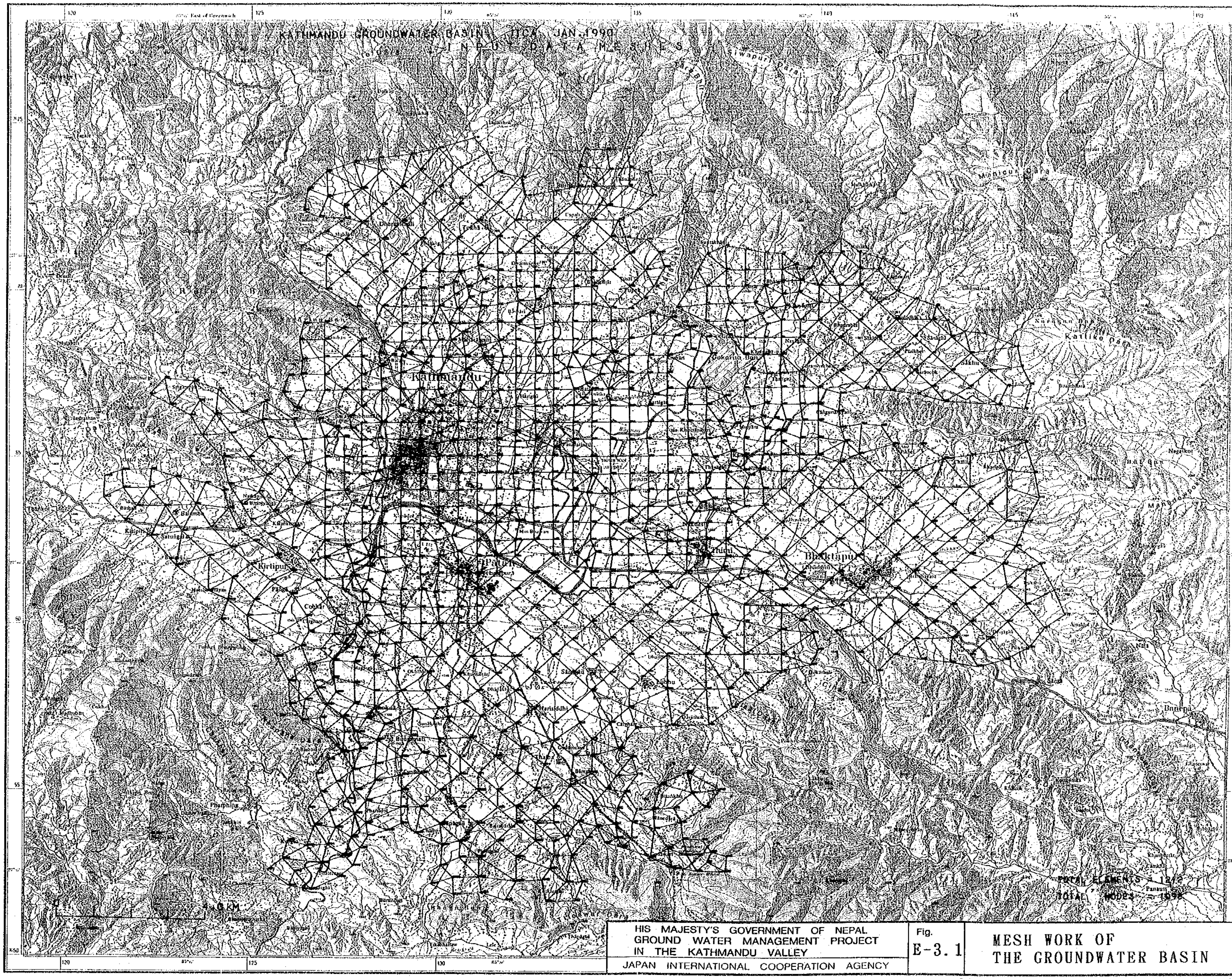
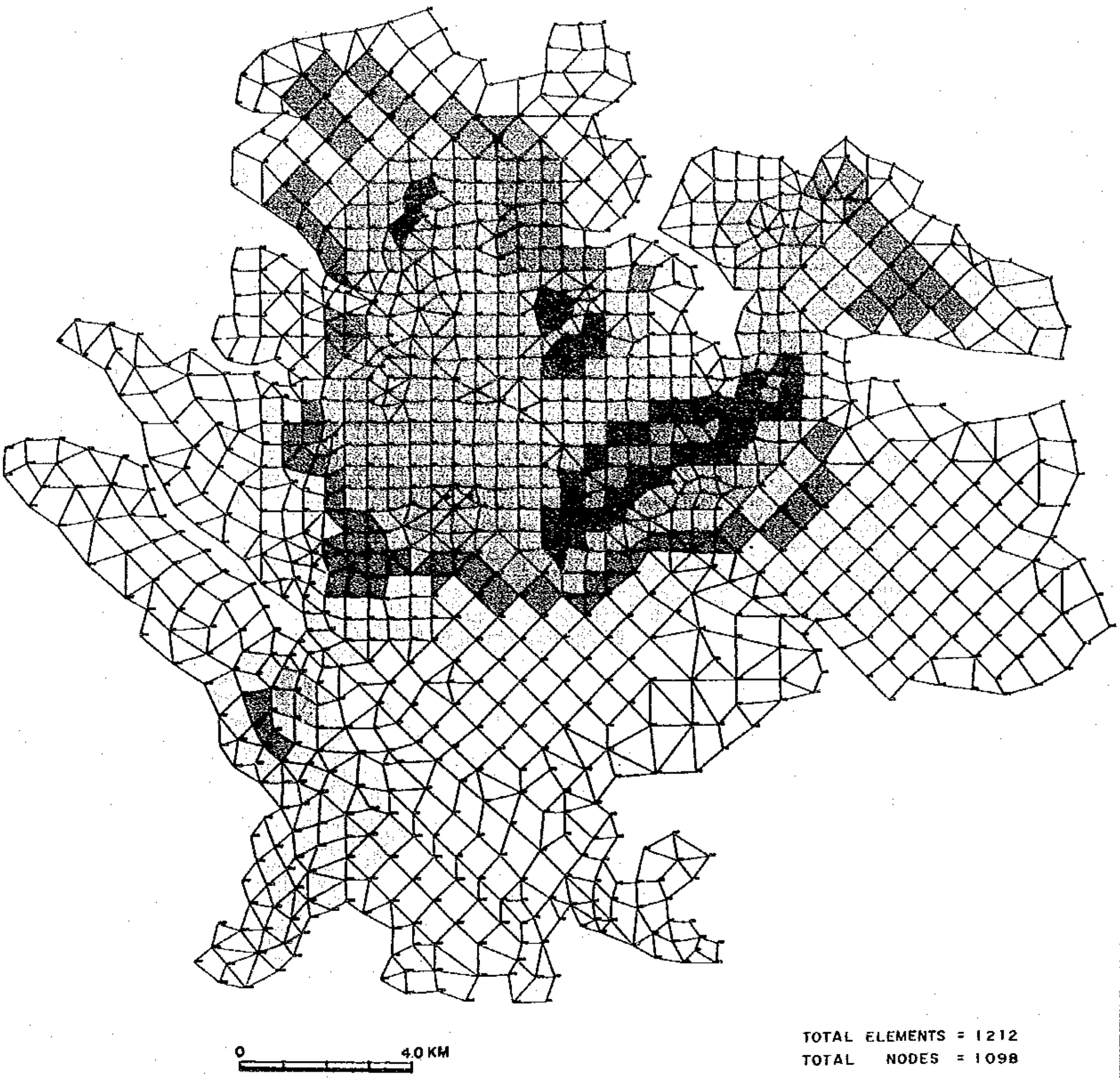


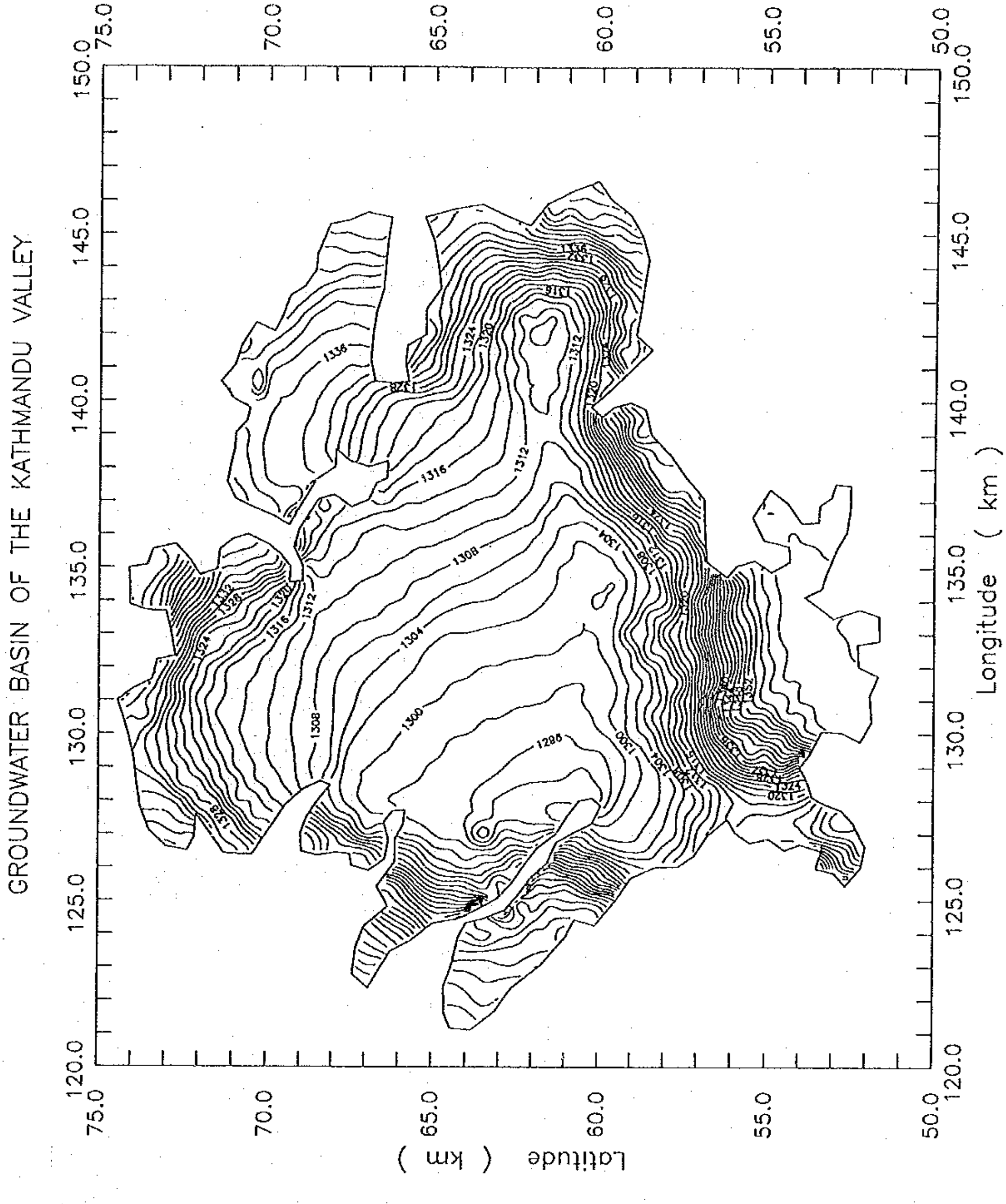
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. E-3.1	MESH WORK OF THE GROUNDWATER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY		



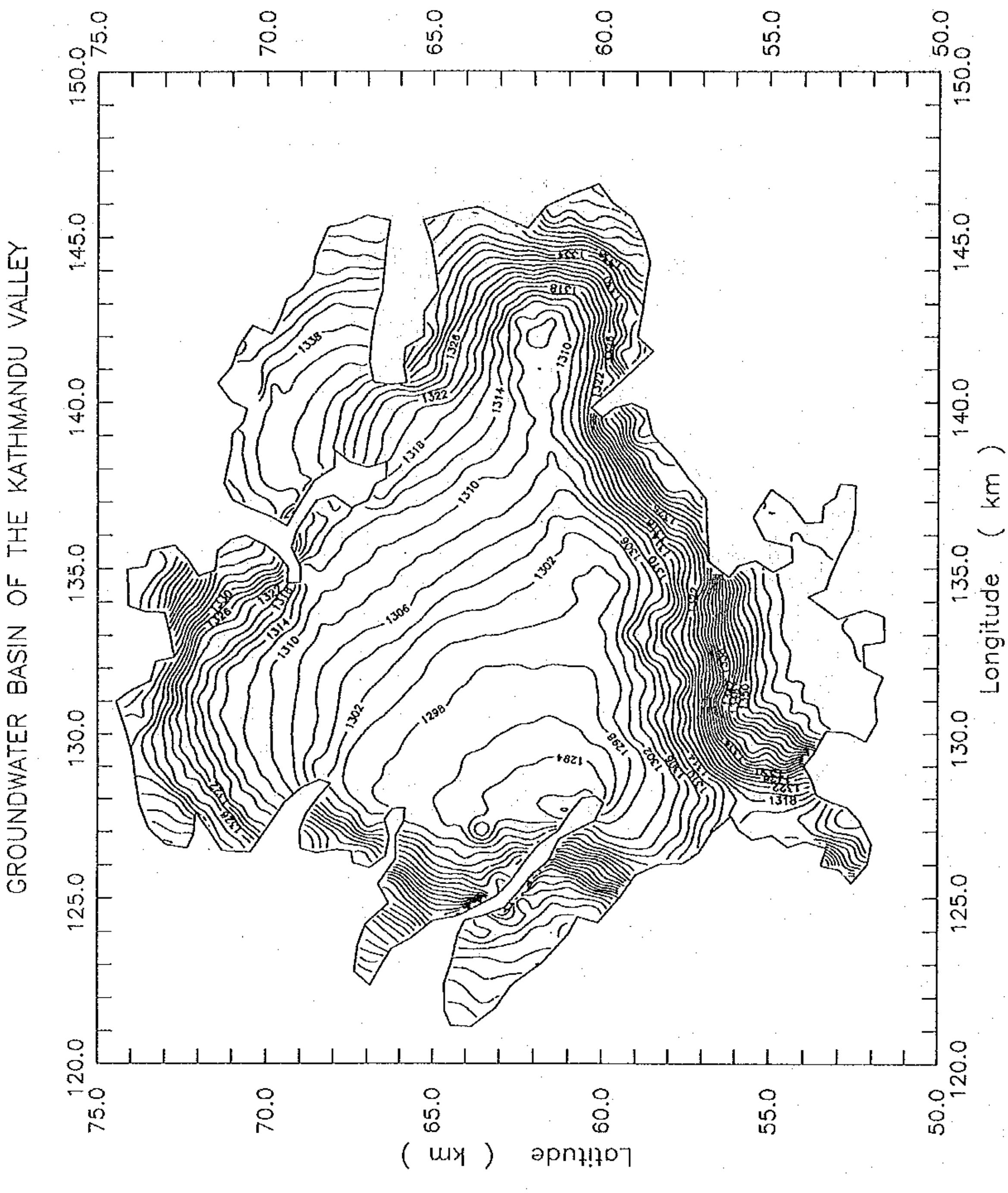
TOTAL ELEMENTS = 1212
TOTAL NODES = 1098

Classification	Transmissivity (m^2 /day)
1	10.0
2	25.0
3	75.0
4	150.0
5	300.0
6	500.0
7	700.0

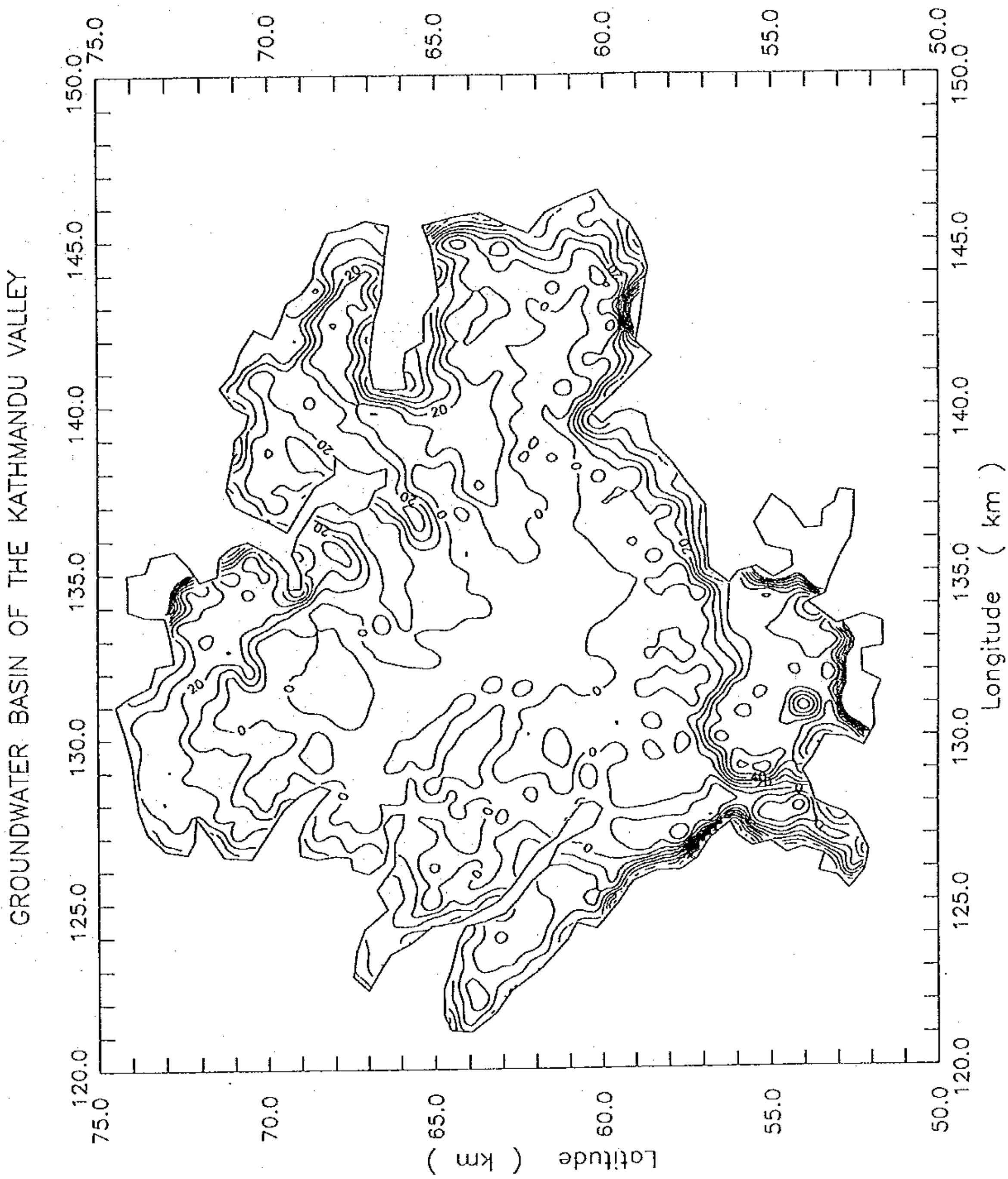
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. E-3.2	CLASSIFICATION OF PERMEABILITY



HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. E-3.3	GROUNDWATER IN 1972 (STEADY CONDITION)
JAPAN INTERNATIONAL COOPERATION AGENCY		

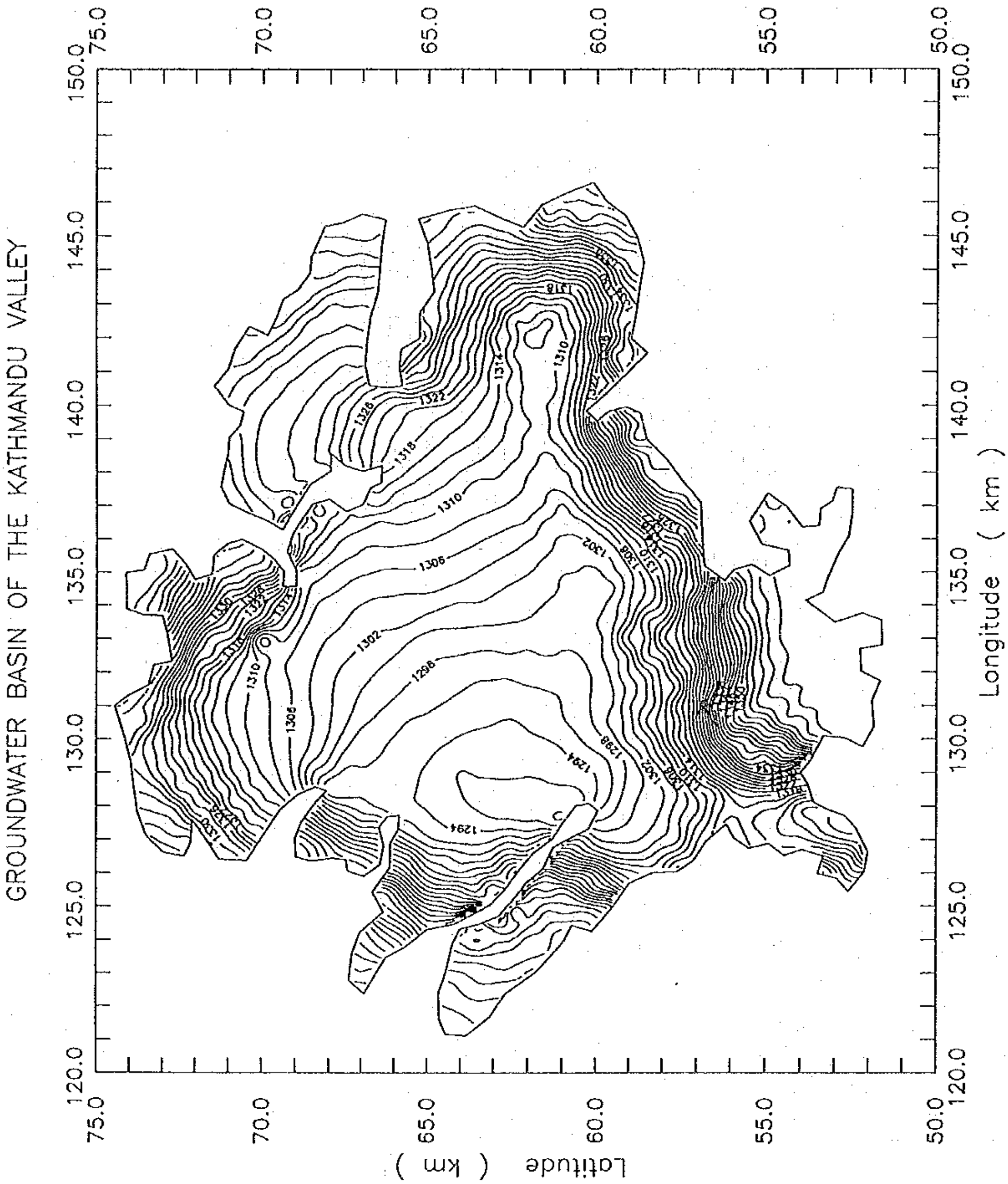


HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. E-3.4	GROUNDWATER IN 1983 (STEADY CONDITION)
JAPAN INTERNATIONAL COOPERATION AGENCY		

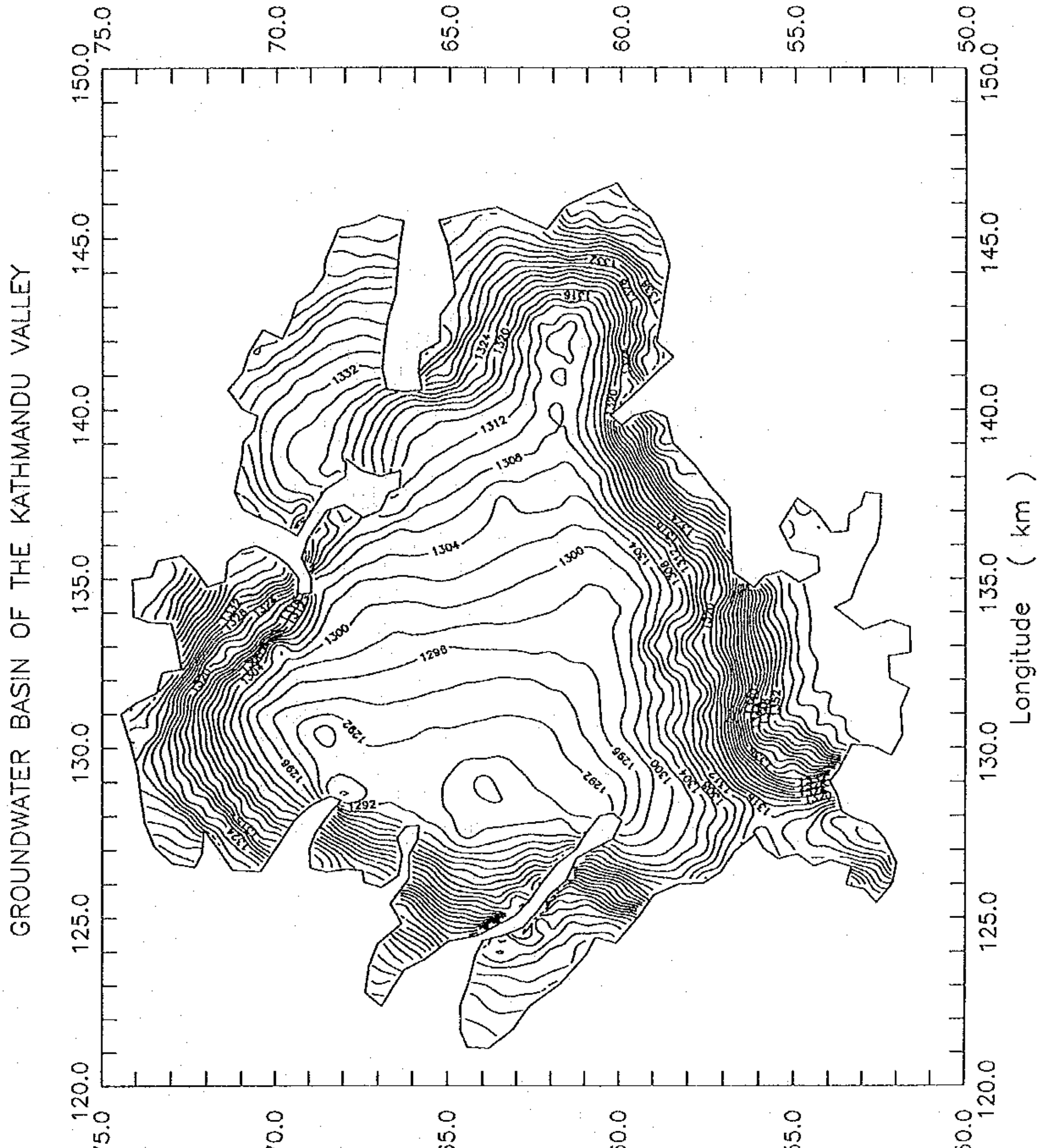


Possible head for artificial recharge in meter
(Head of the main aquifer - head of aquitard layer)

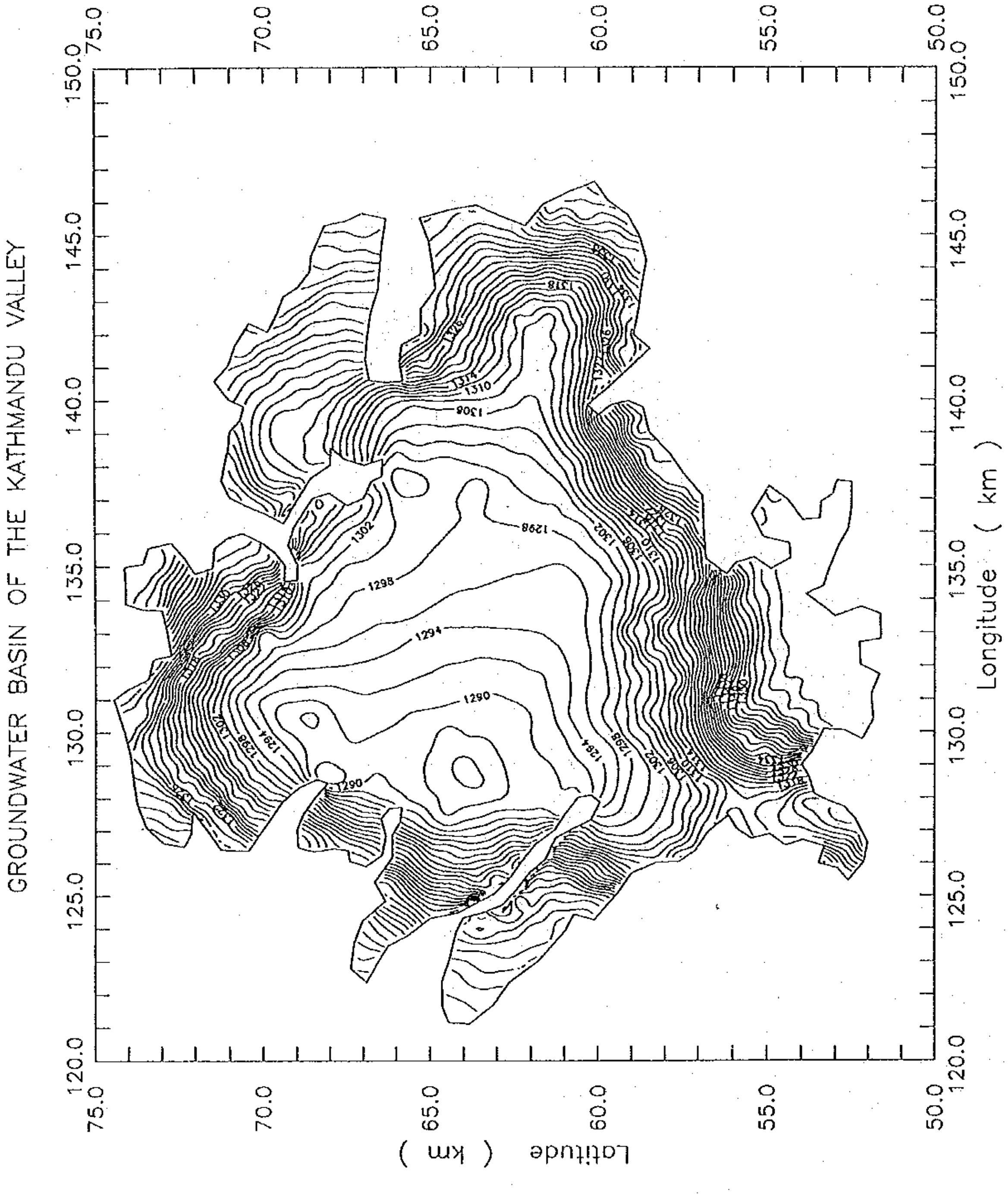
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. E-3.5	POSSIBLE ARTIFICIAL RECHARGE AREA



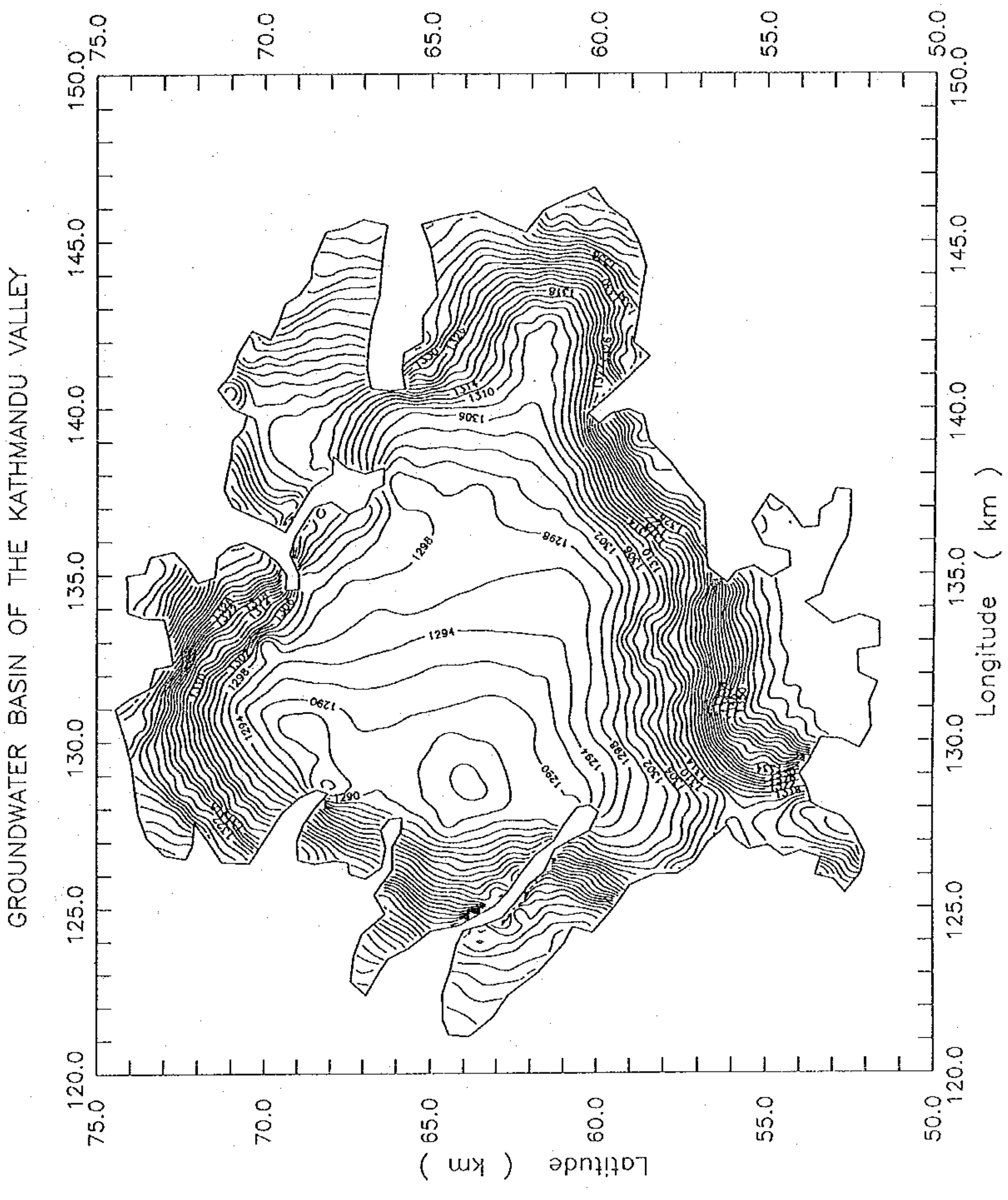
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. E-3.6	GROUNDWATER IN 1985 (NON-STEADY CONDITION)
JAPAN INTERNATIONAL COOPERATION AGENCY		



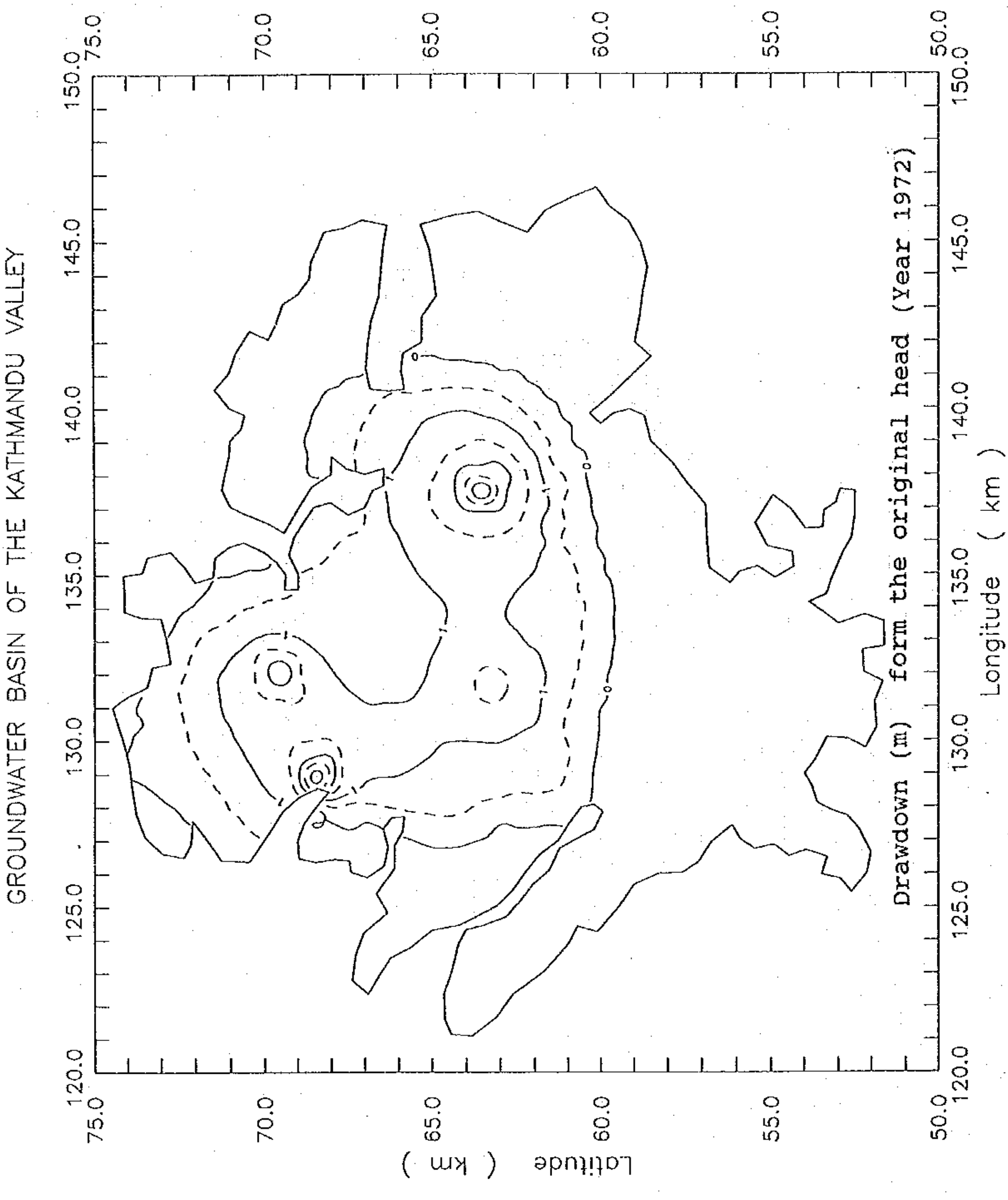
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. E-3.7	GROUNDWATER IN 1987 (NON-STEADY CONDITION)
JAPAN INTERNATIONAL COOPERATION AGENCY		



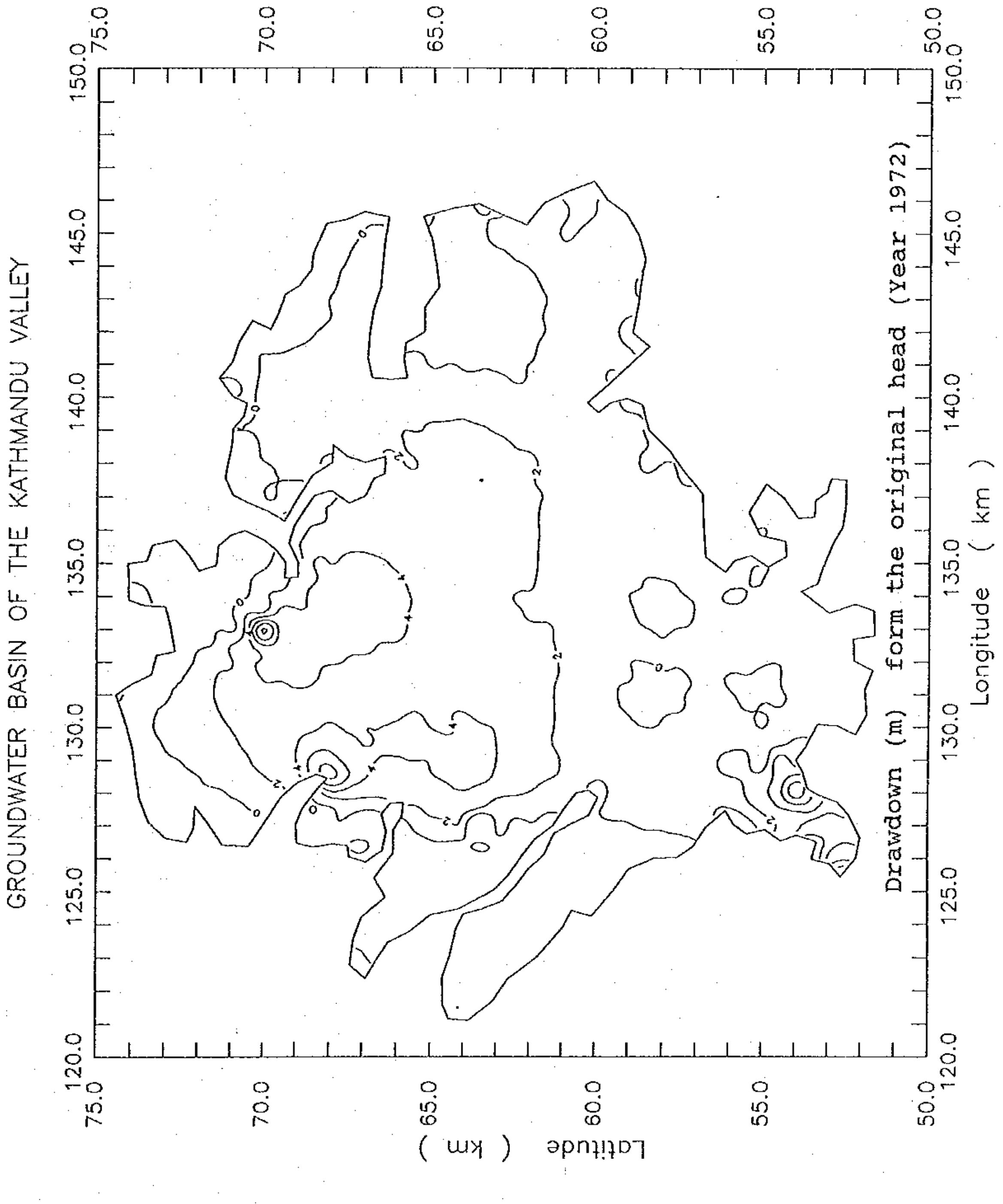
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. E-3.8	GROUNDWATER IN 1989 (NON-STEADY CONDITION)



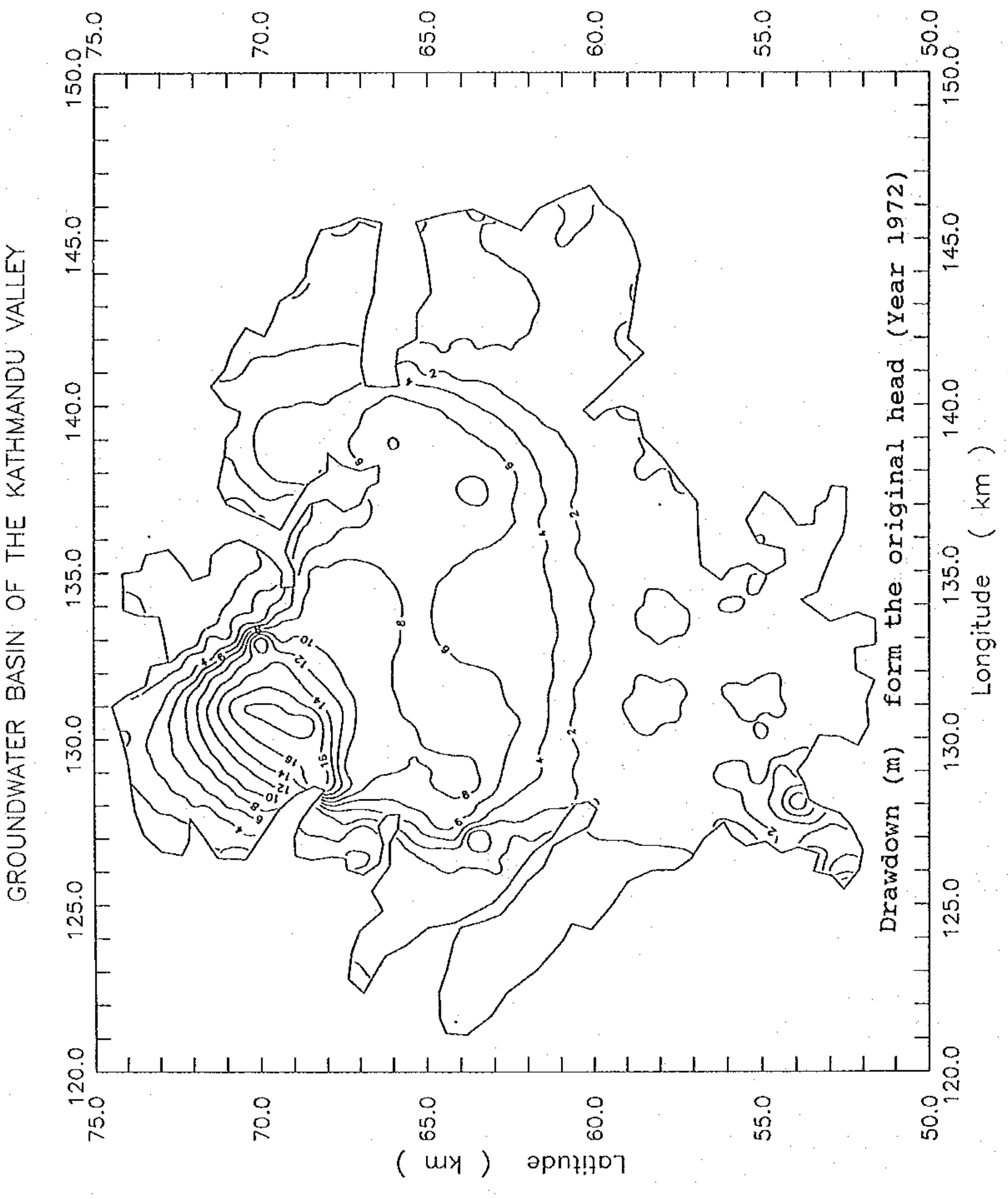
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. E-3.9	GROUNDWATER IN 2001 (ABSTRACTION: YEAR 1988)
JAPAN INTERNATIONAL COOPERATION AGENCY		



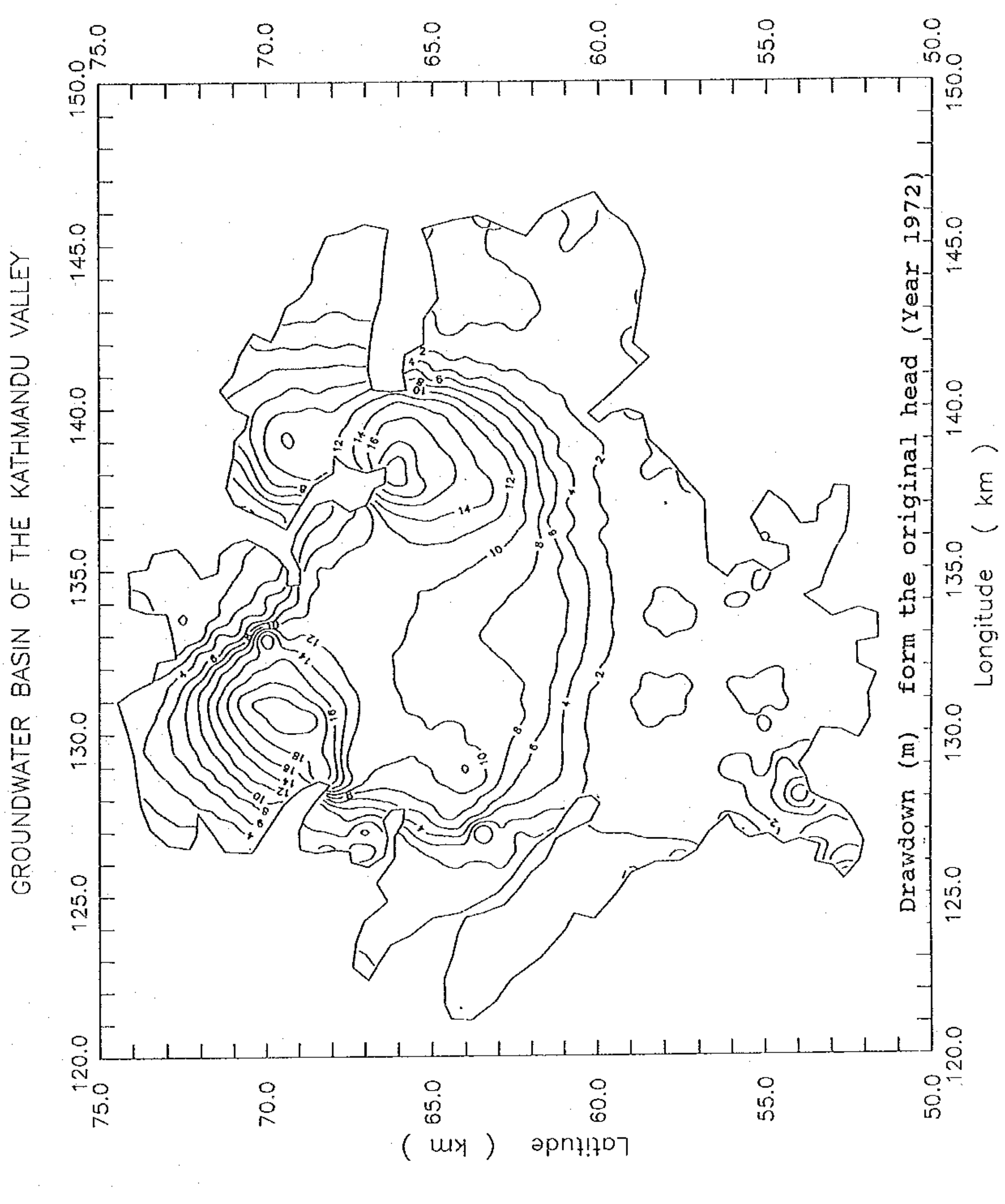
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. E- 3.10	DRAWDOWN OF GROUNDWATER LEVEL IN 1983
JAPAN INTERNATIONAL COOPERATION AGENCY		



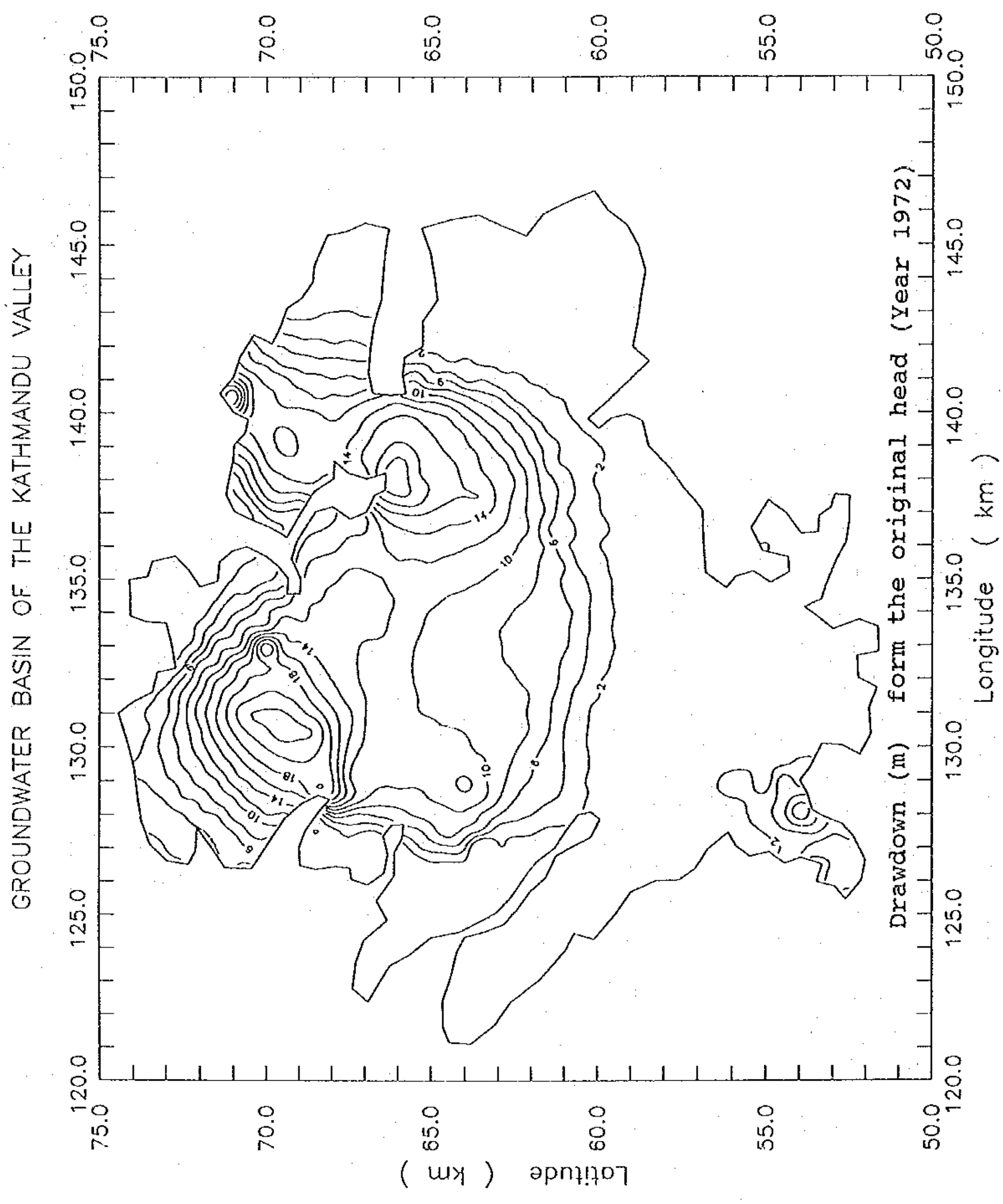
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. E– 3.11	DRAWDOWN OF GROUNDWATER LEVEL IN 1985
JAPAN INTERNATIONAL COOPERATION AGENCY		



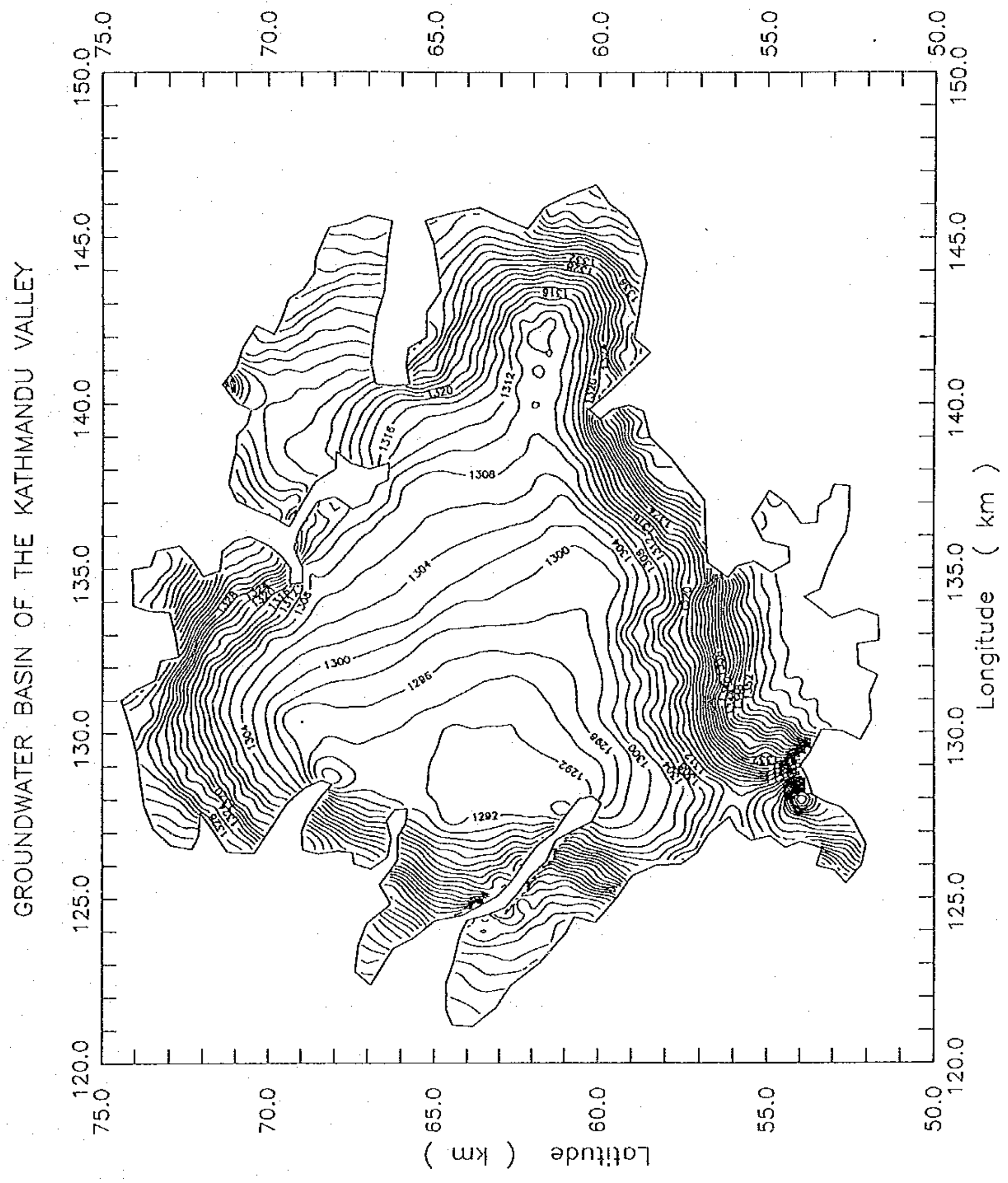
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. E- 3.12	DRAWDOWN OF GROUNDWATER LEVEL IN 1987



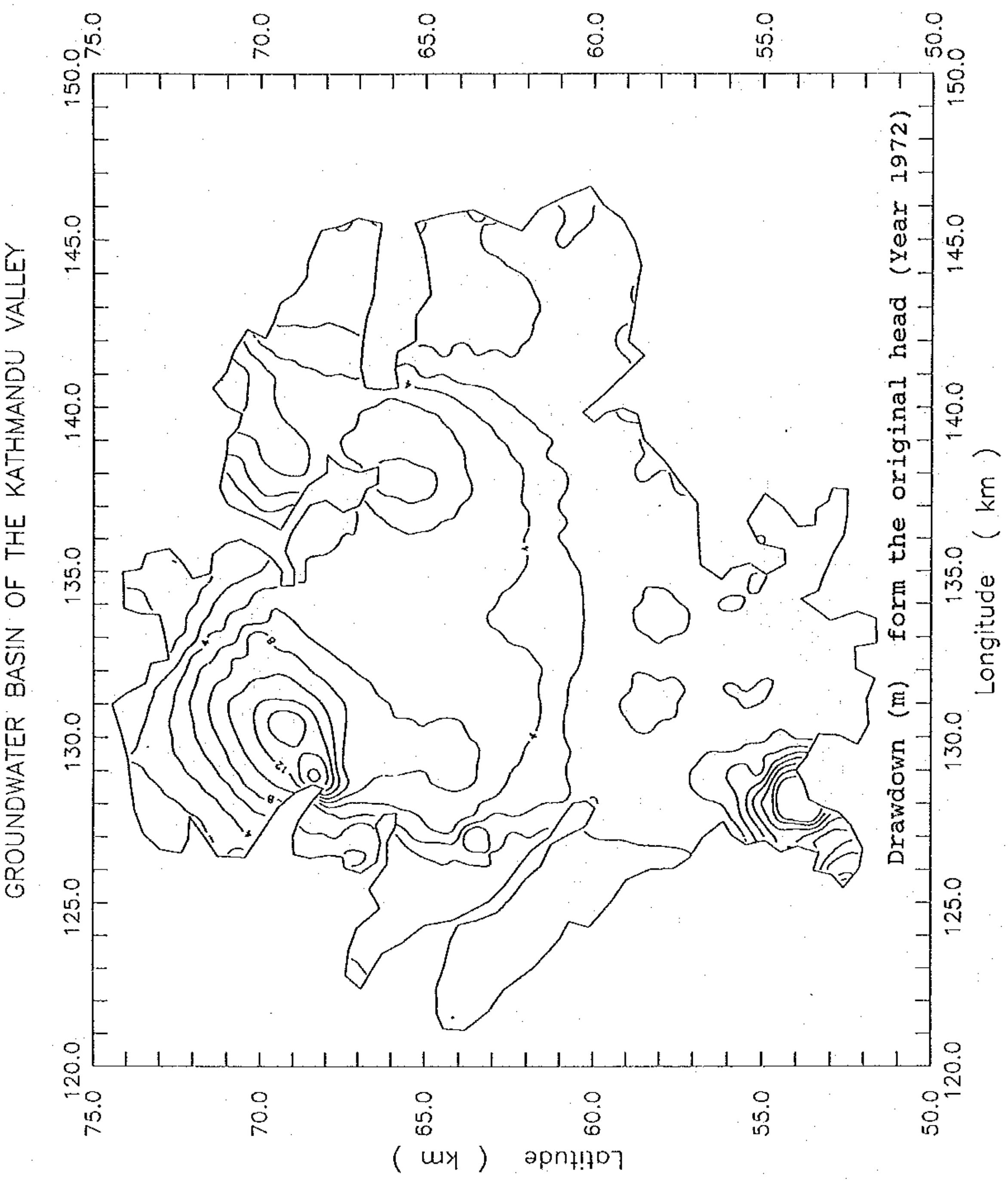
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. E- 3.13	DRAWDOWN OF GROUNDWATER LEVEL IN 1989



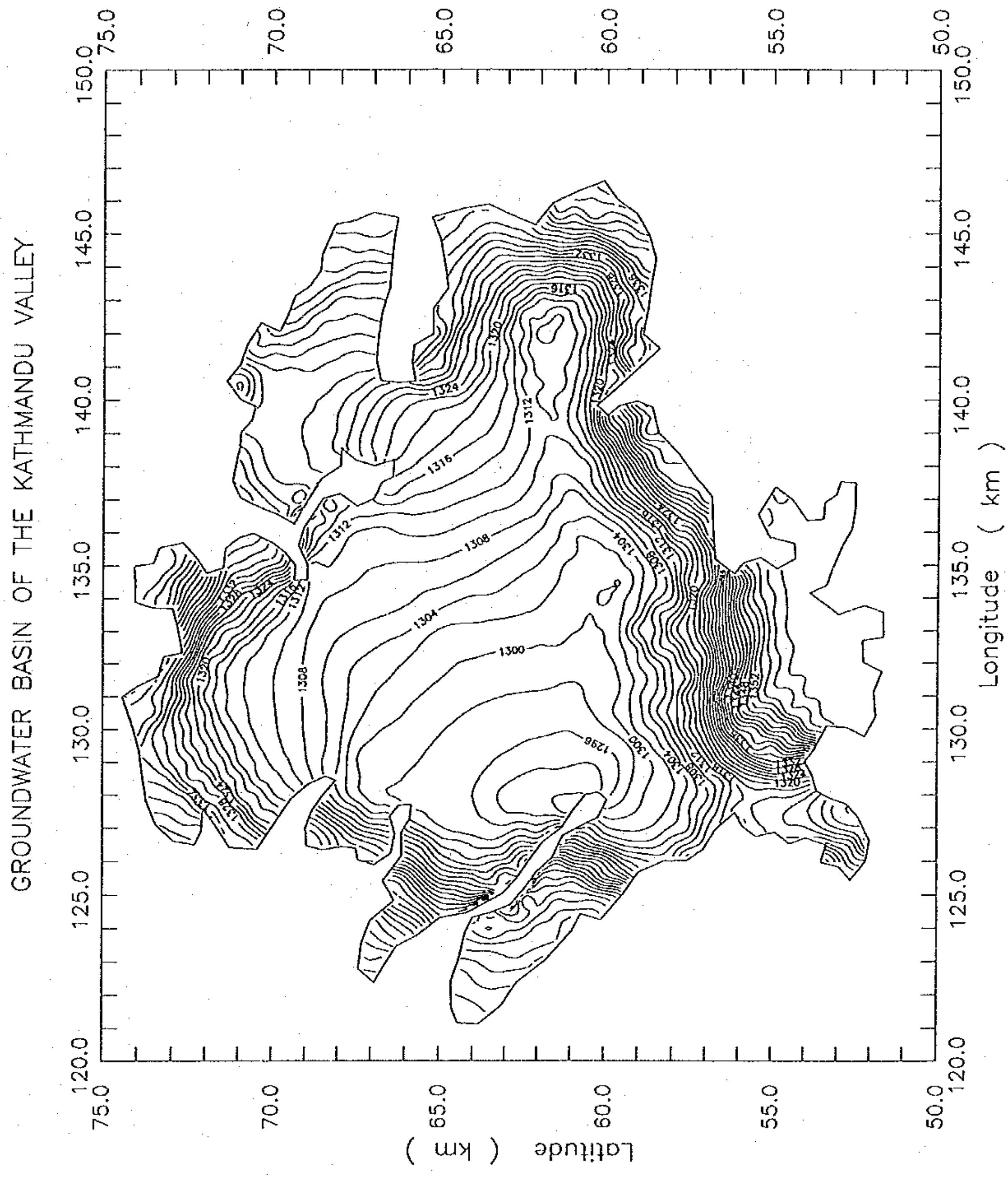
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. E- 3.14	DRAWDOWN OF GROUNDWATER LEVEL IN 2001 (ABSTRACTION:YEAR 1988)
JAPAN INTERNATIONAL COOPERATION AGENCY		



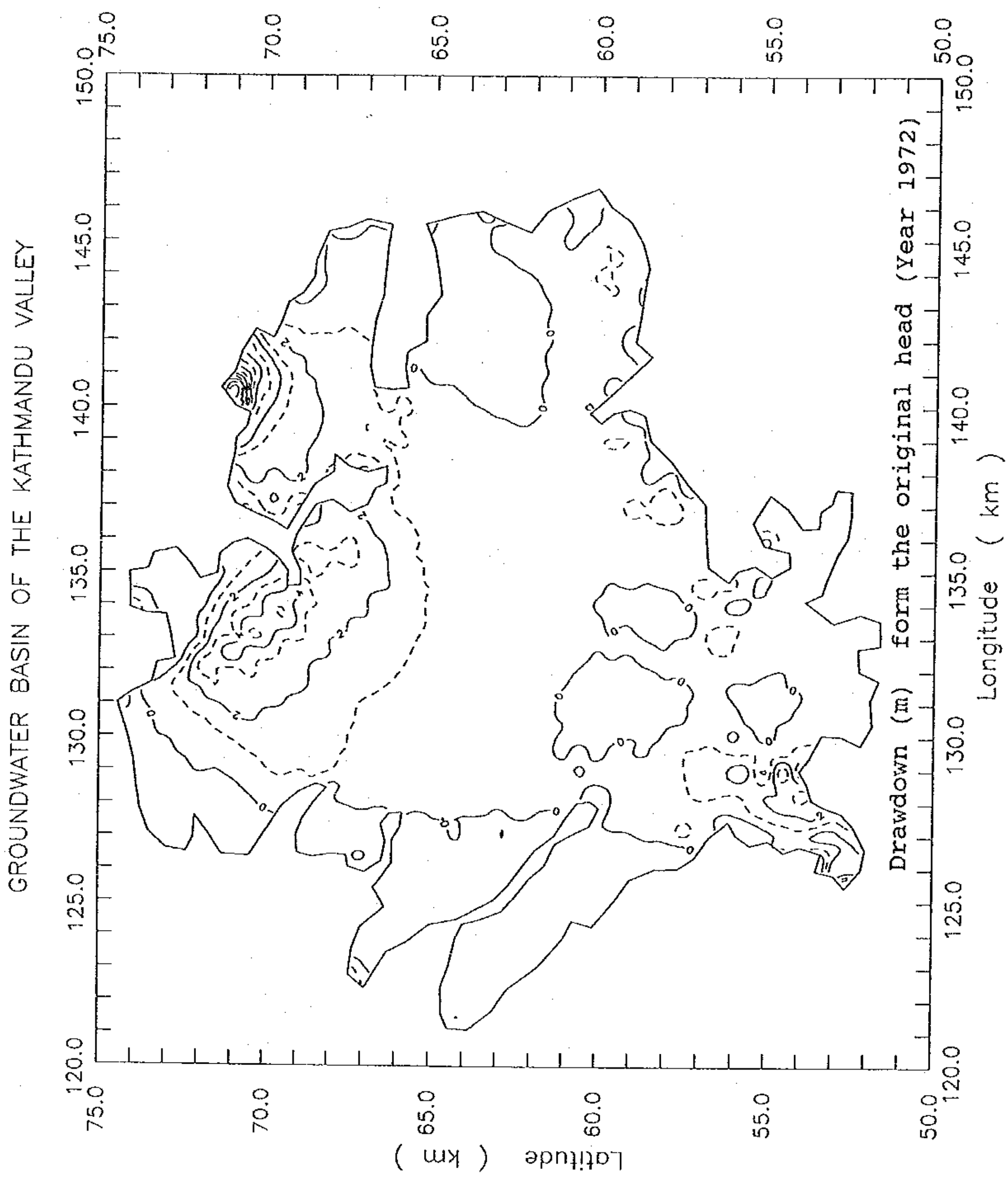
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. E-4.1	GROUNDWATER IN 2001 (ABSTRACTION:OPTIMUM CASE1)
JAPAN INTERNATIONAL COOPERATION AGENCY		



HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. E-4.2	DRAWDOWN OF GROUNDWATER LEVEL IN 2001 (CASE 1)
JAPAN INTERNATIONAL COOPERATION AGENCY		



HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. E-4.3	GROUNDWATER IN 2001 (ABSTRACTION: OPTIMUM CASE2)



HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. E-4.4	DRAWDOWN OF GROUNDWATER LEVEL IN 2001 (CASE 2)
JAPAN INTERNATIONAL COOPERATION AGENCY		

APPENDIX F
SURFACE WATER RESOURCES

APPENDIX F

SURFACE WATER RESOURCES

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Study on surface water resources is intended to assess exploitability regarding surface water sources in the Kathmandu valley for formulating a future municipal water development plan to Greater Kathmandu up to the year 2001. The contents of the study are composed of (1) review of present conditions in the valley, (2) map study and field reconnaissance, (3) surface water balance study, (4) development plan of ROR type surface water sources and (5) preliminary examination of storage reservoir schemes.

Descriptions of study activities in each chapter are as given below:

Chapter II contains an outline of the Kathmandu valley from the viewpoints of land features and present water use.

Chapter III describes (i) identification of all conceivable sites by use of topographic maps and (ii) selection of alternative sites through field reconnaissance for both ROR type and storage reservoir type intake schemes.

Chapter IV states a surface water balance study in the valley for estimation of net surplus river water to be exploitable for future surface water sources.

Chapter V discusses (i) proposed ROR type intakes for water demand projected up to 2001 and (ii) a preliminary study on storage reservoir schemes as valley own water source after 2001.

2. STUDY AREA

2.1 Topography

The Kathmandu valley of the study area lies in the administrative districts of Kathmandu, Lalitpur and Bhaktapur in Bagmati Zone.

The Kathmandu valley, latitude of 27°32'N to 27°49'N and longitude of 85°12'E to 85°32'E, has a circular shape basin with a catchment of 585 km^2 at Cobhar. Greater Kathmandu (Kathmandu and Lalitpur) is located in the central western part of the valley. The central part of the Kathmandu valley, surrounded by high mountain ranges with more than 2,000 m in elevation, consists of very gentle and flat plains of which elevations are ranging between 1,300 m and 1,400 m.

The Bagmati river system is the only river system in the valley which collects and drains whole water in the valley basin to the Ganga through the mid-land mountain range and the Terai plain. The Bagmati river has its origin in Sivapuri Lekh situated at the northern mountainous border of the Kathmandu valley. All Bagmati tributaries originate in the hilly region and flow into the Bagmati mainstream, of which major ones are Mai Khola (hereinafter referred to as "Kh."), Nakhu Kh., Balkhu Kh., Bisnumati river, Dhobi Kh., Manohara river, Kodku Kh., Hanumante river and Godawari Kh..

The landform of the Kathmandu valley is mainly classified into three categories of flat plains, high relief areas and gently inclined slopes.

2.2 Geology

The kathmandu valley is composed of two series of geological successions; the one belongs to Quaternary, which overlies the lower portion of the valley and the other one is in the age of pre-Cambrian to Devonian, which surrounds the Kathmandu valley.

Many mountain ridges extend to the valley bottom from the surrounding mountains, implying there are many buried ridges. The depth from the ground surface to the pre-Cambrian bedrock is ranging from several ten meters to more than 500 m. The ground surface of the Kathmandu valley is flat but the buried bedrock surface appears to abound in irregular shapes and high reliefs.

The thick geological deposits of the central flat plains in the valley consist of lacustrine deposits and fluvial deposits. The lacustrine deposits are classified into three types of arenaceous sediments, argillaceous sediments and an intermediate type of these sediments, as detailed below;

- Arenaceous deposits, which are composed of coarse to medium grain sands with small rock fragments, are surely believed to have been supplied from the northern mountainous areas underlain by gneissose rocks.
- Argillaceous deposits composed of clay materials are considered to have been supplied from erosion of the limestones, which underlie the southern mountainous areas. And,
- Intermediate type deposits of the above-mentioned deposits distribute in the central part of the valley from the west to the east between the areas composed of arenaceous deposits and argillaceous deposits. The materials of this type are consisting of silty clay or clayey silt and intercalations of sandy layers and clayey layers.

2.3 Hydrology

The Kathmandu valley in the semi-tropics is characterized by a warm and temperate climate having a rainy season during a monsoon period (June through September) caused by the winds from the Bay of Bengal. Annual rainfall varies substantially according to altitude: namely, from 1,300 mm in the valley bottom to 3,000 mm in mountainous areas along the valley rim. Temporal rainfall variation indicates that 80 % of the annual rainfall occurs during the rainy season and that July or August is the wettest month. The annual basin rainfall in the valley is 1,900 mm.

The spring season from March to May is characterized by a showery and windy weather, higher humidity and pre-monsoon thunderstorms occasionally accompanied by humidity or hail. On the contrary, the cloudless sky with a calm and windless night is prominent during the period of September to February.

In the winter season from December to February, rainfall is brought by the trade wind from the northwest. Winter and early spring showers occasionally deposit snows on the mountains around the edge of the valley. Dense fog frequently occurs in early mornings.

A mean air temperature is 18°C at Tribhuvan International Airport: the weather is cool with a mean temperature of 11°C from December to February and is warm with 23°C from March to November. The high temperature occurs in June and rises up to about 30°C, while the low is observed from December to January and rarely falls under 0°C.

2.4 Present land use

Most of the land within the valley; say 65 %, is used for agriculture. The hilly land is covered by forest(20%) and shrub(11%), but partly terraced for cultivation near the villages. The agricultural lands are classified into a lowland area (Khet) and a upland area (Pakho). Further, the lowland area is classified into a rainfed area and a irrigated area in view of water availability for irrigation.

In the valley, there exist a number of irrigation systems of which irrigation waters are depending on the Bagmati mainstream and tributaries. The irrigation systems are classified into two systems: one is a government-aided irrigation system and the other is a locally-developed farmers' system. The net commanding area is estimated at about 8,000 ha in total.

2.5 Present water supply

Present water supply systems in the Kathmandu valley, which are using both surface water and ground water sources and are operated by the NWSC (formerly called "WSSC"), are composed of eight(8) systems for Greater Kathmandu and two(2) systems for Bhaktapur. Out of the former systems, three(3) ones of Chapagaun, Dood Phokari and Lokhat are using spring water sources to supply mainly to local towns and villages fringing around Greater Kathmandu.

River water has no special problem for water supply source, if an appropriate treatment is applied, though its turbidity may increase immediately after rainfall in a wet season.

3. ALTERNATIVE DEVELOPMENT SCHEME FOR SURFACE WATER SOURCE

3.1 General

River water is abstracted at many run-of-river type (hereinafter referred to as "ROR type") intake sites and used for irrigation and municipal water within the Kathmandu valley.

In order to assess further surface water exploitability in the valley, alternative sites for surface water development were selected through two study steps of (i) map study to identify all conceivable sites and (ii) field reconnaissance not only at the conceivable sites but at the existing water supply intake sites operated by NWSC. In this study, considered are not only a ROR type development scheme but also a bulk storage reservoir type development scheme with a single purpose of municipal water supply on the basis of the following consideration.

The river water in a dry season is mostly utilized to meet present water demand. On the other hand, surplus water is wasted in a rainy season. This implies that seasonal river water regulation by dam and reservoir development be the most effective and practical method of surface water exploitation in the valley, though this type development is obliged to be basically as a mid and/or long-term countermeasure.

3.2 Identification of Surface Water Development Sites

The identification work of surface water development sites was intensively made mainly from a topographical standpoint through the map study on the basis of 1:10,000 and 1:50,000 topographic maps covering the whole Kathmandu valley.

Consequently, fourteen (14) conceivable intake sites were newly identified through the map study for ROR type development. The sites are located on the Bagmati river (2 sites), the Manohara river (3 sites), the Godawari kh. (4 sites), the Bisnumati river and the Mai, Doldu, Dhobi and Kodku Khs..

In case of the storage reservoir type schemes, thirty five (35) damsites of on-channel storage reservoirs were identified as shown in Table F-3.1, though taking into consideration two (2) types of on- and off-channel storage reservoirs so as not to overlook some possible sites.

The locations of these sites above are illustrated in Fig. F-3.1.

3.3 Selection of Alternative Development Sites

The alternative development sites are selected out of the identified sites above on the basis of additional findings on topography, geology and hydrology obtained from the field reconnaissance in order to be incorporated into the succeeding water balance study.

3.3.1 ROR type development schemes

Field reconnaissance was conducted at the newly identified intake sites by Study Team's Dam Engineer, Hydrologist and NWSC's counterpart personnel, especially paying an attention to assessment of river water availability in a dry season, and also at all of nine (9) existing water supply intakes, which are operated by NWSC, in order to explore the possibility of expanding their present intake capacities for more water abstraction thereat.

At ROR type intake sites located in the central flat plains, a special attention was paid on topographical and geological conditions in connection with easiness in facility construction and operation/maintenance works and certainty in stable abstraction of low flow during a long-term project life, since it was confirmed that river courses of several sections have been shifting due to river bank erosion by flood discharges in the plains which are made of the thick quaternary lake sediments composed mostly of sand, silt and clay.

The field reconnaissance resulted in the following findings:

(i) Significant water abstraction would not be expected at four sites identified on the Godawari tributaries, the Doldu kh. and the Mai kh..

(ii) It would be possible to expand present capacities at existing water intakes from topographical and geological conditions.

Thus, four sites above were discarded from the succeeding study.

3.3.2 Storage reservoir type development schemes

The field reconnaissance was conducted carefully at 35 identified damsites for selecting possible sites by Study Team's Geologist, Hydrologist and Dam Engineer, and NWSC's counterpart personnel, especially with an attention to assessment of the possibility of dam construction from a geological standpoint, since the flat plains widely spread in the central areas of the valley, usually called "floor of the valley", is filled with the thick quaternary sediments, consisting mostly of coarse to medium grain sands, silt and clay, which cause serious problems concerning dam safety such as uneven settlement, under seepage and piping in dam foundation after dam construction and river water impoundment.

According to the field reconnaissance at the respective damsite, confirmed were:

(i) that possible damsites are not able to be found in the flat plains except for the area in which low hills composed of bedrocks are found because dam foundation rocks will not be expected in the flat plains within the reasonable depth. The hazard prone areas have to be eliminated from the possible damsites, and

(ii) that the identified damsites were classified into the following three groups in terms of topographical and geological site conditions, as indicated in Table F-3.1.

- <u>Group A</u>: five (5) damsites, Balkhu kh., Sundarijal, Kodku kh., Lele kh. and Nakhu kl., to be preferably selected as possible ones with proper foundation rocks and storage potential more than 8.0 (mcm) in gross storage capacity on topographically maximum scale,

- <u>Group B</u>: six (6) damsites, Mai kh., Doldu No.1 and No.2 Tribeni No.1, Lambagar No.2 and Godawari kh., in the western and south western parts of the valley, to be discarded from the further detailed studies due to apparently less storage efficiency than those of dam schemes in Group A, and

- <u>Group C</u>: remaining damsites, located mainly on the flat plains filled with the quaternary sediments, to be discarded owing to their geologically inferior conditions of absence of foundation and abutment rocks within the reasonable depth.

The screening of damsite selection was made from geological and topographic approaches. The first priority for the possible damsite is given to the damsites at which foundation rocks are confirmed. The damsites which have wider dam crests and lower dam abutment slopes are rejected from the possible damsites from topographic view points.

The selected damsites are Nakhu dam, Lele dam, Balkhu dam, kodku dam and Sundarijal dam, situating on the middle to upper reaches of the Nakhu, the Lele, the Balkhu, the Kodku, and Bagmati rivers.

<u>Balkhu Khola Dam</u>: located on the Balkhu khola, a right tributary of the Bagmati river, adjacent to Kirtipur. This scheme appears to be a superior dam and reservoir development with a high reservoir yield rate. This damsite has a steep v-shape topography and hard rocks crop out continuously along the riverbed. Lacustrine deposits seem to overlie the flat plains on the left /.abutment. Calcareous schistose sandstones were recovered. Geological boring work was carried out.

<u>Sundarijal Dam</u>: located immediately downstream from the confluence of th river on the upper reach of the Bagmati river(300 m downstream from the existing low intake dam of the Sundarijal hydro-power plant). The storage

capacity is not so large in comparison with other selected damsites, but exploitation possibility is prospective because there are Sundarijal treatment works operated at present 0.7 km downstream of the damsite. The foundation rocks of the damsite are augen gneisses. Continuous outcrops of hard gneissose rocks are observed along the riverbed. Only thin river deposits are observed at and around the damsite.

Kodku Khola Dam: located at the steep and narrow gorge site on the middle reach of the Kodku khola, a left tributary of the Manohara river, 0.5 km to the southeast of Baregau. The storage capacity is not so large, but high storage efficiency will be expected. Almost the same type of rocks as the Balkhu Kh. damsite underlies this damsite. Vertical cracks are frequently developed in the foundation rocks at interval of 20 cm to 30 cm. The schistosity of foundation rocks dips to the downstream side with the angle of about 60 deg. The dam abutment slopes form a steep v-shape to almost vertical topography.

Lele Khola Dam: located at the steep and narrow gorge site on the Lele khola, 0.5 km to the east of the confluence of the Naldu - Lele kholas. The storage capacity is not so large, but high storage efficiency will be expected. Almost the same foundation rocks as at the Nakhu damsite below are observed at this site. Bedrocks crop out continuously in the riverbed generally, and river deposits are almost not found at the damsite. A small saddle composed of the predominant gravel deposits was confirmed behind the left abutment. This saddle is so narrow that water leakage will be expected through this part after impounding water in this reservoir. Special treatment will be required for this saddle portion for preventing the water leakage. Geological boring work was carried out.

Nakhu khola Dam: located in the upper reach of the Nakhu khola, a left tributary of the Bagmati river, 0.5 km downstream from the confluence of the Lele khola. The catchment area of 43(sq.km) and storage capacity of 20.3(mcm) are largest in the selected possible damsites, as compared below and in Fig. F-3.2. This dam scheme is attractive as one of candidate schemes for developing as valley's own water source. Hard silicious schistose sandy limestones are the foundation rocks of this site. The foundation rocks crop out in the left abutment slope. However, the gravel deposits overlie the schistose limestones behind the left dam abutment. Geological boring work was carried out.

Principal features of the dam schemes above are summarized below and the altitudinal relation among them is shown in Fig. F-3.3.

	Scheme Name				
	Balkhu kl.	Sundarijal	Kodku kl.	Lele kl.	Nakhu kl.
River name	Balkhu kl.	Bagmati	Kodku kl.	Lele kl.	Nakhu kl.
C.A.(sq.km)	37	30	16	15	43
Rain(mm/y)	2,161	2,872	1,800	2,095	2,367
HWL(m)	1,345	1,640	1,393	1,505	1,505
GSC(mcm)	18.8	8.6	9.5	10.5	20.3

Note, C A = Catchment area,
HWL = High water level (topographically maximum)
GSC = Gross storage capacity

The reservoir area-storage capacity curves are prepared as shown in Figs. F-3.4 to F-3.8 on the basis of 1:10,000 topo-maps: those of the Nakhu khola reservoir are partially supplemented from 1:50,000 maps.

4. SURFACE WATER BALANCE STUDY

4.1 General

The aim of the water balance study is estimating net surplus river water to be used as future municipal water sources of GREATER KATHMANDU. The balance study was carried out on a 5-day discharge basis under the hydrological conditions during the 46-year period of 1941 through 1986.

The study is divided into two (2) steps: (i) construction of a water demand and supply balance simulation model within the Kathmandu valley and (ii) estimation of net surplus river water ,which is available for the future water sources, on the basis of the simulation model above.

4.2 Water Balance Model

The water balance model simulating water demand and supply in the valley, of which the configuration is schematically illustrated in Fig. F-4.1, consists of (i) the Bagmati mainstream and nine (9) major tributaries; that is, the Bisnumati, Manohara and Hanumante rivers, and the Balkhu, Lambagar, Dhobi, Godawari, Kodku and Nakhu Khs., (ii) existing intake sites for irrigation and municipal water supply, (iii) alternative surface water intake sites newly selected in Chapter III for ROR type and storage reservoir type development schemes and (iv) existing irrigation areas (in total 7,400 ha) operated by the Government and local farmers.

4.2.1 Water balance points

In the model, the following sites are considered as water balance points.

Existing irrigation intake sites

In the Kathmandu valley, there exist a number of irrigation systems diverting a certain amount of river water to the agricultural fields. The irrigation systems are classified into two groups. One group is a government aided irrigation system and the other is a locally developed farmers' system.

The Government aided irrigation schemes are composed of a permanent intake weir equipped with intake gates and main and secondary canals. The gates are operated by a local operator according to the farmers' request. Regarding the farmers' build irrigation systems, generally, they consist of small-scaled temporary diversion weirs made of simple stone piling and small supply ditches without lining and permanent structures. If the temporary weir is washed away by floods, it will be reconstructed by farmers themselves.

In total, fifty six(56) sites of government-aided and private farmers' intakes are incorporated as balance points into the balance modal, as shown in Fig. F-4.1.

Municipal water intake sites

In addition to 9 existing NWSC's intakes, 15 alternative intake sites for ROR type and storage reservoir type schemes are also prepared in the model, as tabulated below:

River Basin	Nos. of Intake Site			
	ROR Type		Storage Reservoir Type	Total
	Existing	New	(New)	
1. Bisnumati Kh.	5	1	-	6
2. Dhobi Kh.	1	1	-	2
3. Bagmati Kh.	2	2	1	5
4. Manohara Kh.	-	3	-	3
5. Hanumante Kh.	1	-	-	1
6. Godawari Kh.	-	2	-	2
7. Kodku Kh.	-	1	1	2
8. Nakhu Kh.	-	-	2	2
9. Balkhu Kh.	-	-	1	1
Total	9	10	5	24

Table F-4.1 compiles the meteoro-hydrological features at respective water balance points above.

4.2.2 Natural river runoff

In the water balance calculation, the whole study basin is divided into sub-basins at all balance points as shown in Fig. F-4.2 and the natural runoff from each sub-basin is estimated.

The Sundarijal stream station which are located in the upper reach of the Bagmati mainstream was adopted as a key station. The key station is defined as a station having reliable and long-term data on natural river runoff which are to be used for estimating natural river runoff in an ungauged basin . The natural runoff data at the Sundarijal station are prepared by means of "Tank Model Method" for 46 years from 1941 through 1986 on a daily basis, as stated in Appendix C.

For this balance model, the whole valley basin was divided into 69 sub-basins. The runoff from each sub-basin was derived by transposing the key station's natural runoff data, using a conversion factor, herein taken to be a ratio of the annual rainfall volume in the sub-basin to that in the drainage basin of the key station. Furthermore, a adjustment factor was introduced for sub-basin situating in the central flat plains because of difference in rainwater retaining capacity in underground zone between the flat plains and the high mountainous area of the key station catchment, as shown in the following equation:

$$Qi = Qs \times (Ri \times Ai) / (Rs \times As) \times AF \quad \text{.................(A)}$$

where, Qi = natural runoff of ungauged basin (m^3/s)
R = annual basin rainfall (mm/y)
A = drainage area (km^2)
AF = adjustment factor due to rainwater retaining capacity
i = for ungaged basin
s = for Sundarijal stream gage basin

4.2.3 Water demand

There are two (2) major types of water consumption in the Kathmandu valley:(i) municipal water consumption for GREATER KATHMANDU, BHAKTAPUR and other small towns/villages fringing around the cities, and (ii) irrigation water consumption for the total command area of 7,400 ha, in the balance model.

For this balance study, irrigation water demand was thoroughly examined on a monthly basis over the whole Kathmandu valley as stated in detail in Appendix C, since irrigation is extensively developed along the Bagmati mainstream and tributaries and is expected to continue competitive river water consumption to municipal water supply. The irrigation demand is summarized in Table F-4.2.

On the other hand, municipal water demand was assumed as follows in accordance with actual supply water records collected in the course of this study:

River	Intake site	Present Demand*
1. Bisnumati Kh.	Allye	1,252 (m^3/d)
	Mahadew Kh.	2,862
	Boude	1,252
	Bhandare	1,610
	Bisnumati	1,120
2. Dhobi Kh.	Shivapuri	2,000
3. Bagmati Kh.	Sundarijal	20,000
4. Hanumante Kh.	Nagarkot	4,320

Note, * present intake capacity

4.2.4 Procedures of balance calculation

Water demand and supply balance is calculated at every balance point on a 5-day basis.

Surplus water (S) at any point is given as the difference between river runoff (R) and present water demand (D) at the point. If the river runoff is lager than the water demand, the difference is discharged downstream as net surplus. If the case is adverse, no surplus would exist. The relationship above is expressed as follows:

$$\text{If } R > D, \quad \text{then } S = R - D$$
$$\text{If } R <= D, \quad \text{then } S = 0$$

If there is no balance point upstream from the objective point, the river runoff is the natural runoff from its own sub-basin. On the other hand, if there is one point or more upstream from the objective one, the river runoff is the sum of (i) the natural runoff from its own sub-basin, (ii) surplus river water to be discharged from the immediately upper points and (iii) catchable irrigation return flows coming into its own sub-basin.

Irrigation water requirement includes various kinds of unavoidable losses such as conveyance, distribution, application, percolation and operation losses. A certain amount of the above irrigation losses is expected to return to the river through drainage networks or underground permeable layer. Since there is no actual measurement and evaluation for the irrigation return flow, it is assumed that 20 % of diverted water may return to the downstream river.

Net river water at arbitrary balance point is calculated by repeating the above-mentioned procedures, as illustrated in Fig. F-4.2.

4.2.5 Verification of balance model

In the first step, the water balance calculation was made during the 46-year period of 1941 to 1986 in accordance with the above procedures under the condition of without irrigation and municipal water abstraction from river water in order to examine the basic hydrological relationship between basin rainfall and natural runoff derived from the simulation model. The calculation resulted in the preferably acceptable relationship in terms of representative hydrological factors of (i) annual runoff coefficient: f=0.53, annual loss=892 mm/year and correlation coefficient between annual rainfall and runoff=0.88 at Cobhar which is the lowest balance point with 585 km^2 in catchment near the outlet of the valley, as shown in Fig. F-4.1.

In the second step, the calculation was carried out under the condition of present river water abstraction in order to compare the simulated and observed river runoffs. The comparison was made on the basis of both river runoffs for 8 years of 1965 to 1969 and 1977 to 1979 at Cobhar, when Cobhar has reliable river runoff records on a daily basis as detailed in Appendix C.

As shown in Fig. F-4.3, two (2) kinds of flow-duration curves coincide well with each other and their mean discharges result in the same value. Moreover, temporal distribution patterns of both river runoffs have also a good coincidence.

Thus, the appropriateness of the water balance model was confirmed by 2 kinds of verification.

4.3 Available Water for Future Water Supply

For future water supply to GREATER KATHMANDU, surplus river water was examined as available water source at 22 sites: 7 existing intake sites and 15 new sites within the valley through the water balance calculation on a 5-day discharge basis during the 46-year period (1941 - 1986) using the simulation model constructed above. The locations of the sites are shown in Figs. F-3.1 and F-4.1.

As a river maintenance flow, Q95 (river discharge with 95% dependability in time) is required to be remained at the most downstream balance point on each river or khola, except for the Bagmati river. The Bagmati river is the religious river for Hindus. The very important temple of the Pasupatinath is situated on both banks of the river upstream from Kathmandu. The river is used thereat for ritual bathing and cremations. In the dry season, the flow in the river is usually about 0.3 (m^3/s) at the Pashupatinath, but often drops to less during the late period of the season and the river becomes highly polluted. In the Bagmati river, river maintenance flows are assigned to the

Pasupatinath and Gokarna Shore temple sites at 0.3 and 0.2 (m^3/s), respectively. The maintenance flows are corresponding to the 1.1-year drought discharges or Q85s at respective sites.

The surplus river waters for 22 sites are compiled in Table F-4.3.

The simulation results imply that river water could be developed as future water sources at only several sites in the Kathmandu valley as discussed in Chapter V.

5. DEVELOPMENT PLAN OF SURFACE WATER SOURCE

5.1 General

It was revealed, through the surface water balance study stated in Chapter IV, that river water could be further developed at several sites in the Kathmandu valley in addition to 9 existing NWSC's water supply intakes.

In this study, ROR type intakes are proposed to be newly constructed on 5 tributaries of the Bagmati river; that is, the Lambagar Khola, Dhobi Khola, Manohara river, Balkhu Khola and Bisnumati river for future Greater Kathmandu water supply increase through 2001.

Furthermore, storage reservoir schemes are also preliminarily studied for water supply source development in the valley as a mid/long-term countermeasure.

5.2 ROR Type Intake Schemes

5.2.1 Exploitable water

For this type of development scheme, examined were 15 alternative intake sites including 5 sites selected for storage reservoir schemes, which are able to be ROR type intake ones from topographical and geological standpoints, and 8 existing NWSC's intake sites operated for Greater Kathmandu , under the developing concepts below:

- The river water is to be abstracted in both dry and wet seasons.
- Planned abstraction water will seasonally change flexibly according to natural variation of available river water with proper reliability: say, more than 80 % dependability on an average under the supply support from ground water sources to supplement the lack of surface water sources.

Out of all sites above, the following five (5) sites are selected as promising ROR type intakes especially from the standpoint of water availability in both seasons, as shown in Table F-4.3.

River name	Location*1	Available Water (m^3/s)	
		Q30*3	Q80
Lambagar	W105*2	0.72	0.08
Dhobi	W202	0.67	0.07
Bagmati	W301*2	1.94	0.12
Manohara	W403	2.30	0.22
Balkhu	D801	1.17	0.12

Note, *1 corresponding to site number in Fig. F-4.1
*2 existing intake sites
*3 discharge with 30% dependability in time

The monthly available waters with several dependabilities in time are shown in Table F-5.1.

Furthermore, the monthly abstraction rates which have 80% dependability in abstraction amount are shown in Table F-5.2. The abstraction rates were incorporated as monthly exploitable maximums of surface water sources into the formulation of future water supply plan to Greater Kathmandu as stated in Appendix J.

5.2.2 Intake Facility Planning

Intake facility plans were made at 4 promising intake sites selected in Section 5.2.1, excluding the W301 site on the Bagmati river, where the existing low intake dam of the Sundarijal hydro-power plant can serve also for the W301 intake, and at the W106 sites on the Bisnumati river which was additionally selected only for rainy season water abstraction, as discussed in details in Appendix J.

There is no large scale irrigation system existing downstream from 5 selected intakes above. However, small private irrigation systems are operated on the Bisnumati and Manohara rivers by local farmers for 30 ha and 17 ha command areas respectively. Thus, 2 intakes on these rivers will abstract only excess river water beyond their irrigation offtake requirements and river maintenance flows, while other 3 intakes will divert river waters except for river maintenance flow to be preferentially released.

The intake facility plans were made on the basis of the following basic concepts;

(1) Intake facilities are run-of-river type water diversion facilities having no regulating capacity.

(2) Sediment deposition near a intake portal will be flushed out through a scouring sluice by opening a sand flush gate periodically, in particular during flood periods.

(3) River water will be diverted through a screened side-overflow intake portal adjoining the scouring sluice.

(4) Rolling loads, if flowing into and being deposited in a sand settling basin, would be removed through a sand drain gate to be provided at a corner of the basin. And

(5) The facilities would be capable of discharging a 50-year flood with due allowance in free board to allow for free and safe passage of floods.

In this study, two types of intake structures; namely, ground-sill type and concrete weir type intakes were considered based mainly on topographical and geological site conditions and easiness in operation and maintenance.

Ground-sill type intake

Intakes of this type were provided at the following 3 intake sites;

River name	Site No.*	Location
Lambagar Kh.	W105	45 m downstream from existing bridge of Balaju-Phutung road
Dhobi Kh.	W202	30 m downstream from existing bridge of the Ring Road
Manohara river	W403	40 m downstream from existing bridge near Vocation Training Center

Note, * corresponding to site number in Fig. F-4.1

The river beds and banks at and around the above intakes are covered with thick quaternary sediments consisting mostly of sand, silt and clay. Thus, a ground-sill type structure was employed in consideration of (i) impossibility in concrete weir construction, (ii) long term stability of river bed and intake water level especially in a dry season and (iii) easier countermeasure to riverbed scouring immediately downstream from intake facilities: the crest of the ground-sill is set at a present riverbed level with the aspects of (ii) and (iii) in mind.

The intake facilities are provided with the following;

(a) a sand flush channel with a gate at the left/right end of a ground-sill so as to flush out sediment deposits in front of a intake portal,

(b) a sand settling basin neighboring a sand flush channel to minimize sand inflow into transmission facilities, and

(c) revetment and riverbed riprap works in a wide range enough to pass a 50-year flood safely.

<u>Concrete weir type intake</u>

This type of intakes was adopted for 2 intake sites below;

River name	Site No.*	Location
Balkhu Kh.	D801	valley bottom on the west side of Kirtipur
Bisnumati river	W106	500 m downstream from existing bridge at Burhanilkanth village

Note, * corresponding to site number in Fig. F-4.1

A gravity type concrete weir would be built at a bottom of a narrow valley, since foundation rocks are exposed at the bottom as well as in the lower parts of the valley slopes and the rocks are expected to be sufficiently strong for supporting a planned scale concrete weir

The weirs are provided with the following facilities;

(a) a non-gated overflow spillway with a design capacity of a 50-year flood,

(b) a sand flush gate to flush out riverbed loads deposited in an upstream pond,

(c) a sand settling basin with a sand drain gate for trapping coarse and fine grains in the basin,

(d) a screened side-overflow intake for water abstraction with a intake gate at the entrance of the settling basin.

The general layout and structure plans of both type intakes are envisaged in this study as shown in Figs. F-5.1 (1/2) and (2/2).

5.3 Storage Reservoir Schemes

As stated in Chapter III, 5 alternative storage reservoir schemes are selected through map study and field reconnaissance as a mid and/or long-term water source development plan.

5.3.1 Reservoir yield potential

A reservoir operation study was carried out in a preliminary study level with the aim to estimate reservoir yield potentials concerning 5 alternative schemes; that is, Balkhu Kh., Sundarijal, Kodku Kh., Lele Kh. and Nakhu Kh. dam schemes. The dam site locations are as shown in Fig. F-3.1.

In the reservoir operation study, each dam is examined as a single purpose dam for Greater Kathmandu water supply. Other conditions given for the study are as follows;

(1) Hydrological condition

The study was executed on a 5-day discharge basis under the hydrological conditions during the 45-year period from 1941/42 through 1985/86.

(2) Existing water demands

Irrigation water demands are taken into account for the schemes distributed in the downstream reaches of the dam sites. The water abstraction rates for the schemes are the same values as employed in the aforementioned water balance study (Chapter IV).

River maintenance flows are assigned to the several sites in the tributary basins where the dam schemes are studied, as well as the water balance study.

(3) A maximum full supply water level (FSL) is given due to topographical and geological reasons, as follows:

Dam Name	CA (km2)	Rainfall (mm/y)	Max. FSL (m)	GSC (mcm)
Balkhu kh.	37	2,161	1,345	18.8
Sundarijal	30	2,872	1,640	8.6
Kodku Kh.	16	1,800	1,393	9.5
Lele Kh.	15	2,095	1,505	10.5
Nakhu Kh.	43	2,367	1,505	20.3

Note, CA = catchment area; GSC = gross storage capacity

(4) Effective storage volume is to be preserved only for municipal water release to Greater Kathmandu with 90 % supply firmness on a yearly basis.

(5) Fifty (50) year volume of reservoir silting is assumed at a basin denudation rate of 1.2 mm/year (equivalent to specific silting volume of 1,200 m^3/km2/year).

(6) The principals of reservoir water release are;

River flow into reservoir is to be released first for the existing water demands in downstream reaches of the dam sites.

For a given constant rate for municipal water supply, the deficit of the river inflow after above water release, if it occurs, is supplied from reservoir water. Excess river water is stored in the reservoir up to FSL.

Study results on the basis of the above planning premises are summarized below, as compiles in Table F-5.3:

Dam	Reservoir			Dam		Index	
	Max. Yield (m^3/s)	Volume (mcm) Effect.	Volume (mcm) Gross	Crest EL. (m)	Height (m)	SE*1	WC*2
Balkhu kh.	0.8	16	18.3	1,350	38	76	1.0
Sundarijal	0.3	6	7.8	1,643	73	4	2.8
Kodku Kh.	0.3	7	8.0	1,395	40	29	1.4
Lele Kh.	0.3	7	7.9	1,507	34	29	2.1
Nakhu Kh.	0.6	17	19.6	1,510	61	25	1.3

Note: *1 effective storage volume/dam volume
*2 ratio of water cost at damsite to that of Balkhu Kh. scheme

In the case of the Kodku Kh. and Lele Kh. schemes, inter-basin water transfer plans from the Nakhu Kh. and Naldu Kh., respectively were incorporated in terms of effective use of their available reservoir spaces, since the spaces are not fully used owing to a small amount of available river waters in their own drainage basins.

The general dam layouts are preliminarily envisaged at each dam site as illustrated in Figs. F-5.2 to F-5.6, adopting a rock fill type dam based on the findings from field reconnaissance: generally, rock fill dams seem to be recommendable for all selected alternative damsites according to the confirmed geological conditions so far, though the preferable types for the dams have to be selected based on the result of the further investigation since topographic conditions of the most damsites seem to be suitable for concrete gravity dams and rocks cropping out at the damsites would be expected to be firmer and less pervious with increasing of depth in general

5.3.2 Present conditions of dam and reservoir areas

The present conditions on land use, building and other major properties were surveyed in the 5 selected dam/reservoir areas, through field reconnaissance by using topographic maps (1:10,000 and 1:50,000), and land utilization maps (1:50,000; published by Topographical Survey Branch of Survey Development in 1984), and are briefly described below, as compiled in Table F-5.4:

(1) Balku kh. dam/reservoir

Paddy fields of 240 ha are spreading over the most part of the reservoir area. There are several truss towers of the cable-way connecting from

Kathmandu to Hetauda for transportation of subsistence goods in the south area, while 3 truss towers of electricity power transmission lines are located in the north. The paved road with 8 m width, leading to Pokara, is laid in the central. Furthermore, there are a lot of houses and other buildings (more than 100 houses) and also Bishnu Devi Temple which is very import religiously to local people at the confluence of the Balkhu-Chatre Khs. (some 1 km upstream from the dam site).

(2) Sundarijal dam/reservoir

The reservoir area is wholly covered by forest, excluding a small upper part of paddy field (2 ha). The low intake dam for the Sundarijal hydroelectric power plant (750 KW) is locating on the Bagmati river 400 m upstream from the damsite.

(3) Kodku kh. dam/reservoir

Paddy fields having 110 ha in total are widely distributed in the reservoir area and small extent of upland field and forest are lying in the north end. A irrigation intake weir is operated at the damsite.

(4) Lele kh. dam/reservoir

The reservoir area is extensively utilized as paddy fields (80 ha) in the north and upland fields (13 ha) in the south. A irrigation intake weir is operated at the damsite.

(5) Nakhu kh. dam/reservoir

The reservoir area is divided into three land use categories of forest/grass lands around the right dam abutment, paddy fields (130 ha) in low and middle lands and upland fields (20 ha) in high lands. On the Naldu kh. 200 m upstream from the confluence of the Lele kh., located is a diversion intake where the Naldu Kh. water is diverted to the irrigation intake at the Lele damsite through a transfer canal. Some 150 private houses are located in the reservoir area.

5.3.3 Storage reservoir development

The 5 alternative schemes for storage reservoir development in the Kathmandu valley are considered as follows from technical, economical and environment viewpoints:

Balkhu Kh. scheme

Since this scheme has the highest reservoir yield potential of 0.8 (m^3/s) in a constant draft rate with 90 % supply firmness on a yearly base out of the 5 alternative schemes and the highest storage efficiency(=effective storage volume/dam volume): 3 times or more compared with those of other schemes, the scheme is expected to be superior to others from an economical standpoint. However, Bishnu Devi Temple located 1 km upstream from the damsite will be submerged after reservoir impounding and local people will be strongly against the temple's resettlement to other site because of its religious importance to them. Unless this social problem is solved in advance, this scheme implementation would be impossible.

Sundarijal scheme

This scheme seems to be remarkably inferior to other schemes economically because of its small storage efficiency owing to topographical disadvantage in the dam and reservoir areas:namely, relatively wide valley shape and small reservoir space.

Kodku Kh. scheme

Its maximum yield potential is as small as 0.2 (m^3/s). However, this scheme has the highest storage efficiency except for the Balkhu Kh. scheme. In case that the Nakhu Kh. water in the adjacent basin is conveyed from Tikabhairav to the reservoir, the yield potential will augment to 0.3 (m^3/s) and the economical superiority of the scheme will become higher.

Lele Kh. scheme

Its maximum yield potential is 0.3 m3/s, incorporating inter-basin water transfer from the Naldu Kh..

A small saddle behind the left abutment, composed predominantly of gravel deposits of which the exact range is unknown so far, is so narrow that water leakage will necessarily occur through this part after impounding water into reservoir and that a high cost countermeasure work will be required for this pervious deposit zone, also accompanied by technical difficulties.

Since this site is located 0.7 km upstream from the Nakhu Kh. dam site, the Nakhu Kh. reservoir impoundment will cause the Lele Kh. dam submergence into the reservoir.

Nakhu Kh. scheme

This scheme can exploit its own basin's river water up to the yield potential of 0.6 (m^3/s) in maximum, corresponding to the second highest one and inhere economical superiority as well as the Kodkhu Kh. scheme.

Based on the considerations above, Nakhu Kh. dam scheme and Kodku Kh. dam scheme with the Nakhu Kh. water transfer appear to be attractive for storage reservoir schemes in the Kathmandu valley in view of their economical superiority and absence of great technical constraints to their implementation. Most of the reservoir areas of both are, however, used as agricultural lands at present and reasonable compensation has to be made for the inundated agricultural lands and other properties. The yield potentials of both are considerably different from each other. Therefore, the future study on these reservoir scheme development should be made, taking into consideration the increase of the water demand after the year 2001 and also necessity of stagewised development.

TABLES

Table F-3.1 LIST OF IDENTIFIED DAMSITES

No.	Stream Name	Dam Name	Location	Findings *1
1	Mai kh.	Mai kh.	Dakkhin Kali	B
2	Doldu kh.	Doldu No.1	Bajrajogini	B
3		Doldu No.2	Pikhel	B
4	Balkhu kh.	Balkhu No.1	Balambu	C
5		Balkhu kh. (Balkhu No.2)	Kirtipur	A
6		Balkhu No.3	Naikap	C
7		Balkhu No.4	Kalankisthan	C
8	Tribeni kh.	Tribeni No.1	Singarepati	B
9		Tribeni No.2	Puldol	C
10		Tribeni No.3	Siptetar	C
11	Ghong kh.	Ghong kh.	Raniban	C
12	Lambagar kh.	Lambagar No.1	Kisandol	C
13		Lambagar No.2	Manakal	B
14		Lambagar No.3	Phutung	C
15		Lambagar No.4	Basnettar	C
16		Lambagar No.5	Purano Gujeswari	C
17	Sanga kh.	Sanga No.1	Tokha	C
18		Sanga No.2	Manmaiju	C
19	Bisnumati kh	Bisnumati No.1	Pasikot	C
20		Bisnumati No.2	Gogabu	C
21	Dhobi kh.	Dhobi No.1	Tupek	C
22		Dhobi No.2	Lasuntar	C
23	Bagmati R.	Sundarijal	Sundarijal	A
24		Gokarna	Gokarna	C
25	Manohara R.	Manohara No.1	Sarancok	C
26		Manohara No.2	Sakintar	C
27	Hanumante R.	Hanumante No.1	Puwargan	C
28		Hanumante No.2	Nalincok	C
29		Hanumante No.3	Bramhaya	C
30	Godawari kh.	Godawari kh.	Manedara	B
31	Kodku kh.	Kodku No.1	Bajrabarahi	C
32		Kodku kh. (Kodku No.2)	Baregau	A
33	Lele kh.	Lele kh.	Tikabhairaw	A
34	Nakhu kh.	Nakhu kh. (Nakhu No.1)	Burunculi	A
35		Nakhu No.2	Theco	C

Note, *1 based on site reconnaissance
A = promising
B = ineffective in water storage
C = geologically unsuitable for dam construction

Table F-4.1 METEORO-HYDROLOGICAL FEATURES IN BASINS OF BALANCE POINTS (1)

River Basin	Balance Points*	CA (sq.km)	Rainfall (mm/y)	R/F Rate	MD (cms)	IA (ha)	AF	MF
1. Bisnumati Kh.	I101	1	2,366	0.2	0	60	1	0
	W101	1.7	2,677	0	0.0145	0	1	0
	W102	2	2,727	0	0.0145	0	1	0
	W103	1.2	2,836	0	0.0186	0	1	0
	W104	3.4	2,897	0	0.013	0	1	0
	I107	0	2,897	0.2	0	123	1	0
	I108	3.7	2,383	0.2	0	60	1	0
	W106	0	2,383	0	0	0	1	0
	I109	5.7	1,770	0.2	0	30	0.75	0.02
	I102	0.6	2,365	0.2	0	60	1	0
	I103	3.3	2,010	0.2	0	8	0.8	0
	W105	17.9	1,805	0	0.0331	0	0.75	0.03
	I104	2.8	2,491	0.2	0	30	1	0.01
	I106	0.7	2,013	0.2	0	147	1	0
	I105	1.1	2,473	0.2	0	25	1	0
	I110	9.7	1,881	0.2	0	107	0.8	0
	B-1	48.6	1,675	0	0	0	0.65	0
								0
2. Dhobi Kh.	W201	2.2	2,889	0	0.0231	0	1	0
	I201	1.7	2,832	0.2	0	40	1	0
	I202	0.3	2,275	0.2	0	100	1	0
	I203	6.3	2,129	0.2	0	70	0.8	0
	W202	13.6	1,637	0	0	0	0.65	0.04
								0
3. Bagmati Kh.	I302	13.5	1,931	0.2	0	100	0.75	0
	I301	0.2	2,125	0.2	0	35	1	0
	W302	0	2,125	0	0	0	1	0
	W301	33.6	2,852	0	0.231	0	1	0
	D301	0.3	2,250	0	0	0	1	0
	G/S Temple	8.2	1,812	0	0	0	0.75	0.2
	I303	0	1,812	0.2	0	152	1	0
	W303	0	1,812	0	0	0	1	0
	W304	2.3	1,625	0	0	0	0.75	0
	P/N Temple	9.6	1,555	0	0	0	0.65	0.3
	I104	0	1,555	0.2	0	20	1	0
								0
4. Manohara Kh.	W402	5.5	2,352	0	0	0	1	0
	I403	0.2	2,125	0.2	0	82	1	0
	I404	2.8	2,447	0.2	0	100	1	0
	W401	8	2,596	0	0	0	1	0
	I401	2.5	2,181	0.2	0	6	1	0
	I402	2.4	2,165	0.2	0	80	1	0
	I405	30.9	1,949	0.2	0	226	0.75	0
	W403	18.5	1,550	0	0	0	0.65	0
	I406	0.8	1,350	0.2	0	17	0.65	0.09
								0
5. Hanumante Kh.	W501	6.5	2,347	0	0.05	0	1	0
	I501	1.8	1,875	0.2	0	90	0.8	0
	I502	3.7	1,897	0.2	0	100	0.8	0
	I503	1.3	1,731	0.2	0	60	0.75	0
	I511	12	1,671	0.2	0	120	0.75	0
	I5004/I505	15	2,021	0.2	0	336	0.75	0
	I506/I506a /I507/I508	6.8	2,008	0.2	0	540	0.8	0
	I609/I510	7.1	1,862	0.2	0	397	0.75	0
	B-5-1	37	1,652	0	0	0	0.65	0
								0

Note, CA = catchment area, R/F = irrigation return flow, MD = municipal watre demand
IA = irrigation area, AF = adjustment factor, MF = river maintenance flow
* The locations are schematically illustrated in Fig. F-4.1.

Table F-4.1 METEORO-HYDROLOGICAL FEATURES IN BASINS OF BALANCE POINTS (2)

River Basin	Balance Points*	CA (sq.km)	Rainfall (mm/y)	R/F Rate	MD (cms)	IA (ha)	AF	MF
6. Godawari Kh.	I517	3	1,683	0.2	0	85	0.75	0
	I515	7.2	1,858	0.2	0	205	0.8	0
	W502	5.1	2,568	0	0	0	1	0
	I512	8.5	2,382	0.2	0	0	0.8	0
	I513	3.7	1,927	0.2	0	200	0.8	0
	W503	2.4	1,801	0	0	0	0.8	0
	I514	1.2	1,435	0.2	0	635	0.75	0
	I516	8.2	1,455	0.2	0	100	0.75	0
	B-5-2	5.8	1,407	0	0	0	0.65	0.05
								0
7. Kodku Kh.	I601	4.2	1,828	0.2	0	75	1	0
	I602	11.8	1,791	0.2	0	275	0.8	0
	D601	0	1,791	0	0	0	0.8	0
	I603	4.5	1,418	0.2	0	30	0.75	0
	W601	3.5	1,283	0	0	0	0.65	0
	I604	10.2	1,260	0.2	0	200	0.65	0.04
								0
8. Nakhu Kh.	I703	5.1	2,199	0.2	0	329	1	0
	I701	5.6	2,878	0.2	0	24	1	0
	I702	21.7	2,445	0.2	0	0	0.85	0
	I704	10	2,022	0.2	0	400	0.8	0
	D701	0	2,022	0	0	0	1	0
	D702	0.5	1,875	0	0	0	0.85	0
	I705	0	1,875	0.2	0	100	1	0
	I706	3.7	1,643	0.2	0	200	0.75	0
	I707	4.3	1,349	0.2	0	925	0.75	0.06
								0
9. Balkhu Kh.	I801	15.2	2,375	0.2	0	260	0.8	0
	D801	21.8	2,013	0	0	0	0.75	0
	I802	0	2,013	0.2	0	50	0.75	0.07
10. Bagmati Kh.	Cobhar (B-10)	59.8	1,338				0.65	0.7

Note, CA = catchment area, R/F = irrigation return flow, MD = municipal watre demand
IA = irrigation area, AF = adjustment factor, MF = river maintenance flow
* The locations are schematically illustrated in Fig. F-4.1.

Table F-4.2 DIVERSION WATER REQUIREMENT FOR IRRIGATION

Unit:l/s/ha

River Basin	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1. Bisnumati Kh.	0.4	0.6	0.9	0.7	0.6	1.1	0.9	0.9	0.8	1.0	0.3	0.3	0.7
2. Dhobi Kh.	0.4	0.6	0.9	0.7	0.6	1.1	0.9	0.9	0.8	1.0	0.3	0.3	0.7
3. Bagmati Kh.	0.4	0.6	0.9	0.7	0.6	1.1	1.0	0.9	0.9	1.0	0.3	0.3	0.7
4. Manohara Kh.	0.4	0.6	1.0	0.7	0.6	1.0	0.8	0.6	0.5	0.9	0.3	0.3	0.6
5. Hanumante Kh.	0.4	0.6	0.9	0.7	0.5	1.1	0.9	0.8	0.8	0.9	0.3	0.3	0.7
6. Godawari Kh.	0.4	0.6	1.0	0.8	0.6	1.2	1.1	1.0	1.0	1.0	0.3	0.3	0.8
7. Kodku Kh.	0.4	0.6	1.0	0.8	0.6	1.2	1.1	1.0	1.0	1.0	0.3	0.3	0.8
8. Nakhu Kh.	0.4	0.6	1.0	0.8	0.6	1.2	1.1	1.0	1.0	1.0	0.3	0.3	0.8
9. Balkhu Kh.	0.4	0.6	0.9	0.7	0.6	1.1	0.9	0.9	0.8	1.0	0.3	0.3	0.7
10. Others	0.4	0.6	1.0	0.7	0.6	1.2	1.1	1.0	1.0	1.0	0.3	0.3	0.8
Max.	0.4	0.6	1.0	0.8	0.6	1.2	1.1	1.0	1.0	1.0	0.3	0.3	0.8
Min.	0.4	0.6	0.9	0.7	0.5	1.0	0.8	0.6	0.5	0.9	0.3	0.3	0.6
Mean	0.4	0.6	1.0	0.7	0.6	1.1	1.0	0.9	0.9	1.0	0.3	0.3	0.7

Table F-4.3 SURPLUS RIVER WATER IN THE KATHMANDU VALLEY

Unit:cms

Time (%)	Bisnumati Kh.						Dhobi Kh.		Bagmati Kh.			
	Balance Points**											
	W101*	W105*	W102*	W103*	W104*	W106	W201*	W202	W301*	D301	W303	W304
5	0.34	2.79	0.41	0.24	0.65	1.28	0.47	2.69	7.15	7.20	9.39	9.63
10	0.26	2.17	0.32	0.19	0.48	0.99	0.36	2.10	5.56	5.60	7.30	7.49
15	0.20	1.69	0.25	0.15	0.36	0.76	0.28	1.62	4.40	4.43	5.70	5.86
20	0.16	1.34	0.20	0.12	0.26	0.57	0.23	1.27	3.54	3.56	4.55	4.67
25	0.11	1.04	0.16	0.09	0.18	0.42	0.17	0.97	2.78	2.80	3.53	3.65
30	0.07	0.72	0.11	0.06	0.10	0.27	0.11	0.67	1.94	1.96	2.42	2.52
35	0.04	0.49	0.07	0.04	0.06	0.17	0.06	0.43	1.30	1.31	1.61	1.68
40	0.02	0.35	0.05	0.02	0.04	0.12	0.04	0.32	0.91	0.92	1.14	1.19
45	0.01	0.27	0.04	0.01	0.02	0.09	0.02	0.25	0.69	0.70	0.86	0.91
50	0	0.21	0.03	0.01	0.01	0.06	0.01	0.19	0.52	0.53	0.64	0.68
55	0	0.17	0.02	0	0	0.04	0	0.15	0.39	0.40	0.50	0.53
60	0	0.14	0.02	0	0	0.03	0	0.13	0.31	0.31	0.39	0.42
65	0	0.12	0.01	0	0	0.02	0	0.11	0.24	0.25	0.30	0.33
70	0	0.11	0.01	0	0	0.01	0	0.09	0.20	0.20	0.22	0.25
75	0	0.09	0.01	0	0	0.01	0	0.08	0.15	0.15	0.17	0.20
80	0	0.08	0.01	0	0	0	0	0.07	0.12	0.12	0.12	0.15
85	0	0.07	0	0	0	0	0	0.06	0.07	0.07	0.07	0.11
90	0	0.06	0	0	0	0	0	0.06	0.01	0.01	0.01	0.05
95	0	0.04	0	0	0	0	0	0.04	0	0	0	0.02
100	0	0.01	0	0	0	0	0	0.03	0	0	0	0
Mean	0.07	0.70	0.10	0.06	0.13	0.29	0.10	0.67	1.78	1.80	2.30	2.38
Max.	0.93	7.71	1.12	0.69	1.95	3.75	1.29	7.52	19.64	19.78	25.97	26.58

Time (%)	Manohara Kh.			Godawari Kh.		Kodku Kh.		Nakhu Kh.		Balkhu Kh.
	Balance Points**									
	W401	W402	W403	W502	W503	D601	W601	D701	D702	D801
5	1.60	0.98	8.68	1.01	2.33	1.60	2.20	5.94	5.94	4.55
10	1.25	0.76	6.80	0.79	1.61	1.16	1.66	4.24	4.24	3.56
15	1.00	0.60	5.34	0.63	1.09	0.86	1.28	3.00	3.00	2.76
20	0.82	0.47	4.29	0.50	0.70	0.62	0.95	2.03	2.03	2.17
25	0.65	0.35	3.28	0.32	0.39	0.42	0.68	1.26	1.26	1.68
30	0.47	0.23	2.30	0.16	0.20	0.25	0.42	0.71	0.71	1.17
35	0.33	0.15	1.54	0.10	0.11	0.16	0.27	0.44	0.44	0.78
40	0.25	0.11	1.13	0.04	0.04	0.10	0.19	0.26	0.26	0.57
45	0.20	0.09	0.91	0	0	0.07	0.13	0.13	0.13	0.45
50	0.16	0.07	0.71	0	0	0.04	0.09	0	0	0.35
55	0.14	0.05	0.57	0	0	0.01	0.04	0	0	0.29
60	0.12	0.04	0.49	0	0	0	0.01	0	0	0.24
65	0.10	0.03	0.40	0	0	0	0	0	0	0.20
70	0.09	0.02	0.33	0	0	0	0	0	0	0.16
75	0.08	0.01	0.27	0	0	0	0	0	0	0.14
80	0.07	0	0.22	0	0	0	0	0	0	0.12
85	0.05	0	0.16	0	0	0	0	0	0	0.11
90	0.02	0	0.11	0	0	0	0	0	0	0.09
95	0	0	0.07	0	0	0	0	0	0	0.07
100	0	0	0.03	0	0	0	0	0	0	0
Mean	0.43	0.23	2.20	0.22	0.42	0.32	0.48	1.14	1.14	1.15
Max.	4.31	2.68	23.69	2.72	7.68	4.86	6.46	17.82	17.92	12.58

Note, (1) Time = dependable time(%)
(2) * existing municipal water intake site
(3) ** The locations are shown in Figs. F-3.1 & F-4.1.
(4) W = ROR type, D = storage dam type

Table F-5.1 MONTHLY DISTRIBUTION OF SURPLUS RIVER WATER (1/2)

Unit:cms

Balance Points**	Time (%)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
(I) Bisnumati Kh.														
W105	50	0.12	0.09	0.09	0.08	0.08	0.38	1.66	2.33	1.52	0.53	0.29	0.16	0.61
	55	0.12	0.09	0.08	0.07	0.07	0.32	1.54	2.17	1.44	0.48	0.26	0.15	0.57
	60	0.11	0.09	0.08	0.06	0.07	0.27	1.44	2.07	1.35	0.45	0.24	0.14	0.53
	65	0.1	0.09	0.07	0.06	0.06	0.22	1.31	1.98	1.25	0.42	0.23	0.14	0.49
	70	0.09	0.08	0.07	0.06	0.06	0.17	1.21	1.88	1.16	0.37	0.2	0.12	0.46
	75	0.09	0.07	0.06	0.05	0.05	0.12	1.15	1.72	1.09	0.35	0.19	0.11	0.42
	80	0.08	0.07	0.06	0.05	0.04	0.08	1.04	1.61	0.98	0.31	0.17	0.1	0.38
	85	0.08	0.06	0.05	0.04	0.04	0.06	0.92	1.48	0.9	0.28	0.15	0.09	0.35
	90	0.07	0.06	0.05	0.04	0.03	0.05	0.77	1.29	0.77	0.24	0.13	0.09	0.30
	95	0.07	0.05	0.04	0.04	0.03	0.04	0.58	1.16	0.58	0.22	0.12	0.08	0.25
	100	0.05	0.04	0.03	0.02	0.02	0.01	0.04	0.72	0.31	0.17	0.09	0.07	0.13
W106	50	0.03	0.01	0	0	0.01	0.07	0.73	1.05	0.65	0.16	0.12	0.05	0.24
	55	0.03	0.01	0	0	0	0.06	0.67	0.98	0.62	0.14	0.11	0.04	0.22
	60	0.03	0.01	0	0	0	0.03	0.62	0.92	0.57	0.11	0.1	0.04	0.20
	65	0.02	0	0	0	0	0.02	0.57	0.89	0.53	0.1	0.09	0.04	0.19
	70	0.02	0	0	0	0	0	0.51	0.83	0.48	0.08	0.08	0.03	0.17
	75	0.02	0	0	0	0	0	0.48	0.76	0.42	0.07	0.07	0.03	0.15
	80	0.02	0	0	0	0	0	0.42	0.68	0.38	0.06	0.06	0.03	0.14
	85	0.01	0	0	0	0	0	0.36	0.63	0.33	0.05	0.05	0.02	0.12
	90	0.01	0	0	0	0	0	0.28	0.53	0.27	0.04	0.04	0.02	0.10
	95	0.01	0	0	0	0	0	0.15	0.47	0.15	0.02	0.03	0.02	0.07
	100	0.01	0	0	0	0	0	0	0.24	0.05	0.01	0.02	0.01	0.03
(II) Dhobi Kh.														
W202	50	0.11	0.08	0.07	0.06	0.07	0.29	1.58	2.23	1.44	0.46	0.28	0.15	0.57
	55	0.11	0.08	0.06	0.06	0.06	0.24	1.46	2.09	1.36	0.42	0.26	0.14	0.53
	60	0.1	0.07	0.06	0.06	0.06	0.2	1.37	1.99	1.26	0.38	0.24	0.13	0.49
	65	0.1	0.07	0.06	0.06	0.06	0.16	1.25	1.9	1.19	0.34	0.23	0.13	0.46
	70	0.09	0.06	0.06	0.05	0.05	0.11	1.16	1.81	1.08	0.3	0.2	0.12	0.42
	75	0.08	0.06	0.06	0.05	0.05	0.09	1.09	1.65	1	0.28	0.18	0.11	0.39
	80	0.08	0.06	0.05	0.05	0.04	0.07	0.99	1.52	0.92	0.25	0.17	0.09	0.36
	85	0.08	0.06	0.05	0.04	0.04	0.06	0.86	1.4	0.82	0.22	0.14	0.09	0.32
	90	0.07	0.05	0.05	0.04	0.04	0.05	0.7	1.19	0.68	0.19	0.13	0.08	0.27
	95	0.06	0.05	0.04	0.04	0.04	0.04	0.48	1.1	0.48	0.16	0.11	0.08	0.22
	100	0.06	0.04	0.04	0.03	0.03	0.03	0.04	0.65	0.24	0.12	0.09	0.06	0.12

Note, (1) Time - dependable time

(2) ** The locations are shown in Fig. F-3.1.

Table F-5.1 MONTHLY DISTRIBUTION OF SURPLUS RIVER WATER (2/2)

Unit:cms

Balance Points**	Time (%)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
(III) Bagmati Kh.														
W301	50	0.24	0.18	0.08	0.07	0.11	1.06	4.31	6.05	3.97	1.47	0.69	0.37	1.55
	55	0.24	0.17	0.06	0.05	0.09	0.89	4.07	5.64	3.75	1.34	0.63	0.35	1.44
	60	0.22	0.15	0.05	0.02	0.06	0.72	3.77	5.39	3.56	1.25	0.59	0.33	1.34
	65	0.2	0.12	0.03	0.01	0.04	0.57	3.47	5.15	3.23	1.17	0.54	0.31	1.24
	70	0.18	0.11	0.03	0	0.01	0.35	3.17	4.85	3.11	1.02	0.48	0.26	1.13
	75	0.16	0.09	0	0	0	0.17	3.04	4.48	2.91	0.97	0.44	0.22	1.04
	80	0.13	0.08	0	0	0	0.05	2.74	4.25	2.61	0.87	0.39	0.2	0.94
	85	0.13	0.06	0	0	0	0	2.52	3.9	2.39	0.76	0.33	0.18	0.86
	90	0.11	0.04	0	0	0	0	2.12	3.38	2.07	0.65	0.29	0.16	0.74
	95	0.09	0	0	0	0	0	1.6	3.06	1.6	0.57	0.24	0.13	0.61
	100	0.05	0	0	0	0	0	0	1.99	0.87	0.4	0.16	0.09	0.30
(IV) Manohara Kh.														
W403	50	0.42	0.29	0.16	0.16	0.25	1.16	5.15	7.25	4.88	1.69	1	0.57	1.92
	55	0.41	0.27	0.14	0.14	0.21	0.95	4.87	6.8	4.59	1.47	0.92	0.54	1.78
	60	0.4	0.26	0.13	0.13	0.18	0.73	4.51	6.43	4.35	1.37	0.87	0.51	1.66
	65	0.37	0.25	0.1	0.12	0.17	0.54	4.14	6.27	4.03	1.25	0.81	0.49	1.55
	70	0.35	0.23	0.1	0.1	0.13	0.38	3.78	5.87	3.69	1.13	0.74	0.44	1.41
	75	0.32	0.21	0.09	0.08	0.12	0.23	3.62	5.34	3.49	1.04	0.68	0.41	1.30
	80	0.31	0.2	0.09	0.07	0.09	0.13	3.26	5	3.22	0.93	0.63	0.37	1.19
	85	0.29	0.15	0.08	0.07	0.07	0.09	2.95	4.6	2.78	0.81	0.55	0.34	1.07
	90	0.27	0.13	0.07	0.06	0.06	0.07	2.51	4.12	2.47	0.7	0.5	0.31	0.94
	95	0.26	0.11	0.06	0.06	0.06	0.06	1.83	3.62	1.81	0.58	0.45	0.29	0.77
	100	0.19	0.08	0.05	0.05	0.05	0.03	0.06	2.42	0.94	0.41	0.35	0.24	0.41
(V) Balkhu Kh.														
D801	50	0.21	0.14	0.11	0.11	0.13	0.51	2.7	3.78	2.45	0.82	0.52	0.3	0.98
	55	0.2	0.14	0.11	0.1	0.11	0.44	2.49	3.54	2.32	0.75	0.48	0.28	0.91
	60	0.2	0.13	0.1	0.09	0.1	0.33	2.35	3.38	2.16	0.7	0.45	0.26	0.85
	65	0.19	0.12	0.09	0.09	0.1	0.27	2.14	3.23	2.04	0.62	0.42	0.24	0.80
	70	0.17	0.12	0.09	0.08	0.09	0.2	1.99	3.07	1.86	0.56	0.38	0.23	0.74
	75	0.16	0.11	0.08	0.07	0.08	0.14	1.88	2.81	1.73	0.51	0.35	0.2	0.68
	80	0.15	0.11	0.08	0.07	0.07	0.1	1.71	2.6	1.6	0.44	0.33	0.19	0.62
	85	0.13	0.1	0.07	0.06	0.06	0.08	1.49	2.39	1.43	0.38	0.28	0.17	0.55
	90	0.12	0.1	0.07	0.06	0.06	0.06	1.23	2.06	1.2	0.32	0.26	0.16	0.48
	95	0.12	0.08	0.05	0.05	0.05	0.04	0.87	1.89	0.87	0.27	0.23	0.13	0.39
	100	0.1	0.07	0.04	0.03	0.03	0	0.03	1.15	0.4	0.21	0.17	0.11	0.20

Note, (1) Time = dependable time

(2) ** The locations are shown in Fig. F-3.1.

Table F-5.2 MONTHLY EXPLOITABLE WATER WITH 80% DEPENDABILITY IN AMOUNT

Unit:cms

Balance Points**	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
(I) Bisnumati Kh.													
W105	0.14	0.11	0.10	0.09	0.08	0.22	1.76	2.57	1.75	0.59	0.31	0.18	0.66
W106	0.03	0.04 *	0.03 *	0.01 *	0.01 *	0.05 *	0.73	1.18	0.65	0.11	0.12	0.05	0.25
(II) Dhobi Kh.													
W202	0.13	0.09	0.08	0.08	0.08	0.16	1.67	2.48	1.56	0.46	0.31	0.17	0.61
(III) Bagmati Kh.													
W301	0.29	0.15	0.03 *	0.01 *	0.01 *	0.17	4.91	7.32	4.46	1.47	0.69	0.41	1.66
(IV) Manohara Kh.													
W403	0.51	0.31	0.16	0.16	0.21	0.38	5.88	8.92	5.57	1.69	1.07	0.63	2.12
(V) Balkhu Kh.													
D801	0.26	0.16	0.13	0.12	0.13	0.27	3.06	4.17	2.85	0.82	0.56	0.33	1.07

Note, * with highest dependability, though less than 80 %
** The locations are shown in Fig. F-3.1.

Table F-5.3 DAM SCALE BY RESERVOIR YIELD RATE

Reservoir Yield Rate*1 (cms)	Reservoir Volume (mcm)			Crest El. (m)	Dam Height (m)	Remarks
	Effective	Silt	Gross			
(1) Balkhu Kh. Dam						
0.2	2	2.3	4.3	1,338	26	
0.3	4	2.3	6.3	1,341	29	
0.4	6	2.3	8.3	1,343	31	
0.5	8	2.3	10.3	1,345	33	
0.6	11	2.3	13.3	1,347	35	
0.7	13	2.3	15.3	1,348	36	
0.8 *2	16	2.3	18.3	1,350	38	
(2) Sundarijal Dam						
0.1	3	1.8	4.8	1,632	60	
0.2	4	1.8	5.8	1,636	64	
0.3 *2	6	1.8	7.8	1,643	71	
(3) Kodku Kh. Dam						
0.1	3	1.0	4.0	1,389	33	
0.2	6	1.0	7.0	1,394	38	
0.3 *2	7	1.0	8.0	1,395	39	*3
(4) Lele Kh. Dam						
0.1	2	0.9	2.9	1,498	23	*4
0.2	5	0.9	5.9	1,504	29	*4
0.3 *2	7	0.9	7.9	1,507	32	*4
(5) Nakhu Kh. Dam						
0.2	5	2.6	7.6	1,498	49	
0.3	7	2.6	9.6	1,501	52	
0.4	9	2.6	11.6	1,503	54	
0.5	12	2.6	14.6	1,507	58	
0.6 *2	17	2.6	19.6	1,510	61	

NOte,

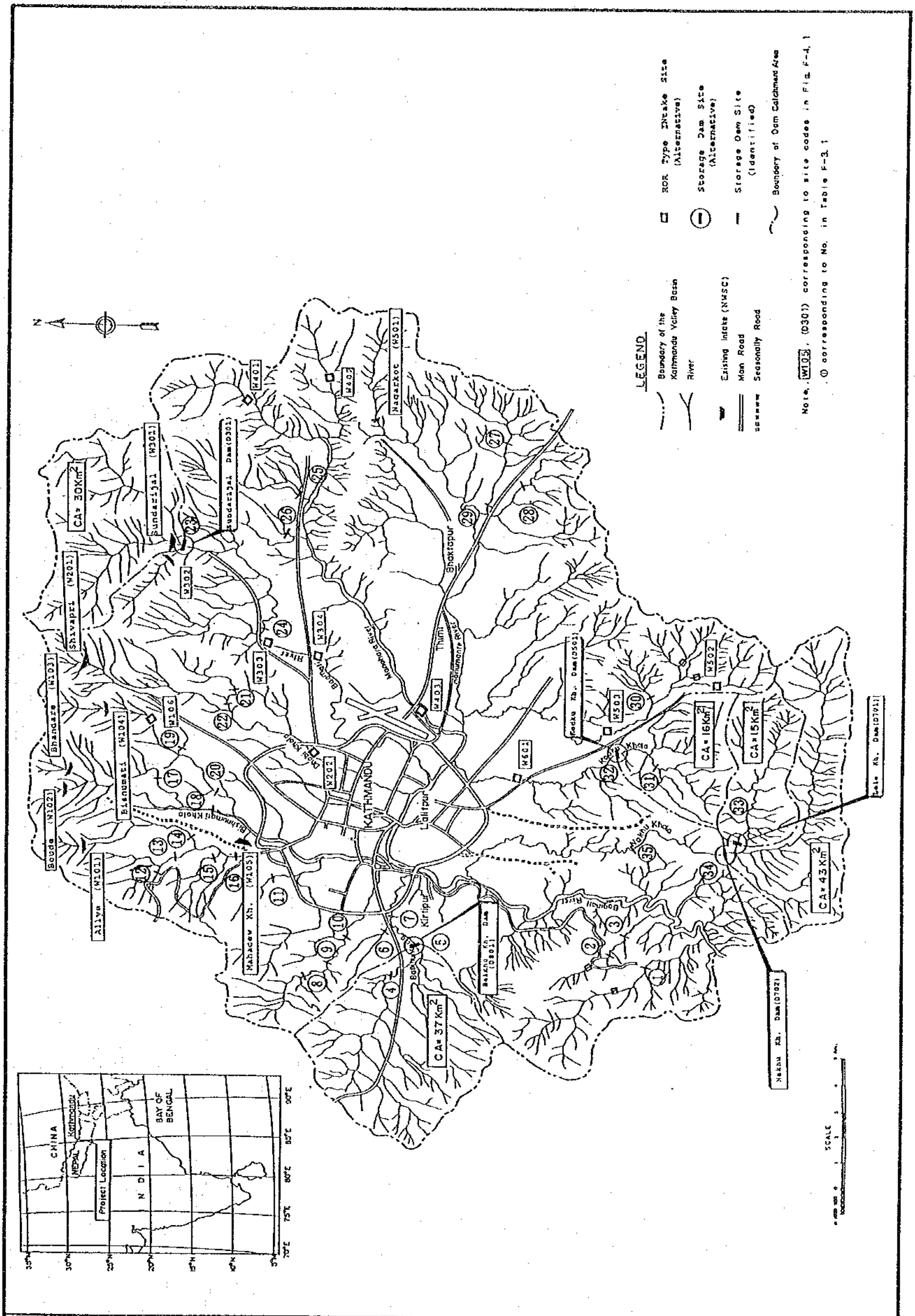
- *1 under 90 % firmness in time
- *2 maximum yield rate
- *3 with water transfer of Qmax = 0.4 (cms) from the Nakhu Kh.
- *4 with water transfer of Qmax = 4.5 (cms) from the Naldu Kh.

Table F-5.4 LAND USE AND MAJOR PROPATY IN RESERVOIR AREAS

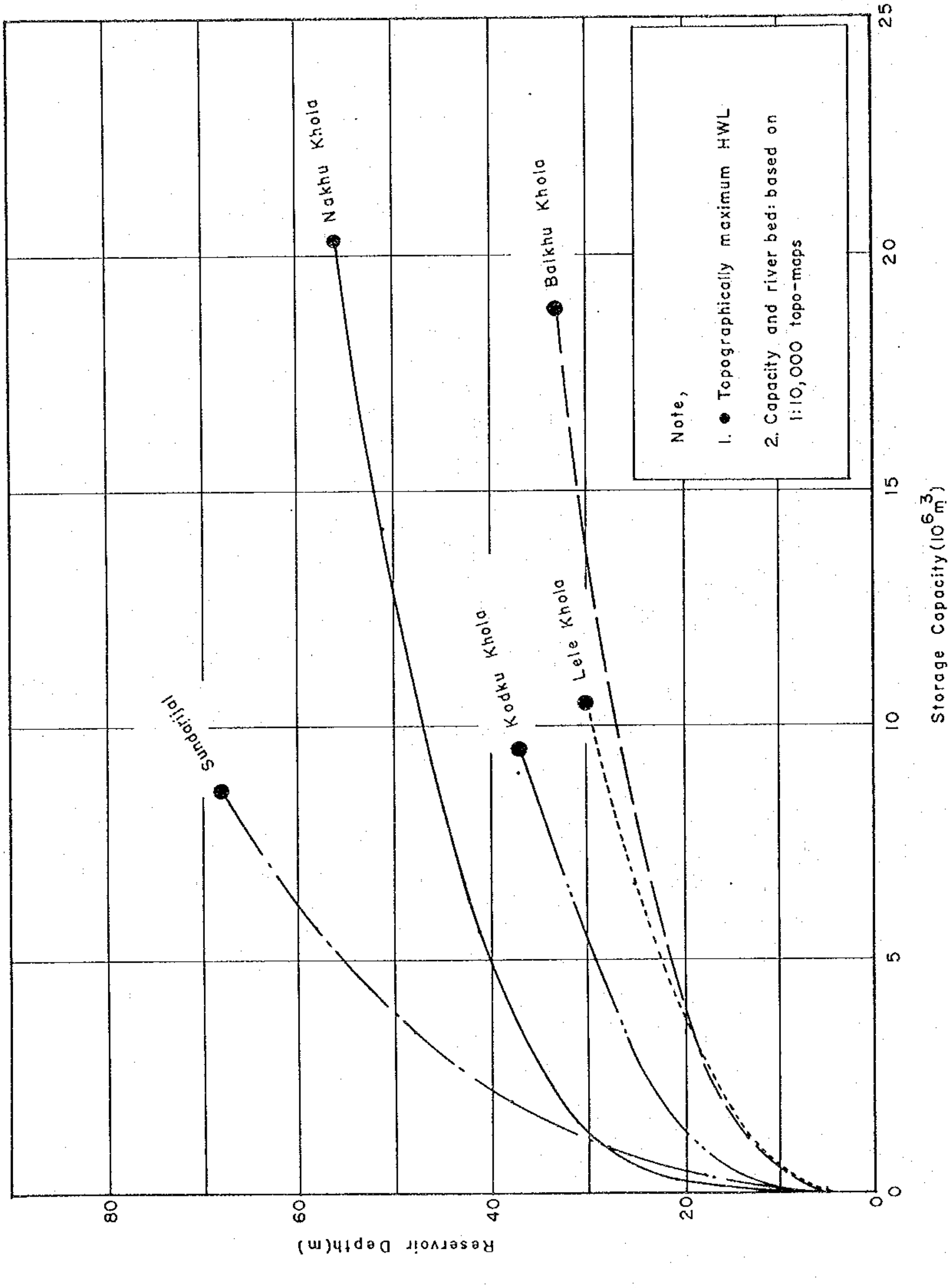
NO.	Name of Dam/ Reservoir	Dam Crest EL*1 (m)	Reservoir Area (sq.km)	Land Use (ha)			Nos. of Buildings (Nos)	Other Propaty
				Paddy Field	Upland Field	Others*2		
1	Balkhu Kh.	1,350	2.50	240.0	0.0	10.0	130	- Bishnu Devi Temple - several truss towers of cable-way (Kathmandu-Hetauda) - 3 truss towers of electricity power transmission line - paved road to Pokala (8 m width; 0.8 km)
2	Sundarijal	1,643	0.34	2.0	0.0	32.0	0	- low intake dam for Sundarijal hydroelectric power plant (750 kW)
3	Kodku Kh.	1,395	1.14	110.0	4.0	0.0	20	- irrigation intake weir
4	Lele Kh.	1,507	0.93	80.0	13.0	0.1	60	- irrigation intake weir
5	Nakhu Kh.	1,510	1.63	130.0	20.0	13.0	150	- irrigation intake weir - diversion fasilities for Naldu Kh. water to above intake

Note, (1) *1 maximum development
(2) *2 including forest and grass land

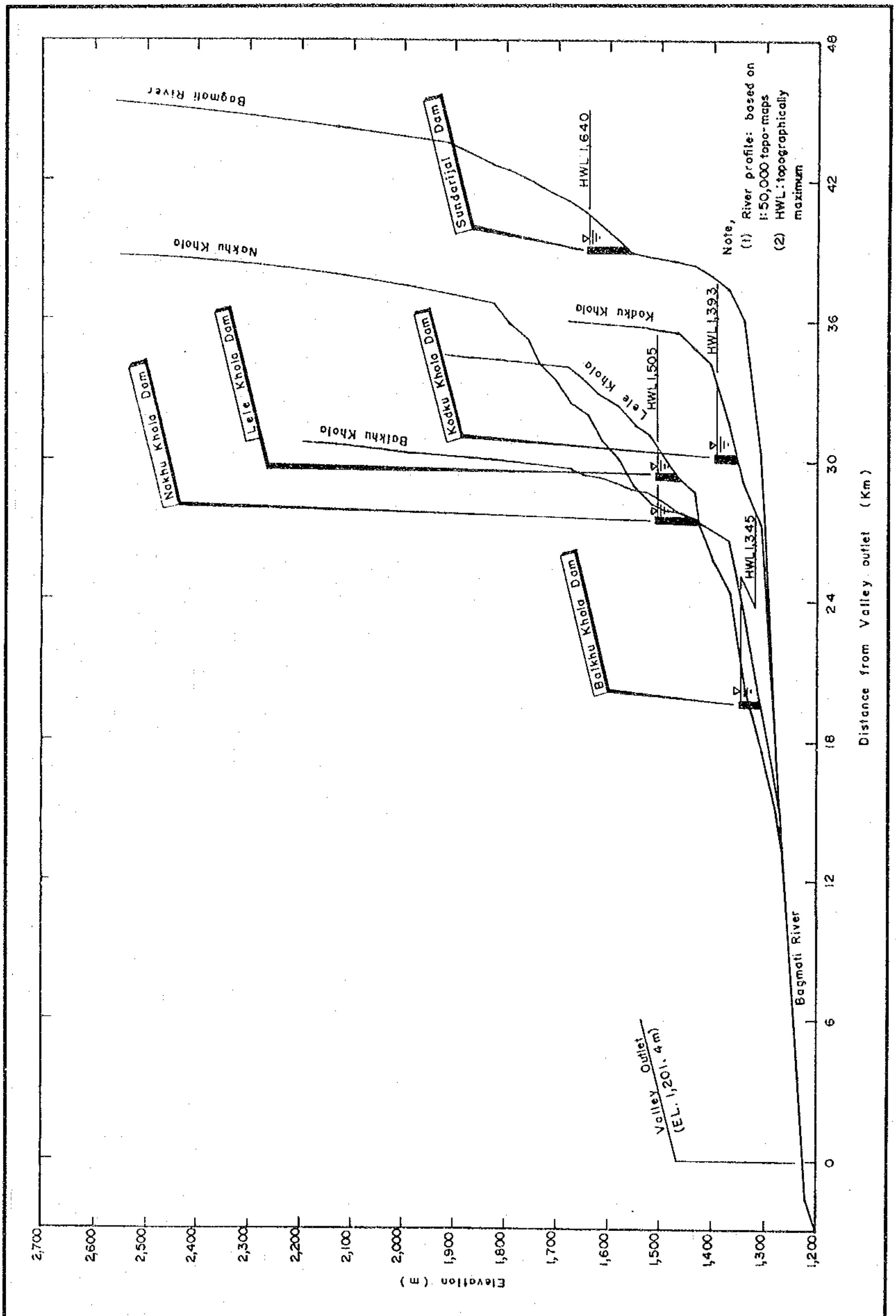
FIGURES



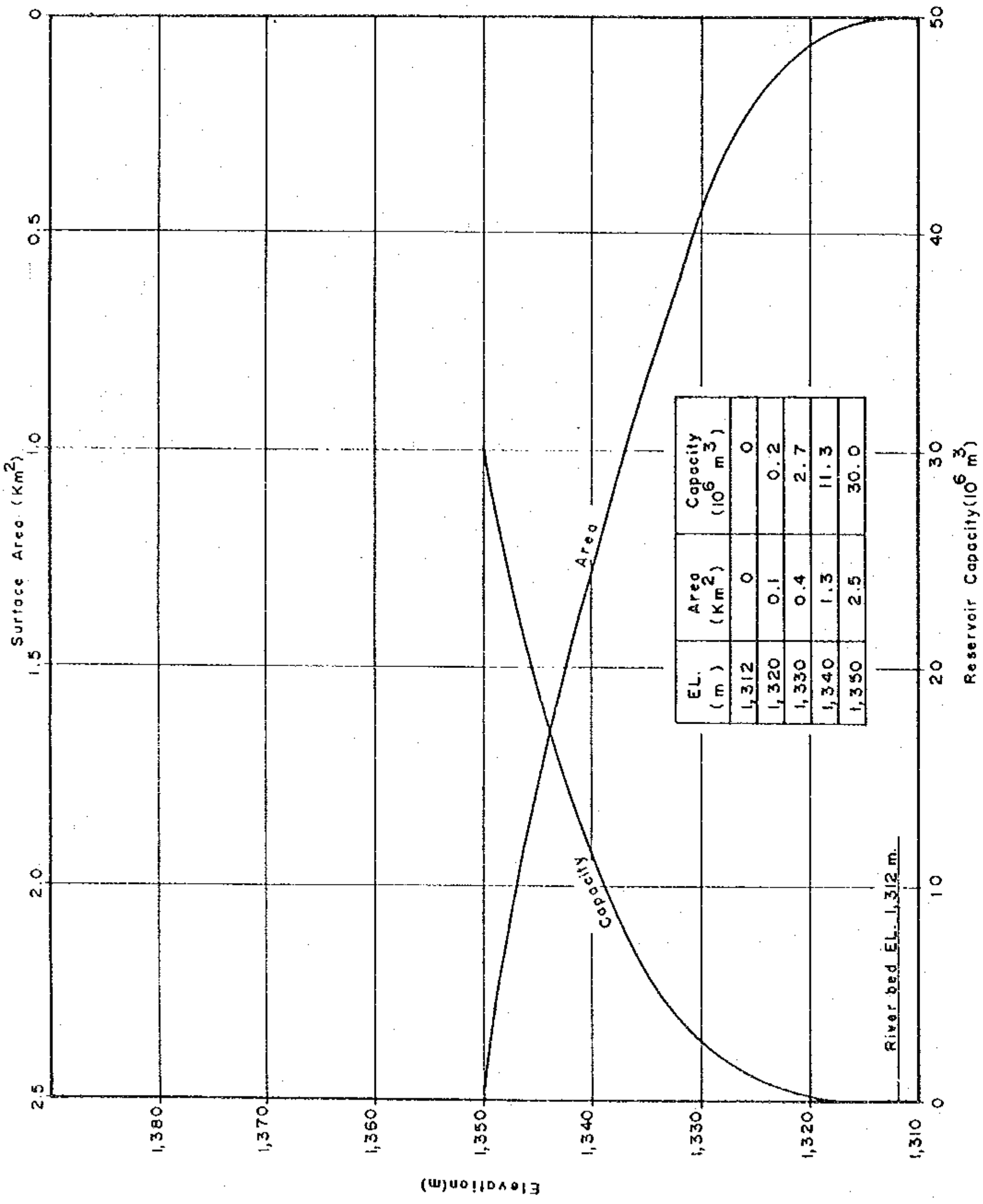
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. F-3.1	LOCATION MAP OF EXISTING & ALTERNATIVE INTAKE SITES
JAPAN INTERNATIONAL COOPERATION AGENCY		



HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. F-3.2	COMPARISON OF RESERVOIR CAPACITIES
JAPAN INTERNATIONAL COOPERATION AGENCY		

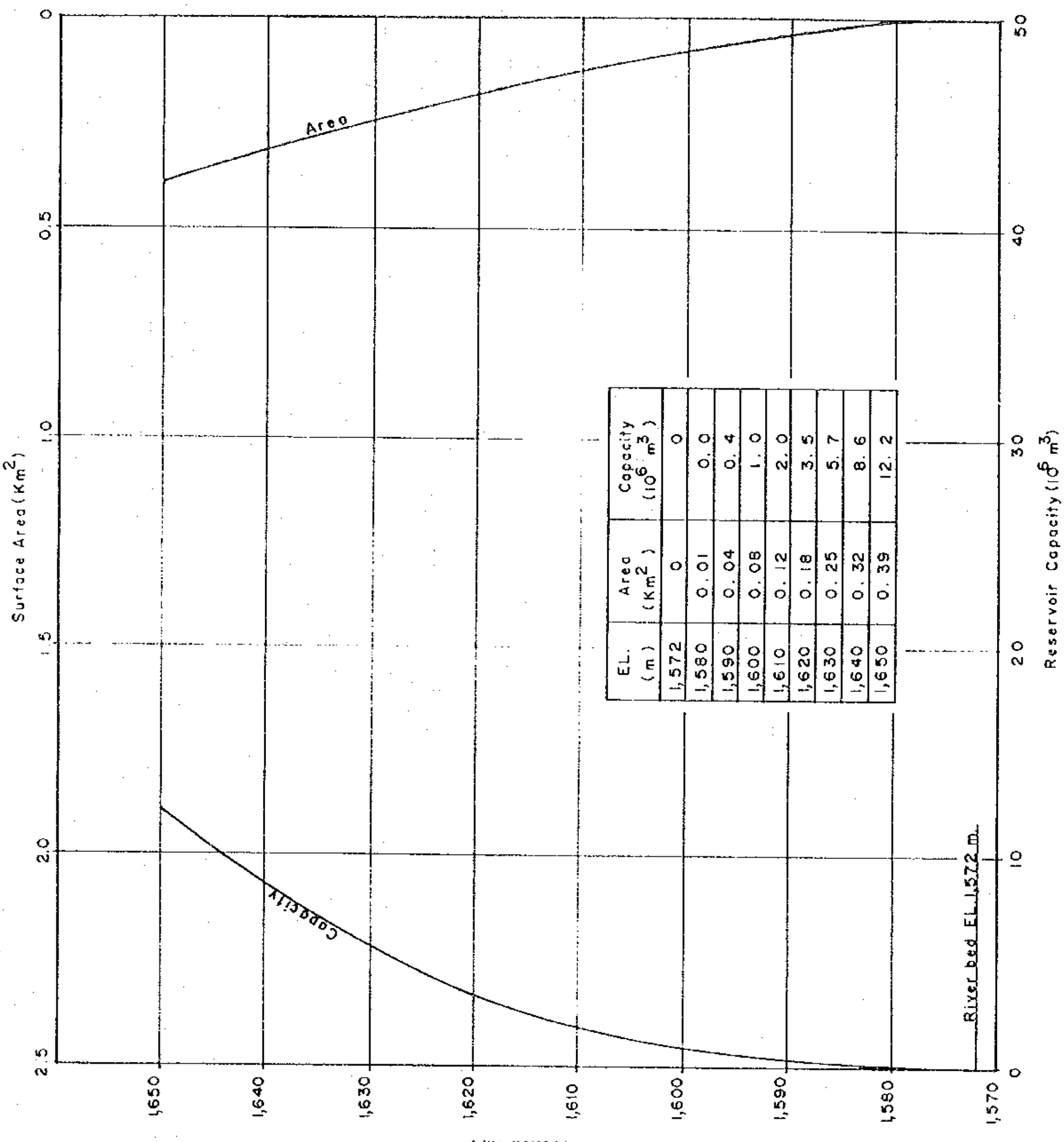


HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. F-3.3	ALTITUDINAL COMPARISON OF STORAGE RESERVOIR SCHEMES
JAPAN INTERNATIONAL COOPERATION AGENCY		



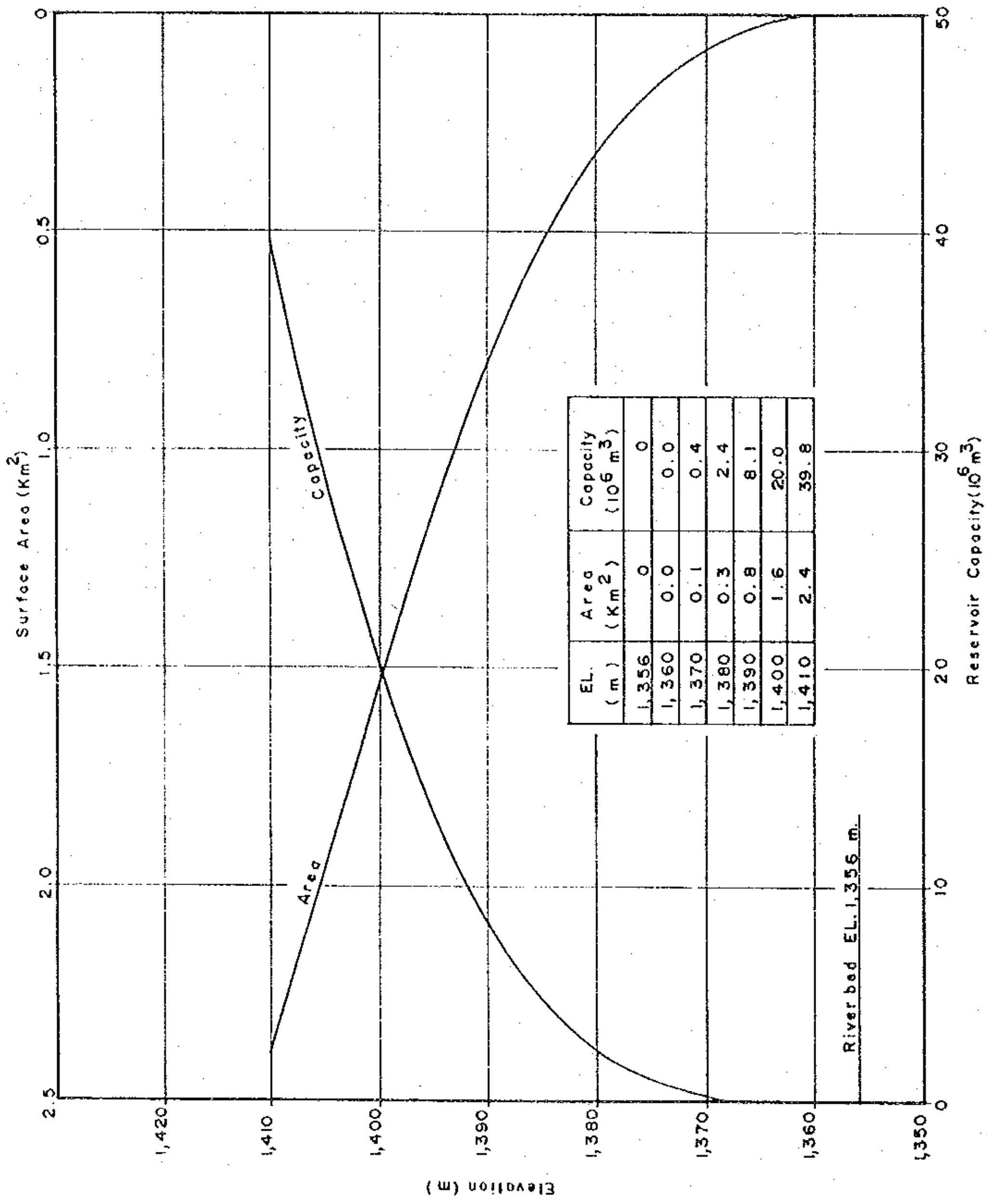
EL. (m)	Area (Km²)	Capacity (10⁶ m³)
1,312	0	0
1,320	0.1	0.2
1,330	0.4	2.7
1,340	1.3	11.3
1,350	2.5	30.0

HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. F-3.4	RESERVOIR AREA STORAGE CAPACITY CURVES OF BALKHU KH. RESERVOIR



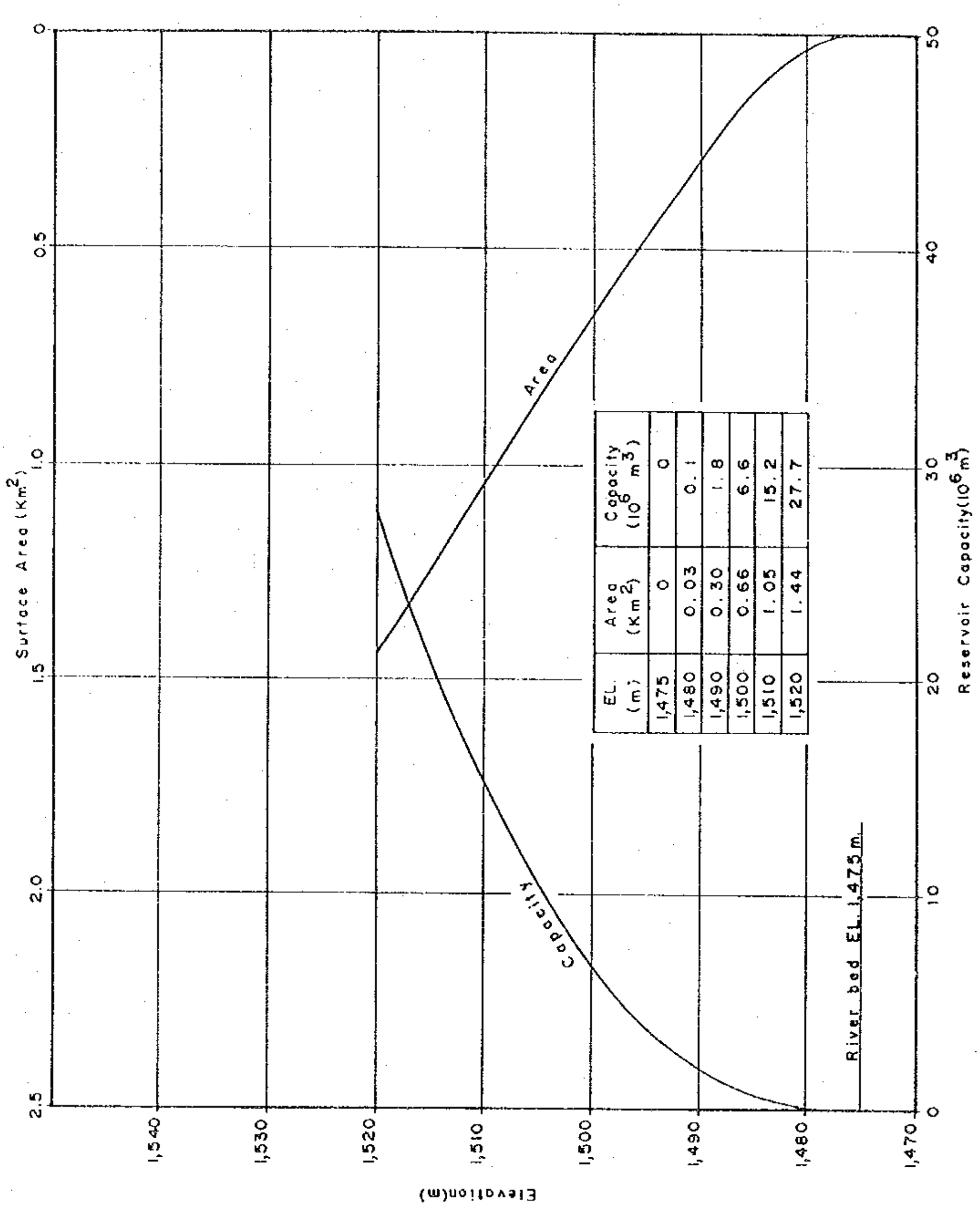
EL. (m)	Area (Km^2)	Capacity (10^6 m^3)
1,572	0	0
1,580	0.01	0.0
1,590	0.04	0.4
1,600	0.08	1.0
1,610	0.12	2.0
1,620	0.18	3.5
1,630	0.25	5.7
1,640	0.32	8.6
1,650	0.39	12.2

HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. F-3.5	RESERVOIR AREA STORAGE CAPACITY CURVES OF SUNDARIJAL RESERVOIR



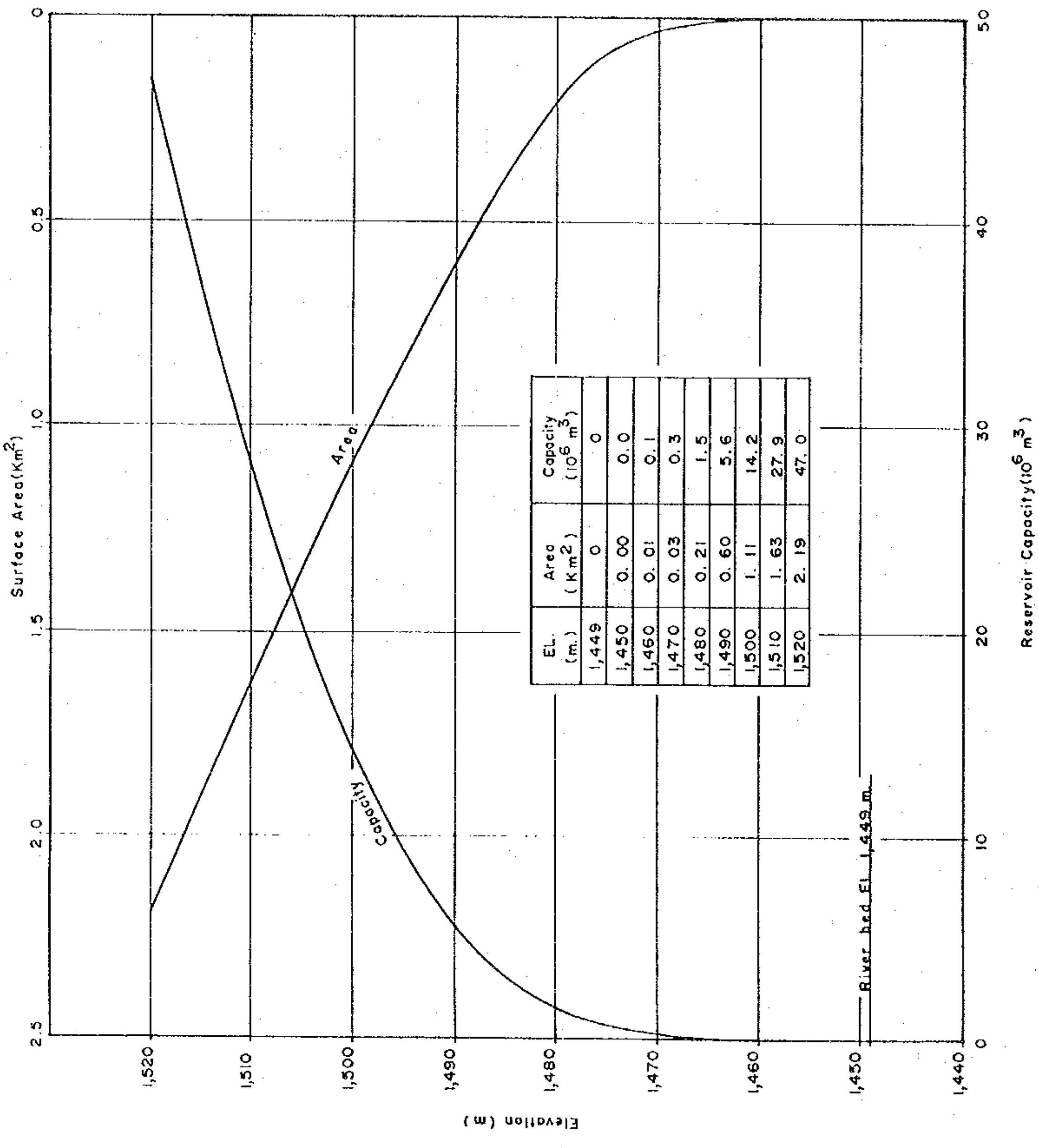
EL. (m)	Area (Km²)	Capacity (10⁶ m³)
1,356	0	0
1,360	0.0	0.0
1,370	0.1	0.4
1,380	0.3	2.4
1,390	0.8	8.1
1,400	1.6	20.0
1,410	2.4	39.8

HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. F-3.6	RESERVOIR AREA STORAGE CAPACITY CURVES OF KODKU KH. RESERVOIR



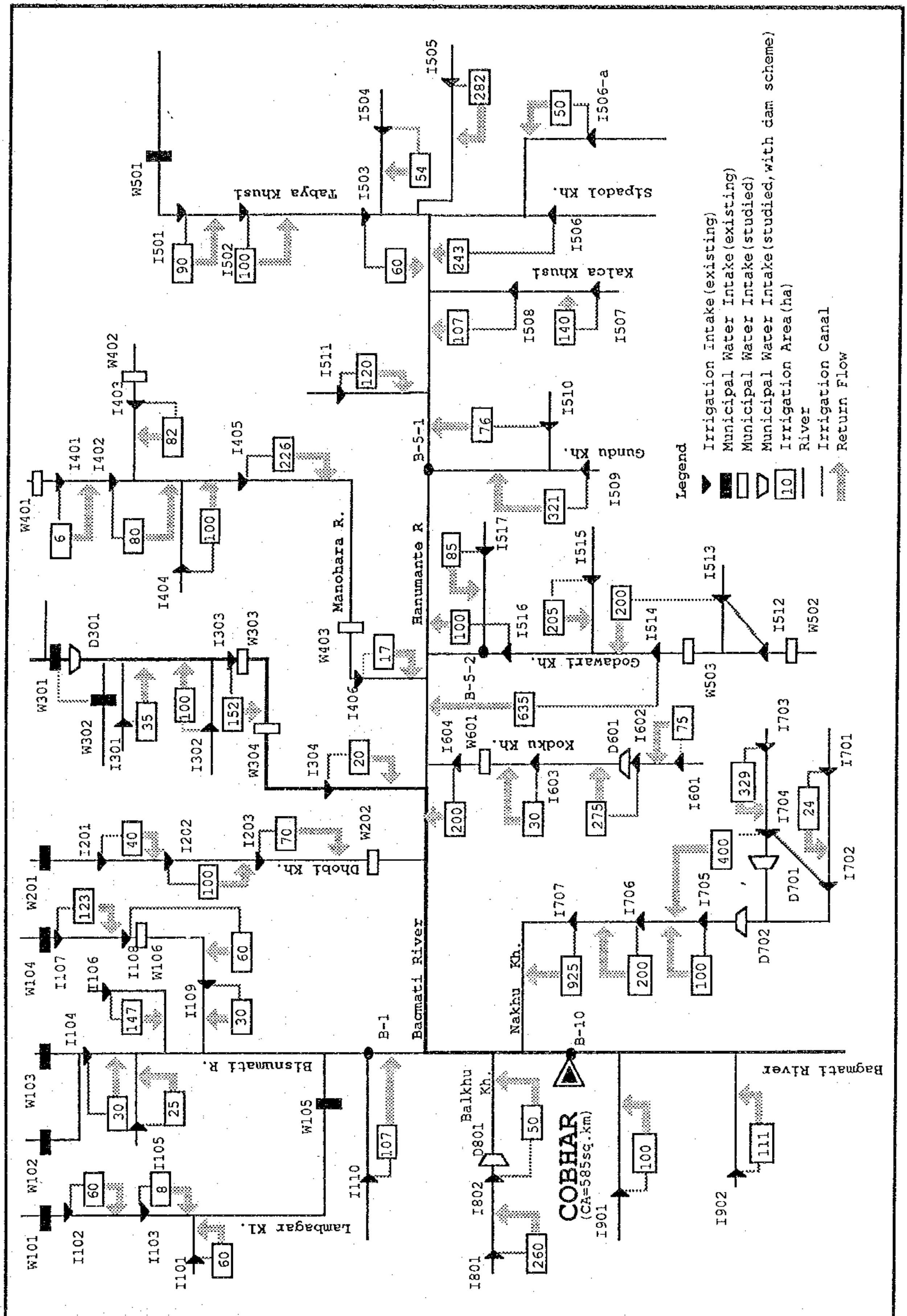
EL. (m)	Area (Km²)	Capacity (10⁶ m³)
1,475	0	0
1,480	0.03	0.1
1,490	0.30	1.8
1,500	0.66	6.6
1,510	1.05	15.2
1,520	1.44	27.7

HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. F-3.7	RESERVOIR AREA STORAGE CAPACITY CURVES OF LELE KH. RESERVOIR
JAPAN INTERNATIONAL COOPERATION AGENCY		

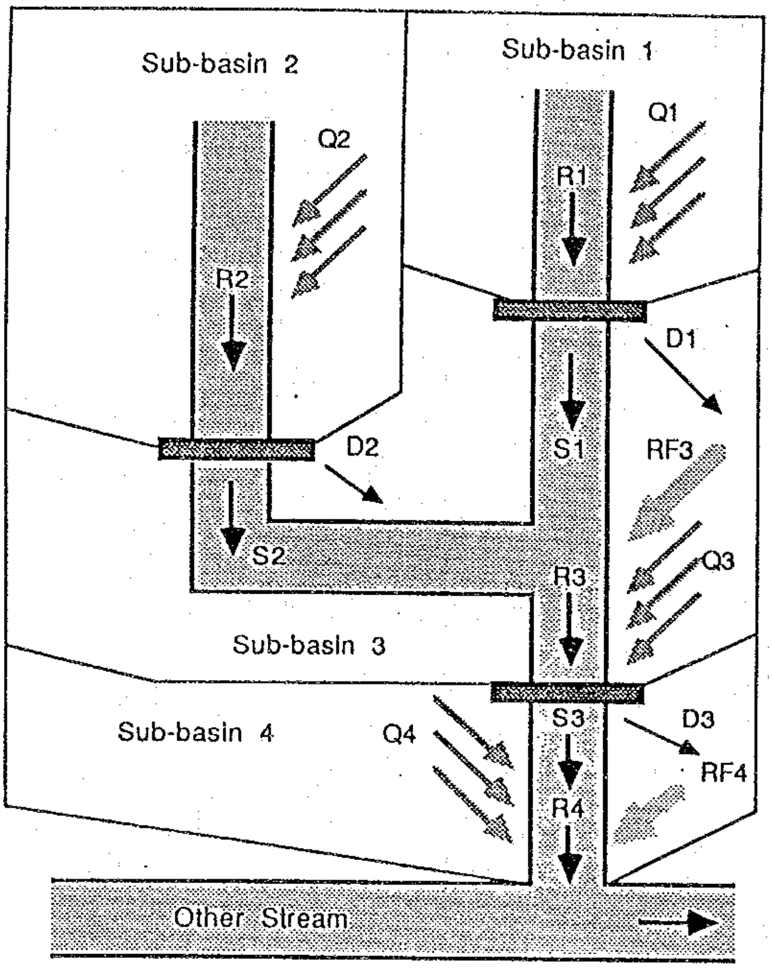


EL. (m.)	Area (Km^2)	Capacity (10^6 m^3)
1,449	0	0
1,450	0. 00	0. 0
1,460	0. 01	0. 1
1,470	0. 03	0. 3
1,480	0. 21	1. 5
1,490	0. 60	5. 6
1,500	1. 11	14. 2
1,510	1. 63	27. 9
1,520	2. 19	47. 0

HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. F-3.8	RESERVOIR AREA STORAGE CAPACITY CURVES OF NAKHU KH. RESERVOIR



HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. F-4.1	WATER DEMAND AND SUPPLY BALANCE MODEL IN THE KATHMANDU VALLEY
JAPAN INTERNATIONAL COOPERATION AGENCY		



Ri ; Avairable runoff at intake i (i=1-3)
Di ; Water demand at intake i (i=1-3)
Si ; Surplus runoff at intake i (i=1-3)
DFi ; Water deficit at intake i (i=1-3)
Qi ; Natural runoff in sub-basin i (i=1-4)
RFi ; Return flow in sub-basin i (1=1-4)
R4 ; Runoff into the main stream

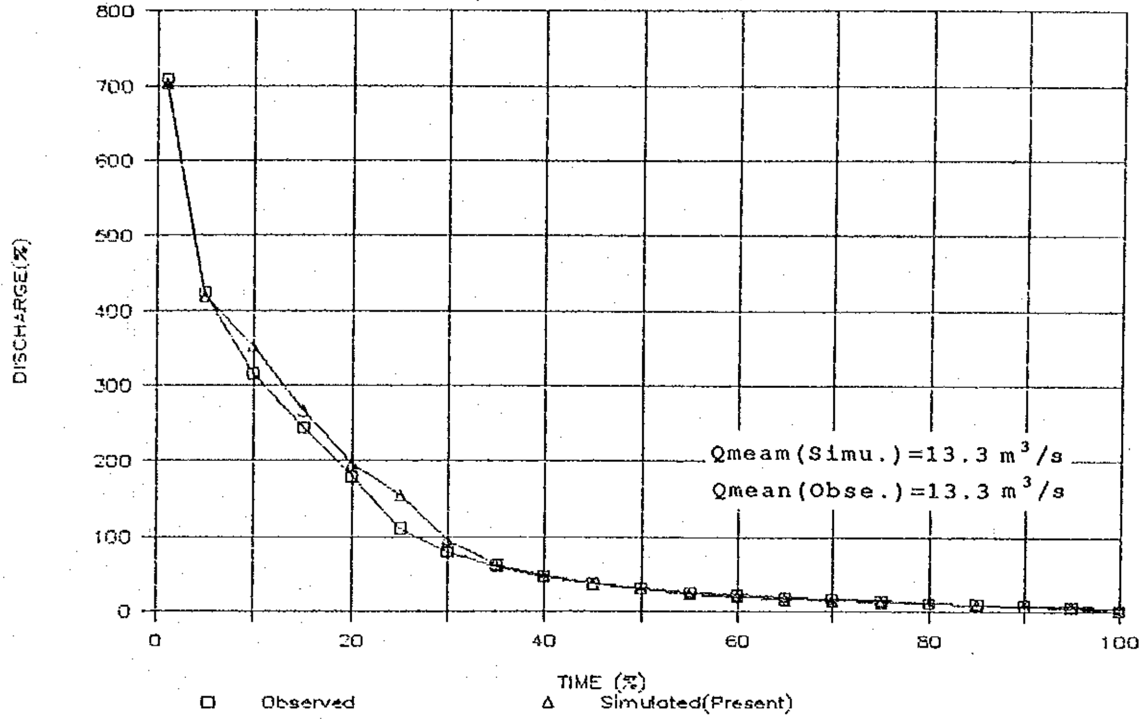
R1=Q1
R2=Q2
R3=Q3+S1+S2+RF3
R4=Q4+S3+RF4

IF ; Ri>Di
DFi=0, Si=Ri-Di
IF ; Ri<Di
DFi=Di-Ri, Si=0

HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. F-4.2	PROCEDURES OF WATER BALANCE CALCULATION

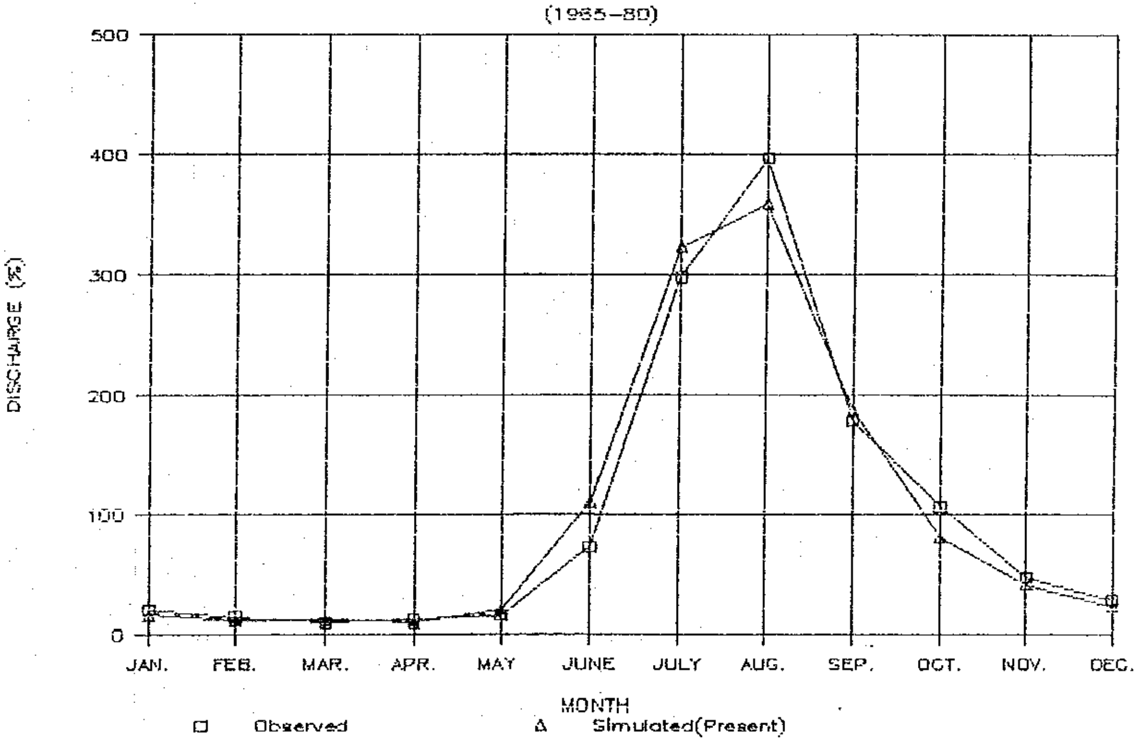
FLOW DURATION CURVE AT COBHAR

(1965–1980;5–DAY BASE)

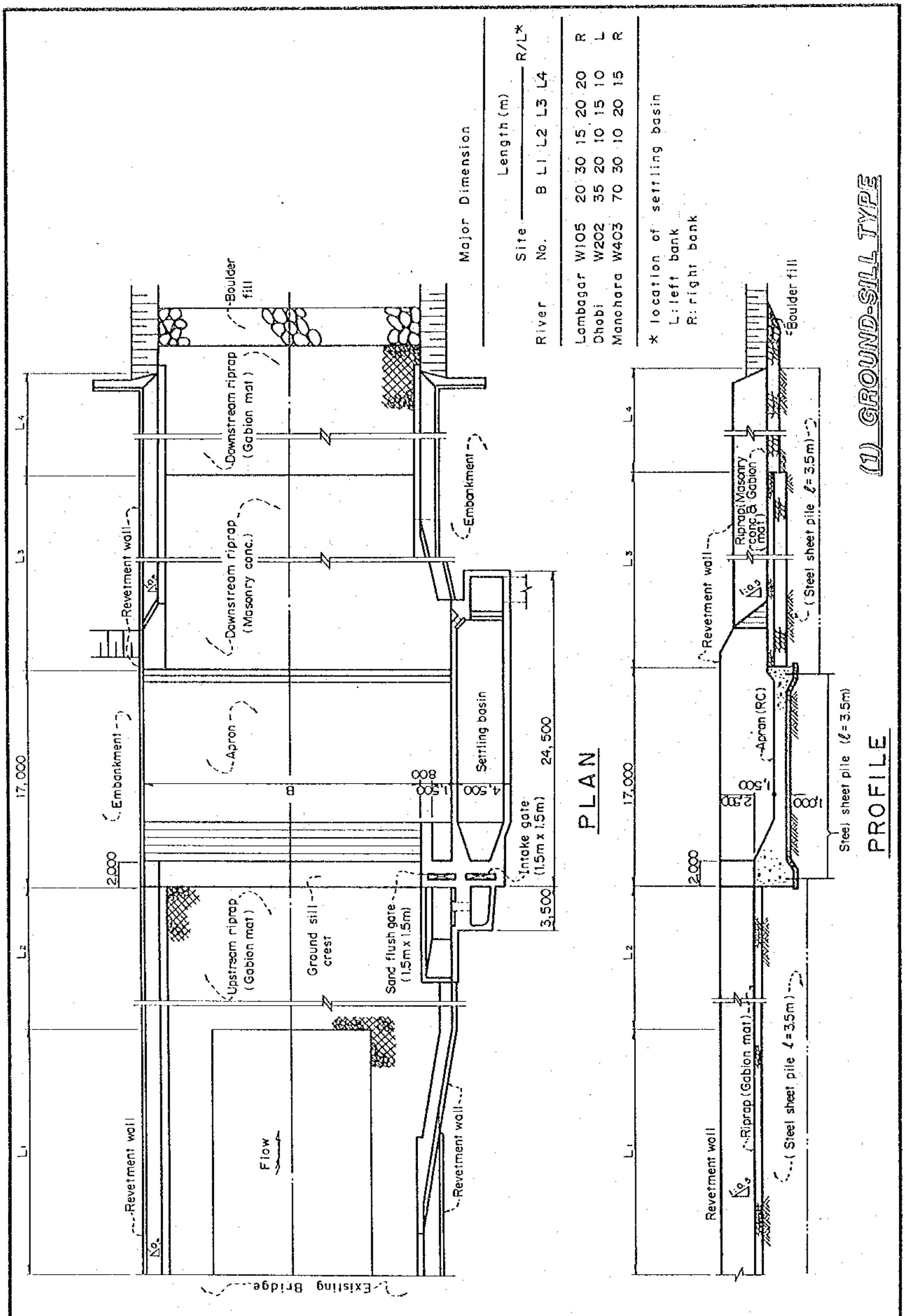


MONTHLY DISCHARGE AT COBHAR

(1965–80)



HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. F-4.3	NET RIVER RUNOFF AT COBHAR (PRESENT CONDITION)
JAPAN INTERNATIONAL COOPERATION AGENCY		



Major Dimension

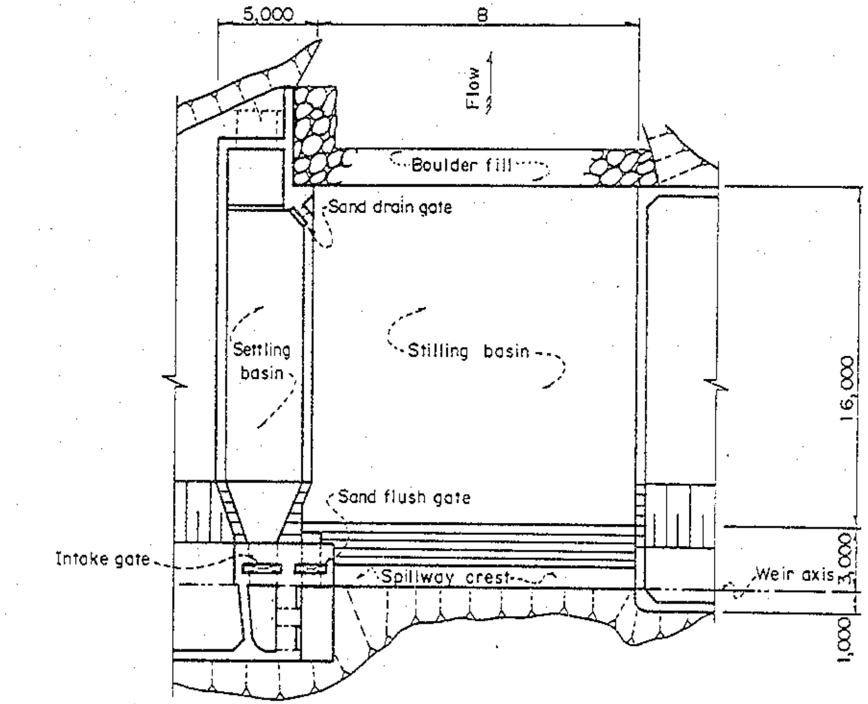
River	Site No.	B	L1	L2	L3	L4	R/L*
Lambagar	W105	20	30	15	20	20	R
Dhobi	W202	35	20	10	15	10	L
Manohara	W403	70	30	10	20	15	R

Length (m): B, L1, L2, L3, L4

* location of settling basin
L: left bank
R: right bank

HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. F-5.1	GENERAL LAYOUT OF ROR TYPE INTAKE (1)
JAPAN INTERNATIONAL COOPERATION AGENCY		

(2) CONCRETE WEIR TYPE

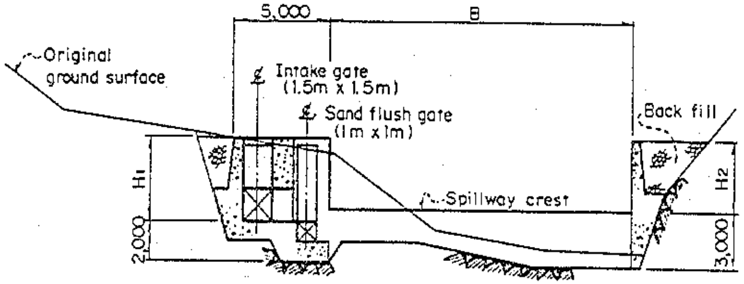


PLAN

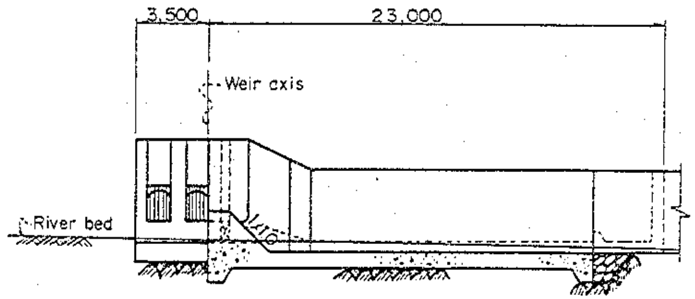
Major Dimension

River	Site No.	Length (m) B	Length (m) HI	Length (m) H2	R/L*
Balkhu	D801	16	4	3.5	L
Bisnumati	W106	6.5	3	2.5	L

* location of settling basin
L: left bank
R: right bank

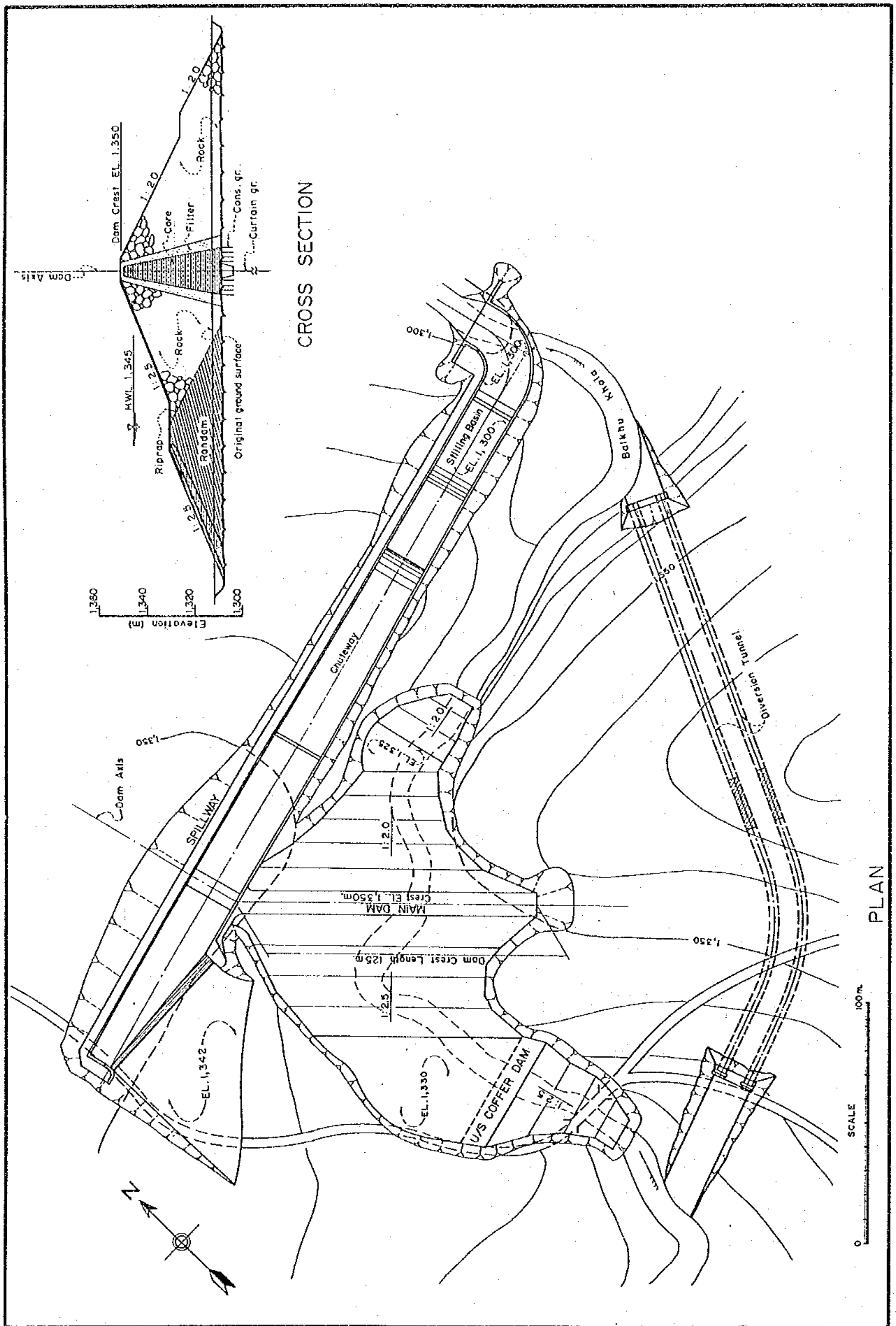


UPSTREAM ELEVATION

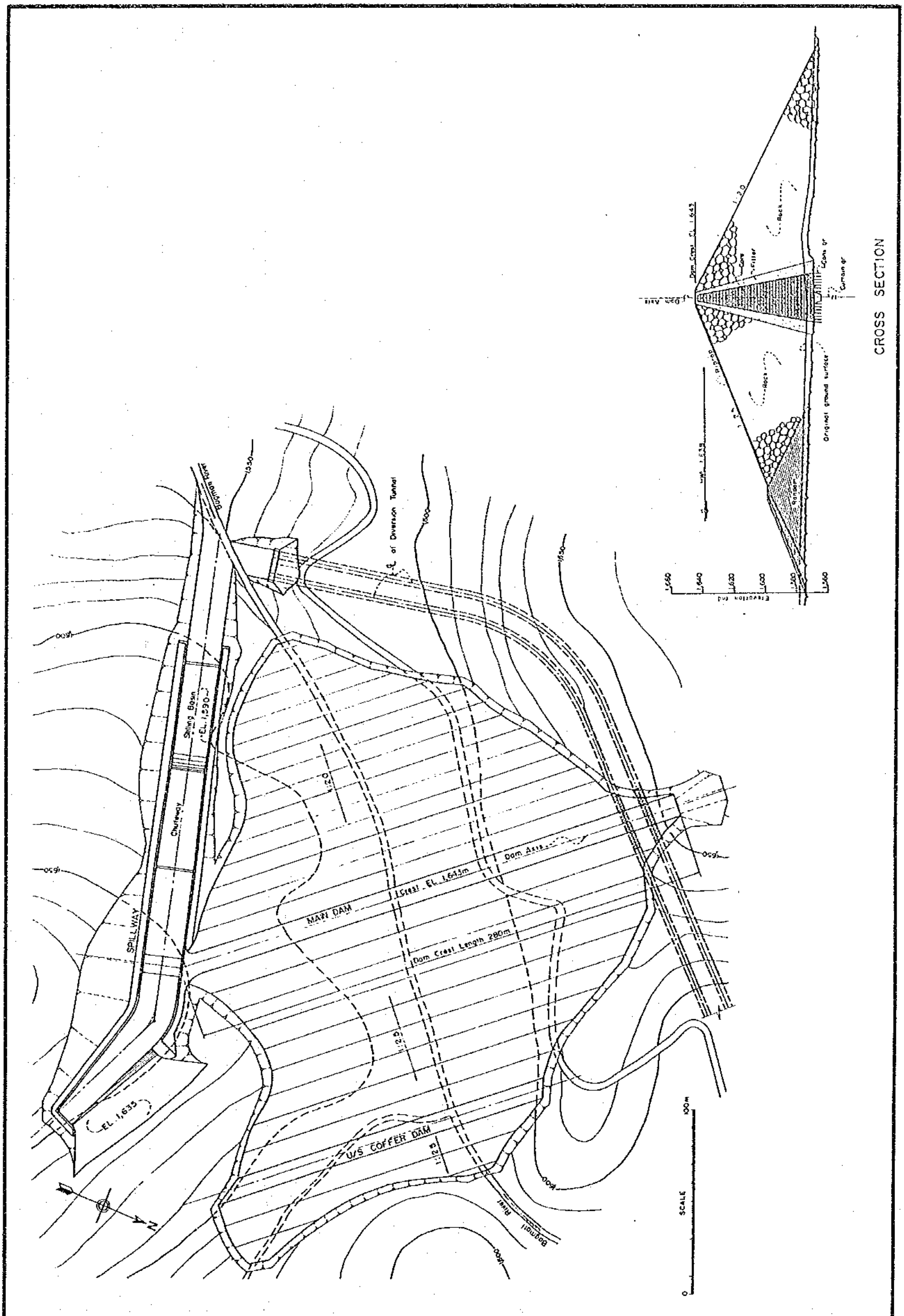


PROFILE

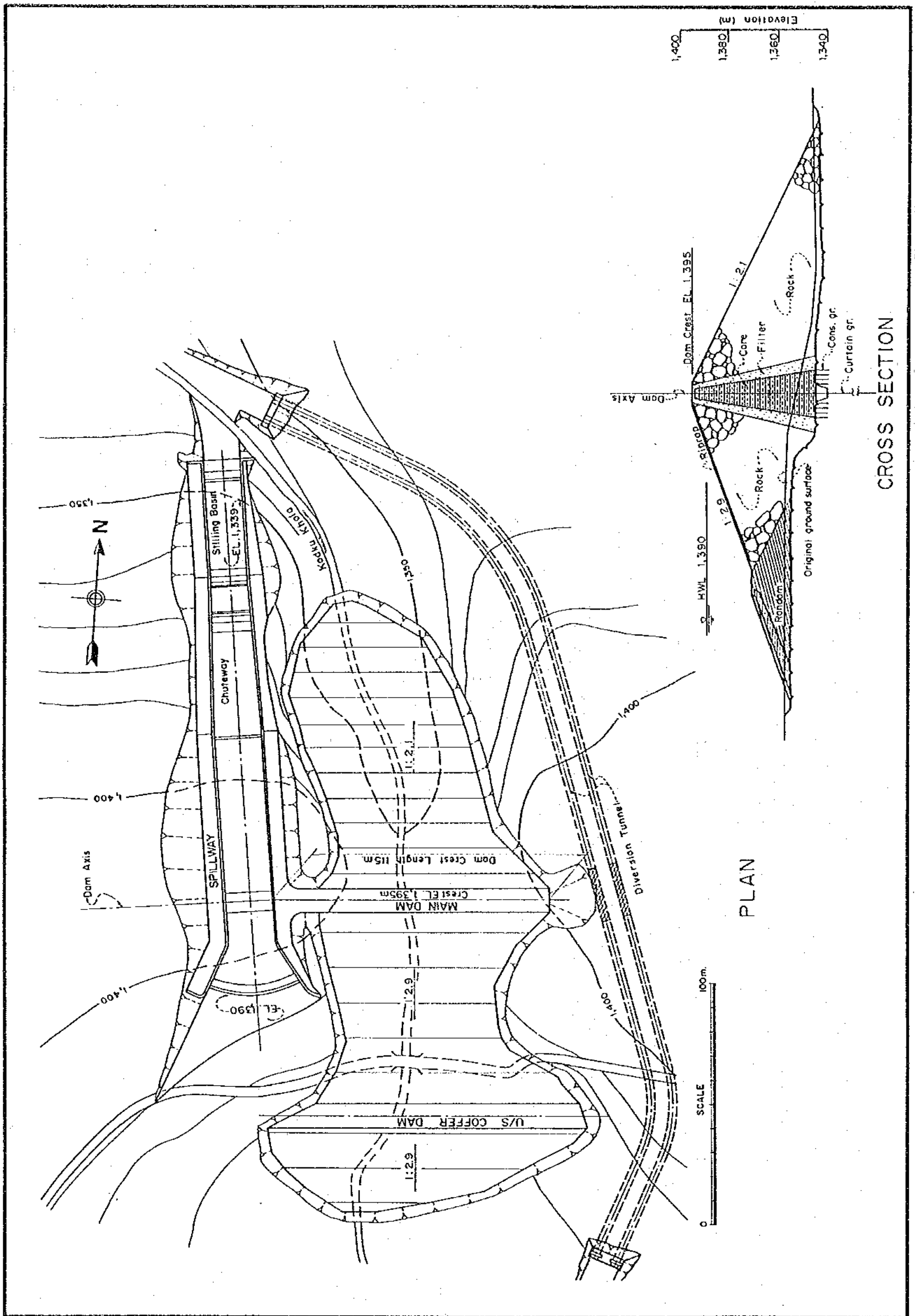
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. F-5.1	GENERAL LAYOUT OF ROR TYPE INTAKE (2)



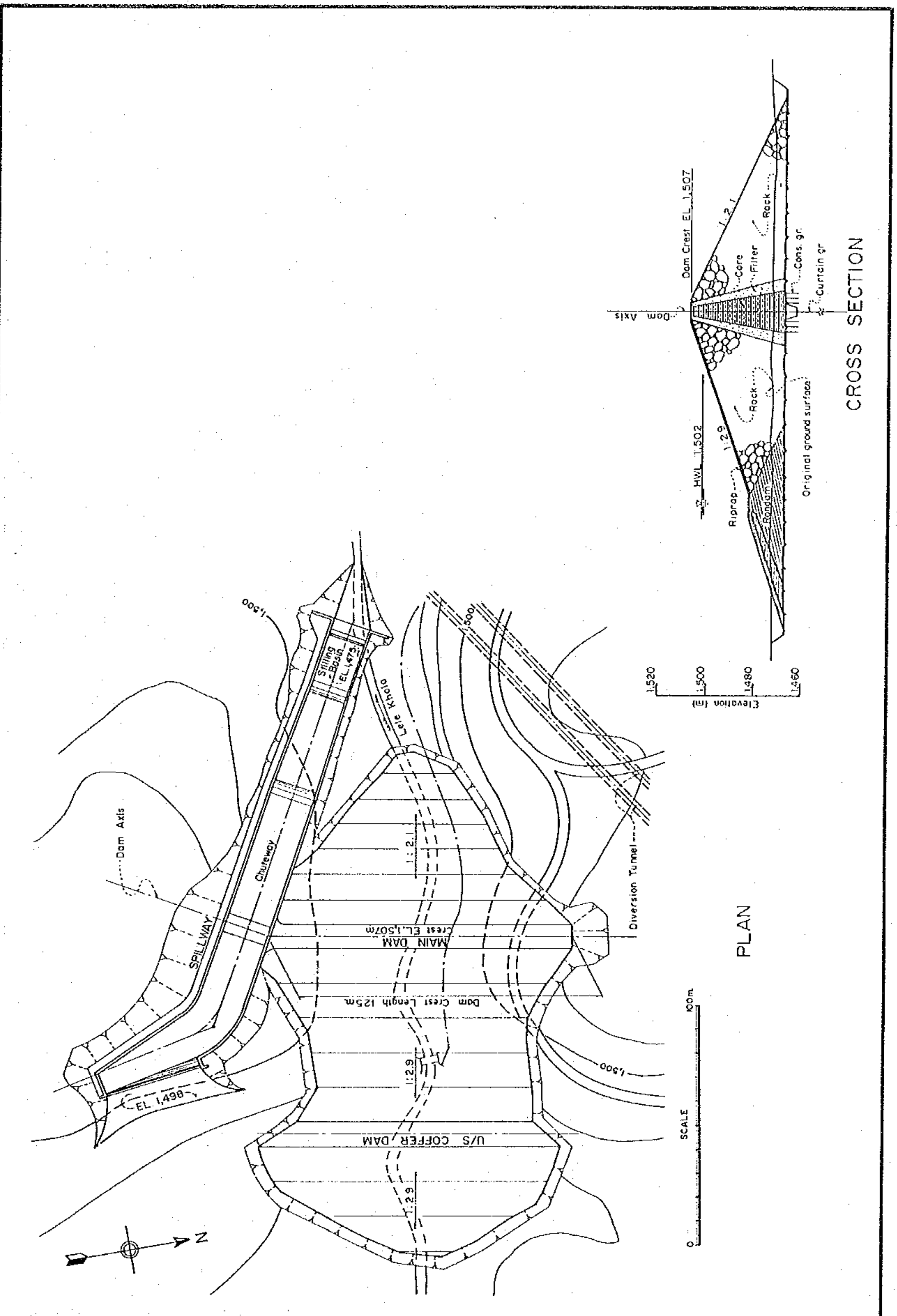
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. F-5.2	GENERAL LAYOUT OF BALKHU KH. DAM



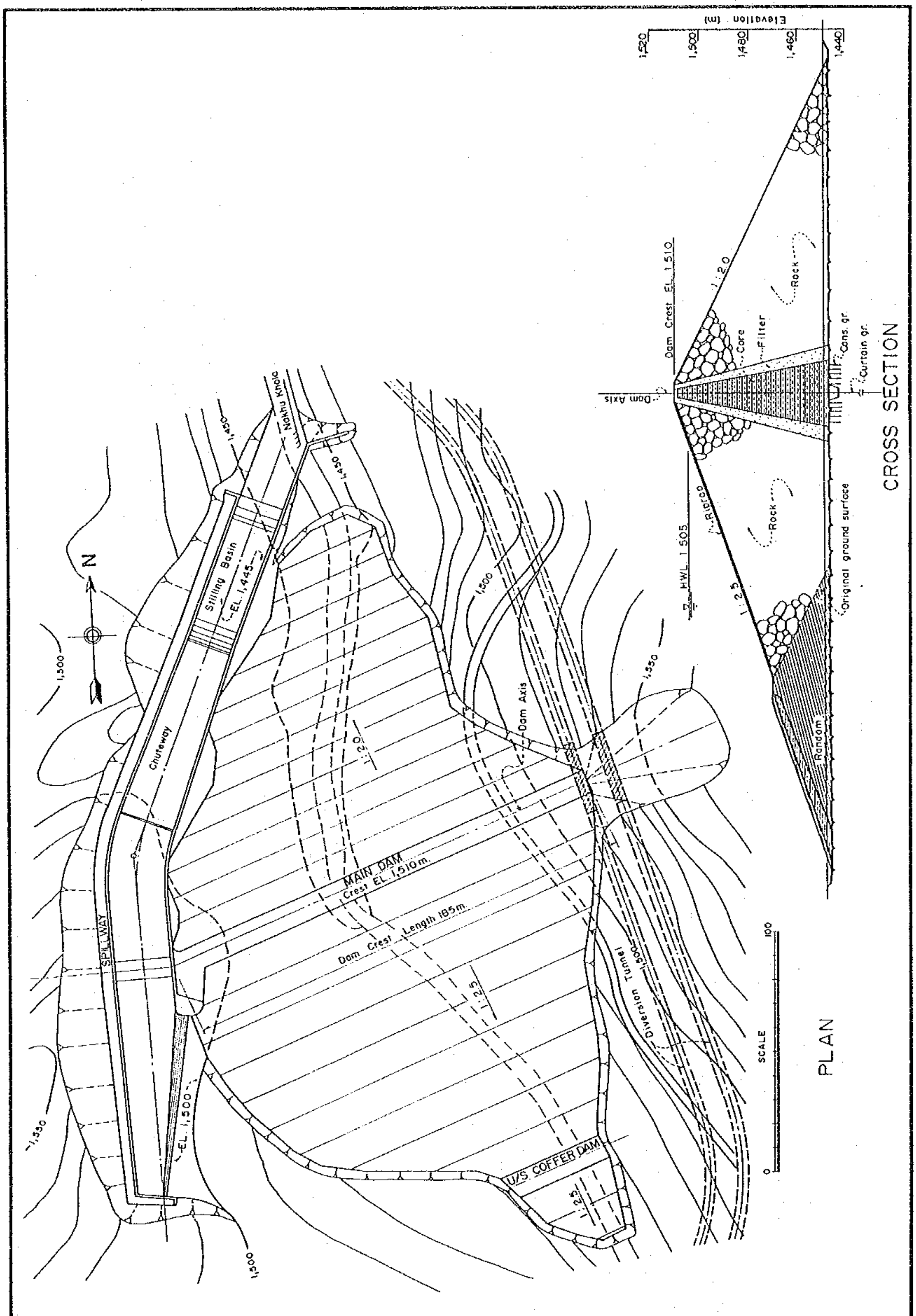
HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. F-5.3	GENERAL LAYOUT OF SUNDARIJAL DAM
JAPAN INTERNATIONAL COOPERATION AGENCY		



HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. F-5.4	GENERAL LAYOUT OF KODKU KH. DAM



HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. F-5.5	GENERAL LAYOUT OF LELE KH. DAM
JAPAN INTERNATIONAL COOPERATION AGENCY		



HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	Fig. F-5.6	GENERAL LAYOUT OF NAKHU KH. DAM
JAPAN INTERNATIONAL COOPERATION AGENCY		

APPENDIX G
WATER SUPPLY SYSTEM AND WATER QUALITY

APPENDIX G

WATER SUPPLY SYSTEM AND WATER QUALITY

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1 EXISTING WATER SUPPLY SYSTEM AND FACILITIES

1.1 General

In order that the current water supply facilities in Kathmandu may satisfy the increasing water demand following a recent rapid increase in the population, three water development projects have already been implemented, based on the 1973 master plan. These projects have included both the development of water resources such as springs, deep wells etc. and construction of water supply facilities such as reservoirs, pipelines, etc.

However, the existing water supply facilities can not perform their functions efficiently, because of deterioration, incomplete construction, and insufficient and improper operation and maintenance. Consequently, they often supply water in insufficient quantities. Moreover, there is the problem that each project has been expanded without sufficient study of the rationality and balance in the entire system.

With regard to quantity, after completion of the 3rd project which involves the construction of new wells, the available water supply should rapidly increase and meet the water demand by 1994.

The following describes the current status of water supply systems and facilities in Kathmandu.

1.2 Source of Supply

Surface water and groundwater are used in combination as water sources. The river water which comes from the Sundarijal dam, a water source for Sundarijal treatment plant and from the Lambagar Khola, a water source for Balaju treatment plant to supply water to the city of Kathmandu, and from the Mahadew Khola, a water source for the Bansbari treatment plant in the city of Bhaktapur and springs are also used.

Groundwater is mostly being produced by the wells constructed under the 3rd project. The groundwater produced by well fields of Bansbari, Dhobi Khola, Manohara and Gokarna in the northern part of the Kathmandu valley and through the southern Pharping well field, is now being supplied to the cities of Kathmandu and Lalitpur. For the city of Bhaktapur, there is a Bhaktapur well field in Bore.

The water supply systems managed in the Kathmandu valley by the NWSC can broadly be classified into eight systems which supply the cities of Kathmandu and Lalitpur, and two systems for the city of Bhaktapur. Of the former, the three systems for Chapagaun, Dood Phokari and Lokhat use springs as their water source mainly to supply villages around the cities.