) In order to save irrigation water, it is most important to identify when and how much irrigation water should be given. Tensiometer is very useful for this purpose. According to the result of the irrigation experiment during Phase I Study, the measurement of soil moisture by tensiometer at even only one depth among 20 cm, 40 cm or 60 cm is sufficient to know such timing for irrigation.

(v) DSI's effort paid on this experiment up to present should be strongly appreciated. It is recommended that the experiment should be done for other crops which are common in this area.