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ARAKHTHOS RIVER
MIDDLE COURSE HYDROELECTRIC PROJECTS

MASTER PLAN

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CHAPTER 5 : HYDROLOGY

5.1 INTRODUCTION

The hydrological data used to determine the energy outputs from the projects and to design the spillways and diversion works is taken from the PPC hydrology report for the Middle Arakhthos river, Pistiana and Aghios Nikolaos projects, dated July 1982. As pointed out in the PPC report the three major requirements of the studies were to provide information for sizing of the structures and for ensuring the safety of the structures from floods and for checking that the reservoirs do not become silted up during the economic life of the schemes.

Wherever possible, direct use was made of the data provided in PPC's report. However, as is explained in more detail in the sections that follow, certain adjustments were made to eliminate apparent discrepancies in the monthly flows from the intermediate catchment. The need for further adjustments is apparent. The basic data provided by PPC was used to construct the necessary spillway and diversion design floods, taking account of attenuation provided by the upstream Steno and Kalaritikos reservoirs.

5.2 DESCRIPTION OF CATCHMENT

The Arakhthos river basin is shown on Appendix 2/01. The basin is located in Epirus, a province of Western Greece. It drains the western slopes of the Pindos mountains, which are among the highest in Greece. The highest point in the Arakhthos catchment area is in the Athanandou mountain range at an elevation of 2.429 m a.s.l. The river discharges into the Amvrakian Gulf near the town of Arta. It flows predominantly north-south, has a total length of 140 km and drains a catchment area of about 2000 km^2. Because of its exposure to rain-producing westerly winds and its location on the windward side of the Pindos mountains, the river has one of the highest specific flow rates in Greece.

The portion of the catchment drained by the Arakhthos and its tributaries up to the confluence with the Kalaritikos river is known as the Upper Arakhthos basin. Three tributaries, namely the Zagoritikos, Vardas and Metsovitikos with catchment areas of 128 km², 168 km² and 217 km² respectively, combine to form the main stream which is later joined from the left bank by the Kalaritikos river. The catchment area of the Kalaritikos basin is 228 km², and that of the Upper Arakhthos basin as a whole is about 880 km².

The Middle Arakhthos basin comprises the area between the Arakhthos/ Kalaritikos confluence and the Pistiana dam site, and has a total area of 340 km². The total catchment area at the Pistiana site is 1.220 km².

Generally the Upper and Middle Arakthos catchments are sparsely vegetated although there are also significant areas of forest and woodland. The areas are thinly populated, with mainly small village communities and only one major town, namely Arta, in the catchment.

5.3 HYDROMETEOROLOGY

5.3.1 General

There are a number of meteorological stations in and around the catchment, operated by several independent agencies including PPC, the National Meteorological Service, the Ministry of Public Works and the Forest Research Institute. Tables of monthly and yearly mean values of temperature, humidity and evaporation for each station, as well as precipitation tables giving monthly and yearly areal means, are given in the PPC hydrology report and the summarized data from these tables is discussed below.

5.3.2 Temperature

Mean monthly air temperatures at selected stations are given in the PPC hydrology report and are summarized in Table 5.1. The mean annual temperature gradient as determined by PPC is 0,61°C per 100 m decrease of elevation. Monthly mean temperatures at the Aghios Nikolaos and Pistiana reservoirs, which were used to estimate the evaporation rates of the reservoirs, are also given in Table 5.1.

Table 5.1

Mean monthly air temperatures (°C) at selected stations and at proposed dam sites

Location	O	N	D	J	F	M	A	M	J	J	A	S
Arta	18,1	13,8	10,3	8,9	10,0	12,1	15,2	20,0	24,1	26,5	26,6	22,9
Louros	18,8	14,3	10,5	8,9	9,7	12,0	15,0	19,4	23,4	25,8	26,3	23,1
Templa	15,9	11,6	7,5	5,9	7,3	9,6	13,3	18,0	21,7	24,3	24,7	21,3
Ioannina	14,9	10,0	6,3	4,9	6,4	9,0	12,5	17,5	22,0	24,9	24,6	20,3
Kipi	13,7	8,3	6,2	4,8	7,0	9,0	10,9	15,7	18,8	21,0	20,3	19,0
Ag.Nikolaos	16,5	12,0	9,0	7,0	8,0	10,0	14,0	18,0	22,5	25,0	25,0	21,2
Pistiana	17,5	13,5	10,0	8,0	9,0	11,5	15,0	18,8	22,9	25,5	25,5	22,0

5.3.3 Humidity

Mean monthly relative air humidity values are given for the Arta, Louros, Templa and Ioannina Stations in the PPC hydrology report. The long term averages are summarized in Table 5.2.

Table 5.2

Average relative humidities (%)

Location	time	O	N	D	J	F	M	A	M	J	J	A	S
Arta	08.00	75	82	80	79	79	77	77	76	72	69	69	74
	14.00	53	62	64	62	61	58	57	54	51	49	48	53
	20.00	74	80	78	76	76	75	76	73	67	67	67	72
Louros	08.00	81	88	85	83	86	81	79	72	73	68	74	79
	14.00	52	61	57	59	62	53	52	47	45	41	41	46
	20.00	78	86	82	78	79	75	72	67	64	61	61	70
Templa	08.00	89	94	93	92	92	90	87	81	75	71	72	82
	14.00	43	54	64	61	57	48	45	42	38	34	28	35
	20.00	74	86	88	85	81	73	68	63	59	50	45	60
Ioannina	08.00	85	90	88	86	86	83	82	80	73	67	70	81
	14.00	53	66	70	68	64	55	53	49	43	35	34	42
	20.00	71	81	81	77	74	68	67	67	59	50	50	62

5.3.4 Evaporation

In order to estimate the pan evaporation at the proposed dam sites, PPC established the correlation between air temperature and evaporation using data from the Pournari evaporation station. Using this relationship, monthly pan evaporation depths at Aghios Nikolaos and Pistiana were estimated using the temperature data given in Table 5.1. Monthly pan coefficients determined from studies at Marathon Lake were then applied to the pan evaporation depths in order to determine monthly reservoir evaporation depths. These are given in Table 5.3.

Table 5.3

Monthly reservoir evaporation rates

Month	Pan evaporation (mm) at the Pournari station corresponding to the monthly air temperature at the : Pistiana reservoir	Aghios Nikolaos reservoir	Pan coeffi-cient	Lake evaporation (mm) Pistiana reservoir	Ag.Nikolaos reservoir
October	90,0	80,0	0,74	66,6	59,2
November	47,0	43,0	1,17	55,0	50,3
December	46,0	43,0	1,29	59,3	55,5
January	42,0	41,0	0,94	39,5	38,5
February	43,0	42,0	0,59	25,4	24,8
March	48,0	58,0	0,55	26,4	31,9
April	95,0	89,0	0,43	40,9	38,3
May	116,0	110,0	0,41	47,6	45,1
Juni	154,0	149,0	0,50	77,0	74,5
July	195,0	188,0	0,55	107,3	103,4
August	195,0	188,0	0,62	120,9	116,6
September	130,0	123,0	0,74	96,2	91,0
Year	1201,0	1154,0	0,71	762,1	729,1

5.3.5 Precipitation

As noted in the PPC hydrology report the characteristic seasonal precipitation pattern of the Arakhthos basin is typical of basins in western Greece. 50% of the annual precipitation occurs in December, January and February while 80% occurs from November to March. A substantial proportion of the winter precipitation falls in the form of snow, so that runoff is delayed until spring.

In wet years, up to 150% of the mean annual precipitation may occur, whereas in dry years it may fall to 70% of the mean.

A total of fourteen precipitation stations in the Arakhthos basin were used to establish the mean areal precipitation at points of interest in the basin. Eight of these stations, belonging to the Ministry of Public Works, have been in operation since 1950. The remaining six stations which belong to PPC commenced operation only after 1960. Multiple regression techniques were used to fill in any gaps in the records.

The Thiessen polygon method was used to produce values of mean monthly precipitation separately for the two periods of analysis namely 1950-1960 and 1960-1978. The precipitation values for the first period were then corrected using a homogenization coefficient, which is the mean ratio of annual precipitation for the basins determined using the PPC stations to that determined using the Ministry of Public Works stations. The monthly precipitation records so obtained, covering the period period 1950 to 1978, are given for the Aghios Nikolaos and Pistiana catchments in Table 5.4 and 5.5 respectively.

Table 5.4

Mean monthly precipitation (mm) 1950 - 1978

Arakhthos river basin at the Ag. Nikolaos dam site

Hydrological year	O	N	D	J	F	M	A	M	J	J	A	S	ANNUAL
1950-51	174	320	367	107	134	181	64	133	79	18	10	77	1664
1951-52	256	137	107	349	203	50	42	64	23	42	16	39	1328
1952-53	103	362	415	232	174	23	118	121	123	21	5	59	1756
1953-54	86	89	93	279	324	126	148	118	67	4	11	9	1354
1954-55	165	258	171	280	173	130	94	31	45	40	52	166	1605
1955-56	266	230	96	227	412	156	90	94	74	13	15	21	1654
1956-57	187	347	154	237	112	32	53	157	41	14	32	109	1475
1957-58	229	145	277	207	108	310	148	86	39	24	2	55	1630
1958-59	128	291	258	339	28	78	194	93	91	77	53	94	1724
1959-60	157	205	297	338	218	117	173	112	48	1	2	87	1755
1960-61	145	188	421	145	107	45	115	112	54	29	11	5	1377
1961-62	108	304	263	191	172	398	105	46	69	37	21	92	1806
1962-63	243	603	359	383	450	121	110	180	69	54	64	48	2684
1963-64	146	83	317	84	145	223	125	122	177	42	39	63	1566
1964-65	151	294	371	215	245	58	308	76	45	10	18	19	1810
1965-66	30	381	454	397	184	207	80	100	107	31	51	46	2068
1966-67	157	422	478	247	69	28	150	99	38	111	36	100	1935
1967-68	55	61	349	334	201	109	29	124	144	3	28	37	1474
1968-69	62	135	304	179	354	204	79	49	52	26	60	77	1581
1969-70	2	173	478	299	220	143	98	93	75	58	23	49	1711
1970-71	165	116	206	259	161	337	79	60	31	59	49	127	1649
1971-72	104	275	130	210	211	155	185	83	16	103	83	98	1653
1972-73	358	162	72	202	237	249	118	34	50	59	58	97	1696
1973-74	142	141	299	96	248	108	243	115	43	26	42	130	1633
1974-75	313	254	95	53	125	156	67	94	75	69	59	20	1380
1975-76	166	194	142	120	101	113	102	100	81	103	37	72	1331
1976-77	188	316	466	155	140	38	59	66	58	1	52	137	1676
1977-78	56	276	177	255	259	149	239	97	41	1	10	187	1747
MEAN VALUES	154	242	272	229	197	144	122	95	66	38	34	76	1669

Table 5.5

Mean monthly precipitation (mm) 1950 - 1978

Arakhthos river basin at the Pistiana dam site

Hydrological year	O	N	D	J	F	M	A	M	J	J	A	S	ANNUAL
1950-51	181	317	378	110	142	187	63	130	78	17	11	79	1693
1951-52	259	140	110	354	205	50	43	67	21	42	17	40	1348
1952-53	105	367	420	243	178	23	120	126	129	23	5	58	1797
1953-54	87	89	93	284	303	129	148	118	66	4	11	9	1341
1954-55	165	257	175	288	173	130	97	31	43	41	53	166	1619
1955-56	230	234	103	235	412	156	89	95	74	13	14	21	1676
1956-57	186	351	157	235	114	31	52	157	39	14	32	111	1479
1957-58	233	145	276	214	108	310	150	85	38	22	2	53	1636
1958-59	130	289	262	341	27	79	195	94	87	75	52	94	1725
1959-60	160	205	306	350	213	118	171	112	50	1	3	89	1779
1960-61	141	190	426	146	106	45	116	109	55	28	10	4	1378
1961-62	108	312	296	219	178	402	103	45	65	36	20	92	1877
1962-63	247	605	363	394	462	123	110	180	68	54	63	48	2717
1963-64	150	85	315	877	150	223	124	122	171	43	38	61	1569
1964-65	151	293	378	230	249	60	311	77	46	11	18	18	1842
1965-66	29	384	460	407	178	208	80	101	103	31	51	44	2076
1966-67	162	425	449	253	79	28	147	95	37	110	36	99	1920
1967-68	56	63	358	343	205	110	27	122	141	3	30	37	1495
1968-69	65	145	312	189	354	202	79	47	52	25	59	78	1607
1969-70	1	175	460	318	223	145	97	91	74	57	23	50	1714
1970-71	163	120	210	262	168	340	77	60	29	56	50	127	1662
1971-72	102	282	131	213	215	160	184	86	15	108	79	95	1668
1972-73	352	96	76	209	247	248	115	32	46	58	56	97	1632
1973-74	146	148	302	142	247	107	247	113	41	26	41	135	1695
1974-75	319	226	92	54	126	159	67	92	73	68	58	19	1353
1975-76	170	194	144	121	101	113	104	96	82	103	36	70	1335
1976-77	191	320	460	159	139	38	58	62	57	1	50	134	1669
1977-78	55	279	179	257	226	151	240	95	41	1	10	185	1719
MEAN VALUES	155	241	275	238	197	146	122	94	65	38	33	75	1679

5.4 STREAMFLOWS

Monthly streamflows at the proposed Aghios Nikolaos and Pistiana dam sites are needed for purposes of estimating the firm energy output from the projects. Synthesized records of monthly average flow at the two sites are given in the PPC hydrology report for the Middle Arakhthos projects. It is acknowledged in the PPC report that because the Middle Course reservoirs will be operated only in conjunction with the upstream Steno and Kalaritikos reservoirs, it will be necessary to modify the inflow records when the operational characteristics of the Upper Course scheme are finally known.

In the present studies, inflows from the intermediate catchments have been estimated generally by subtracting the contribution upstream of the Steno and Kalaritikos dam sites from the total inflow at the Middle Course dam sites. However, this method is not valid in cases where it produces negative or unrealistically low flows. This occurs when the combined monthly flow given for Steno and Kalaritikos is greater than that in the Middle Course. For the present, the problem has been solved by proportionally adjusting any flows that appear excessively low but for the Engineering Report studies it would be advantageous to receive from PPC a representative record of inflows for the intermediate catchment.

The Middle Course flows given by PPC were calculated from the observed and synthesized monthly flow record at the Plaka bridge measuring station. From the start of the record in 1950 to 1964 the flows at Plaka are estimated indirectly using the monthly flows at Tsimovo and Gogo bridge stations, which were themselves synthesized from precipitation data using a multiple linear regression technique. From 1964 onwards, the flows at Plaka are directly measured values.

The monthly records of net inflow to the Steno-Kalaritikos, Aghios Nikolaos and Pistiana reservoirs over the period 1951-1980 used in the reservoir operation studies are given in Tables 5.6, 5.7 and 5.8 below. The record

for Steno-Kalaritikos includes an average flow of 6,36 m^3/s (5,5 m^3/s of which is fully regulated) from the Pigai HEP on the Aoos river, whose tailrace tunnel will discharge into the upper reaches of the Metsovitikos river upstream of the Steno reservoir. It may be deduced from Tables 5.6 and 5.7 that the mean unit discharge upstream of Steno-Kalaritikos is 0,038 $m^3/s/km^2$ while that of the intermediate catchment between Steno-Kalaritikos and Aghios Nikolaos is 0,053 $m^3/s/km^2$, which is significantly higher. The difference might be explained by the fact that a larger proportion of the intermediate catchment drains the western slopes of the Pindos mountains. The Kalaritikos catchment, which also drains mainly the Pindos slopes, has a unit discharge of 0,054 $m^3/s/km^2$. However, in view of the possible anomaly it is recommended that a gauge should be established at Aghios Nikolaos to confirm the relationship between the flows at Steno-Kalaritikos and the Middle Course. There appears to be a gauge house and a current meter cable across the river just downstream of site B1, which may be suitable for the purpose.

Table 5.6

Monthly inflows to Steno-Kalaritikos

(including contribution of 5,5 m^3/s from Pigai HEP on Aoos river)

Catchment area excluding Pigai = 835 km^2

AVERAGE MONTHLY INFLOW (M3/S)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1951	26.30	37.10	48.30	48.20	39.50	29.60	11.50	8.00	11.00	35.20	22.10	29.20	28.80
1952	100.10	61.00	26.80	33.40	28.30	17.40	12.60	8.40	8.80	16.60	73.00	93.20	40.00
1953	56.70	52.30	23.40	36.90	42.50	35.50	11.60	7.80	10.80	14.90	14.30	28.10	27.90
1954	74.10	91.20	38.10	68.00	49.00	27.70	10.80	8.20	7.30	22.30	46.40	38.20	40.10
1955	76.80	52.30	40.60	48.40	30.20	21.70	12.10	9.60	17.40	30.10	39.10	26.10	33.70
1956	59.80	125.70	46.40	78.20	38.60	30.70	11.00	8.00	8.00	55.60	69.00	35.50	44.70
1957	68.00	32.20	24.50	27.50	39.70	21.30	11.40	8.80	13.60	30.30	23.40	63.40	30.30
1958	49.30	32.90	91.50	77.60	42.20	21.00	11.60	7.70	10.00	19.00	55.00	55.60	39.30
1959	102.10	16.00	30.90	44.30	48.50	32.00	14.20	10.10	13.00	21.80	34.80	61.60	35.80
1960	94.20	66.50	36.60	64.00	49.30	21.70	10.70	7.70	12.10	22.00	30.10	99.30	42.90
1961	36.20	34.40	26.20	35.40	42.60	22.70	11.80	8.30	7.30	16.90	52.80	52.30	28.90
1962	41.30	47.40	124.40	93.50	35.80	27.20	12.00	8.50	12.30	31.90	153.60	79.20	55.60
1963	119.40	125.40	38.90	73.20	49.10	26.90	12.80	10.30	9.40	20.20	13.50	72.50	47.60
1964	14.70	41.60	66.90	65.70	46.10	45.60	12.00	9.00	9.60	20.20	44.40	80.40	38.00
1965	51.00	49.40	44.30	70.30	55.20	27.80	12.50	10.00	8.80	8.60	72.30	99.40	42.50
1966	120.10	52.00	51.90	40.20	40.70	32.70	13.20	9.60	12.40	19.50	85.20	116.70	49.50
1967	79.70	25.70	25.30	48.80	49.00	23.20	16.60	13.20	16.50	13.20	11.60	59.20	31.80
1968	74.60	63.00	37.60	40.50	34.60	29.20	12.20	9.40	9.30	11.80	19.30	51.30	32.70
1969	46.30	92.20	62.30	41.40	44.20	20.90	11.80	9.80	11.80	8.60	21.20	109.10	40.00
1970	79.30	71.20	58.60	58.30	36.00	26.40	13.20	9.20	8.90	33.00	24.30	49.70	39.00
1971	79.40	41.10	83.20	58.90	35.60	19.90	11.90	9.90	14.00	24.60	46.20	44.50	38.20
1972	34.90	52.60	54.10	63.80	45.00	16.90	16.00	11.50	12.90	61.20	35.70	23.90	35.70
1973	44.30	61.60	66.30	60.20	54.30	22.40	11.80	9.80	12.00	19.10	22.90	68.30	37.80
1974	31.70	67.50	39.80	59.80	60.10	25.50	12.20	9.10	13.80	40.70	55.20	28.10	37.00
1975	15.10	31.20	41.20	44.50	32.60	20.00	13.60	10.60	7.80	15.30	28.30	41.40	25.10
1976	21.80	25.60	29.30	33.50	32.40	19.80	16.00	10.60	15.40	17.30	74.00	96.20	32.70
1977	45.90	37.30	24.00	28.00	24.50	17.50	10.00	9.30	13.50	12.20	39.20	40.40	25.20
1978	53.20	71.10	46.00	77.00	52.80	20.90	11.70	8.50	18.80	13.30	25.90	50.70	37.50
1979	115.50	93.60	32.00	73.60	53.10	31.00	15.30	11.40	10.00	21.70	55.50	45.70	46.50
1980	61.90	27.10	62.20	42.30	68.80	32.40	13.40	11.10	11.10	0.00	0.00	0.00	36.70
AVERAGE	62.50	55.90	47.40	54.50	43.30	25.60	12.60	9.50	11.60	22.00	44.40	60.00	

Mean flow = 37,10 m^3/s

Table 5.7

Monthly inflows to Aghios Nikolaos

(intermediate catchment only)

Catchment area = 283 km²

AVERAGE MONTHLY INFLOW (M3/S)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1951	11.10	17.70	21.80	12.60	13.60	13.40	5.40	5.70	5.90	13.20	5.50	6.20	11.00
1952	42.80	23.70	9.30	10.80	11.60	5.80	4.00	8.60	4.90	5.60	21.60	29.20	14.80
1953	25.20	20.40	6.80	15.10	16.70	19.60	7.90	5.60	6.00	4.70	2.20	6.50	11.40
1954	30.80	34.10	16.30	20.20	16.00	9.80	7.10	8.70	4.30	9.20	12.40	10.50	15.00
1955	31.70	20.30	15.10	18.20	10.90	10.40	7.90	5.30	7.60	12.00	10.90	8.50	13.20
1956	24.10	44.80	17.00	23.90	11.00	7.10	5.60	5.10	4.90	9.50	20.70	9.90	15.30
1957	24.90	14.20	11.10	9.70	16.20	7.00	7.70	6.40	6.90	11.90	5.40	16.00	11.50
1958	22.80	13.20	37.20	27.30	16.50	8.50	6.00	11.20	5.60	6.60	14.50	16.10	15.50
1959	40.20	7.20	11.20	16.00	20.10	11.10	7.60	5.50	6.30	8.40	9.10	19.10	13.50
1960	42.10	23.60	16.10	21.70	18.50	10.80	4.90	11.20	6.10	6.80	3.90	29.20	16.20
1961	15.00	9.10	9.10	12.60	14.90	11.20	8.70	5.00	3.50	5.50	33.50	32.90	13.40
1962	36.60	22.80	52.90	24.40	12.10	5.00	8.20	5.70	3.60	19.60	54.20	22.70	22.30
1963	45.20	68.20	14.30	27.30	20.30	9.60	8.20	6.20	4.70	6.20	10.30	18.90	20.00
1964	25.20	20.50	35.60	16.90	18.30	19.10	12.40	8.30	7.70	10.40	30.70	35.20	20.00
1965	28.90	15.70	17.10	36.60	14.40	12.40	10.50	6.10	4.40	6.70	20.60	45.00	18.20
1966	51.20	21.50	28.90	21.60	17.80	12.90	7.30	7.70	5.30	8.50	23.30	25.50	19.30
1967	19.90	14.60	18.00	12.20	18.10	9.90	9.00	5.30	8.90	5.80	5.40	17.50	12.10
1968	29.00	23.80	15.70	10.20	15.10	9.20	7.20	6.10	5.80	5.50	5.50	13.60	12.20
1969	16.20	36.10	27.60	16.70	13.90	9.20	5.60	6.70	6.30	4.30	6.20	32.80	15.10
1970	43.60	21.20	29.20	16.70	11.00	9.90	8.50	6.00	5.80	6.40	4.30	15.90	14.90
1971	34.00	15.30	30.00	21.80	16.50	10.00	6.10	6.10	4.80	7.20	15.00	13.80	15.10
1972	17.50	30.80	25.70	15.90	20.80	6.10	9.80	5.60	7.90	33.20	8.50	12.90	16.20
1973	16.40	22.20	21.60	18.10	19.10	10.50	10.50	6.10	6.70	12.50	7.10	32.90	15.30
1974	15.20	39.70	11.20	21.00	13.60	8.60	7.40	5.90	7.20	6.90	23.40	14.40	14.50
1975	13.70	5.80	10.30	9.70	6.30	2.90	6.30	6.00	4.80	6.20	7.70	10.00	7.50
1976	9.10	9.30	4.60	9.40	8.20	8.10	8.00	3.30	7.30	2.50	20.30	50.00	11.70
1977	23.80	25.00	14.20	4.50	3.10	1.80	3.40	4.00	1.80	3.50	7.00	16.70	9.10
1978	10.80	36.30	25.50	15.60	12.70	13.70	5.00	8.60	6.40	5.30	6.10	22.30	14.00
1979	36.20	40.80	29.40	55.00	10.20	13.60	10.50	17.50	18.40	5.40	14.60	22.20	22.80
1980	29.90	28.20	30.50	12.50	28.60	24.10	15.10	10.10	6.90	0.00	0.00	0.00	20.20
AVERAGE	27.10	24.20	20.40	18.50	14.30	10.40	7.70	7.00	6.20	8.60	14.10	20.90	

Mean flow = 14,90 m³/s

Table 5.8

Monthly inflows to Pistiana

(intermediate catchment only)

Catchment area = 104 km²

AVERAGE MONTHLY INFLOW (M3/S)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1951	3.90	7.80	8.20	4.00	3.20	3.00	.40	1.50	1.30	4.50	2.50	3.70	3.70
1952	14.70	8.10	2.80	4.70	4.90	0.00	1.00	1.90	1.00	1.90	9.40	12.00	5.20
1953	10.90	7.70	2.30	5.10	7.40	9.20	2.70	.80	.80	1.50	1.00	2.60	4.30
1954	11.00	10.10	5.70	7.50	5.40	2.30	.70	1.00	.40	2.40	4.70	5.00	4.70
1955	12.50	6.20	4.50	7.70	3.00	1.20	1.70	1.10	1.80	4.00	4.80	5.00	4.50
1956	10.10	14.90	5.30	7.70	4.50	3.00	1.00	.10	.70	2.50	8.70	4.40	5.20
1957	7.10	4.50	1.60	2.20	4.50	1.30	1.10	.90	1.60	4.10	2.10	6.40	3.10
1958	8.50	3.70	11.30	10.40	4.20	1.40	0.00	.50	.50	2.10	5.40	7.10	4.60
1959	13.30	.80	3.80	5.30	6.50	1.70	1.00	.60	1.20	2.70	3.50	9.40	4.20
1960	17.10	5.60	4.70	6.30	5.80	3.80	2.50	10.10	1.40	1.40	7.30	12.90	6.60
1961	4.60	7.70	2.60	4.30	3.30	3.20	.90	0.00	0.00	1.60	9.70	8.80	3.90
1962	7.70	8.30	17.50	7.90	2.90	1.20	.90	.30	1.00	5.00	18.70	10.00	6.80
1963	17.50	22.60	5.20	7.00	5.70	2.40	1.40	.80	.80	2.50	2.10	7.20	6.30
1964	5.50	7.30	8.90	6.40	5.50	3.10	2.10	.70	.60	2.30	6.00	12.30	5.40
1965	10.40	6.50	7.10	10.30	6.60	4.10	3.40	1.00	.20	.50	8.90	18.10	6.40
1966	19.60	6.80	7.20	5.10	5.50	2.10	1.20	1.10	.50	2.80	10.20	13.00	6.30
1967	11.10	2.00	3.60	3.80	2.90	1.60	1.60	1.10	1.60	1.50	1.40	8.40	3.40
1968	11.80	8.70	4.80	.70	3.20	2.30	1.10	1.70	.80	1.70	3.40	7.10	3.90
1969	8.60	11.10	6.80	5.00	2.30	2.20	.50	.80	1.80	.20	2.20	15.90	4.70
1970	13.40	9.10	8.80	5.60	2.70	2.40	1.10	.90	1.00	2.70	3.00	6.80	4.80
1971	11.20	7.10	10.80	4.80	4.30	.60	.40	1.20	1.20	1.20	6.60	5.20	4.60
1972	5.00	8.70	9.40	6.30	7.80	.50	2.90	.40	.90	6.50	6.00	3.80	4.90
1973	7.20	10.80	7.20	4.60	1.90	.10	1.20	.50	1.20	3.20	3.60	9.80	4.30
1974	4.90	11.20	3.70	8.20	4.90	1.00	1.30	.60	2.10	4.70	9.90	3.90	4.70
1975	2.50	3.10	5.20	4.40	2.30	1.10	1.00	.80	.30	1.90	2.80	4.90	2.50
1976	2.50	2.80	2.60	4.10	1.70	2.40	1.70	.50	1.10	1.60	9.40	15.50	3.80
1977	7.60	4.60	2.80	1.90	.60	.90	2.00	.40	.60	.70	4.10	5.40	2.60
1978	5.90	9.80	7.00	8.20	3.90	2.60	2.80	1.10	1.60	1.20	3.30	7.20	4.60
1979	18.10	15.70	6.10	15.80	4.80	3.60	.80	2.20	.60	1.40	6.70	6.50	6.90
1980	6.70	7.50	13.00	4.60	8.50	7.50	2.10	2.00	.60	0.00	0.00	0.00	5.80
AVERAGE	9.70	8.00	6.40	6.00	4.40	2.40	1.40	1.20	1.00	2.40	5.80	8.20	

Mean flow = 4,70 m³/s

5.5 FLOOD STUDIES

5.5.1 General

The flood studies described here comprise the studies performed to determine the capacities required in the spillways and diversion works for Middle Course reservoirs. The assumption was made in the Report on Alternative Studies that the upstream Steno and Kalaritikos reservoirs might not be in operation when the Middle Course was completed. The attenuating effect of these reservoirs was therefore neglected, giving conservative preliminary estimates of cost for the flood control structures at Aghios Nikolaos and Pistiana. It was evident, though, that for more refined studies such as those performed for the Master Plan, account would have to be taken of the Upper Course reservoirs.

The flood hydrographs supplied by PPC in their July 1982 hydrology report on the Middle Course reservoirs do not take account of upstream reservoirs, because the spillway details and operational characteristics of the Steno and Kalaritikos dams, and hence the amount of attenuation provided by the reservoirs, were not known when the report was prepared. For the final hydrology reports, which PPC will prepare separately for the Aghios Nikolaos and Pistiana projects at Engineering Report stage, the hydrographs will no doubt be amended to take account of the Upper Course reservoirs. In the meantime, the method used in the present studies is that given in the "Guide to spillway flood calculations for a cascade of reservoirs", a flood studies draft supplementary report of the Institute of Hydrology.

5.5.2 Data

The following data were used for the studies :

5.5.2.1 Intensity-duration-recurrence interval (i-t-T) curves

These are given in PPC's hydrology reports for both Upper and Middle Arakhthos projects. The curves have the analytical expressions given in Table 5.9.

Table 5.9
i-t-T curves (i in mm/h and t in h)

Basin	T = 100 yrs	T = 10.000 yrs
Steno	$i = \frac{29,1}{t^{0,4566}}$	$i = \frac{47,15}{t^{0,4566}}$
Kalaritikos	$i = \frac{45,9}{(t+0,4)^{0.515}}$	$i = \frac{72,2}{(t+0,4)^{0,515}}$
Intermediate	$i = \frac{38,7}{t^{0,506}}$	$i = \frac{60,8}{t^{0,506}}$

5.5.2.2 Unit hydrographs

Unit hydrographs for the Steno and Kalaritikos basins are given in the PPC hydrology report for the Upper Arakhthos projects.

Unit hydrographs for the intermediate basins are given in PPC's hydrology report for the Middle Course projects. According to PPC these unit hydrographs are not appropriate for very long rain durations, but as no other data is available, they have been used in the present study for rain durations as long as 60 h. The results of the application of these unit hydrographs show that there are no problems that give rise to abnormal inaccuracy.

5.5.2.3 Inflow flood hydrographs

Of the hydrographs given by PPC only those for the Steno basin for the rain duration of 48 h (T = 100 and T = 10.000 yrs) were used in the present study. The other PPC hydrographs are not appropriate for the study because the rain durations differ from the design storm duration of the Middle Course projects.

The inflow flood hydrographs given by PPC for the intermediate basins are based on very short rain durations (9 - 22 h) and were therefore not used. The hydrographs given for the whole basins down to the Aghios Nikolaos and Pistiana sites respectively were also not used because:

(i) for large basins the separation into sub-basins and routing of the flood through river reaches gives more accurate results and

(ii) in most cases it is assumed that the flood hydrographs of the Upper Arakhthos basins are routed through existing spillways or diversion tunnels.

All the inflow flood hydrographs needed (except those for Steno) were produced using the data mentioned in paragraphs 5.5.2.1 and 5.5.2.2.

5.5.2.4 Outflow flood hydrographs

The outflow flood hydrographs for the Steno and Kalaritikos spillways are given in the Steno-Kalaritikos Engineering Report.

5.5.3 Design storm duration

The design storm duration, considered unique for the whole basin, was estimated by using a formula given in the Guide mentioned in paragraph 5.5.1, which relates the design storm duration to the mean annual precipitation and the lag time of the catchment including the mean reservoir lag. The latter in turn is computed by taking an areally weighted average of the cumulative lags for each reservoir in the system.

Using the formula mentioned above, the design storm durations are estimated as follows :

D = 60 h — for the design of the spillways and for the design of the diversion tunnels in the case that the Upper Arakhthos projects are assumed to exist

D = 48 h — for the design of the diversion tunnels in the case that the Upper Arakhthos projects are assumed to be under construction or not built.

In the case of the spillway flood routing the appropriateness of the selected 60 h duration was checked by routing also the floods from 48 h and 72 h storms through the reservoirs.

5.5.4 Inflow flood hydrographs

5.5.4.1 Assumptions

a) The rain depths are derived from the formula of paragraph 5.5.2.1 for each sub-basin. Design hyetograms for the 1:10.000 and 1:100 year events are given in Figs 5.1 and 5.2.

b) The losses are assumed to be as given in Table 5.10.

Table 5.10

Storm losses

Basin	Percentage of losses for	
	T = 100 yrs	T = 10.000 yrs
Steno	26	10
Kalaritikos	22	6
Intermediate	32	15

c) In all cases it is assumed that the design storm follows the time distribution of the standard second quartile storm of 50 % probability level.

d) For the time distribution of the losses an empirical formula suggested by the U.S. Bureau of Reclamation was used (see : U.S. Bureau of Reclamation :"Design of Arch Dams" 1977).

e) The base flows used are those suggested by PPC, and are given in Table 5.11.

Table 5.11

Base flows

Basin	Base flow in m^3/s for	
	T = 100 yrs	T = 10.000 yrs
Steno	200	250
Kalaritikos	70	100
Subbasin I (between Steno, Kalaritikos and Aghios Nikolaos)	30	30
Subbasin II (between Aghios Nikolaos and Pistiana)	20	20

5.5.4.2 Calculations and results

The main characteristics of the design storms and inflow flood hydrographs are given in Tables 5.12 to 5.19.

Table 5.12

Summarized inflow hydrographs at Steno dam site

(T = 10.000 yrs)

Design storm characteristics	Storm duration	48*	60	72
	Time pattern	2nd quartile - 50% prob. level		
	Total rain depth (mm)	387,0	436,2	481,7
	Losses (%)	10	10	10
	Losses (mm)	38,7	43,6	48,2
	Net rain depth (mm)	348,3	392,5	433,5
Inflow hydrograph characteristics	Flood duration (h)	85	96	108
	Base flow (m^3/s)	250	250	250
	Net flood volume ($m^3 \times 10^6$)	223	251	277
	Total flood volume ($m^3 \times 10^6$)	300	337	375
	Peak discharge (m^3/s)	3251	2918	2755
	Time to peak (h)	27	34	40

* Given by PPC

Table 5.13

Summarized inflow hydrographs at Kalaritikos dam site

(T = 10.000 yrs)

Design storm characteristics	Storm duration	(h)	48	60	72
	Time pattern		2nd quartile - 50 % prob. level		
	Total rain depth	(mm)	470,0	524,2	572,9
	Losses	(%)	6	6	6
	Losses	(mm)	28,2	31,5	34,4
	Net rain depth	(mm)	441,8	492,7	538,5
Inflow hydrograph characteristics	Flood duration	(h)	86	98	110
	Base flow	(m^3/s)	100	100	100
	Net flood volume	($m^3 \times 10^6$)	96,3	107	117
	Total flood volume	($m^3 \times 10^6$)	127	143	157
	Peak discharge	(m^3/s)	1344	1284	1166
	Time to peak	(h)	22	28	34

Table 5.14

Summarized inflow hydrographs of intermediate basin I

(between Steno,Kalaritikos and Aghios Nikolaos dam sites)

T = 10.000 yrs

Design storm characteristics	Storm duration	(h)	48	60	72
	Time pattern		2nd quartile - 50 % prob. level		
	Total rain depth	(mm)	411,6	459,5	502,8
	Losses	(%)	15	15	15
	Losses	(mm)	61,7	68,9	75,5
	Net rain depth	(mm)	349,9	390,6	427,3
Inflow hydrograph characteristics	Flood duration	(h)	65	77	89
	Base flow	(m^3/s)	30	30	30
	Net flood volume	($m^3 \times 10^6$)	99	111	121
	Total flood volume	($m^3 \times 10^6$)	106	119	131
	Peak discharge	(m^3/s)	1372	1289	1196
	Time to peak	(h)	25	31	36

Table 5.15

Summarized inflow hydrographs of intermediate basin II

(between Aghios Nikolaos and Pistiana dam sites)

T = 10.000 yrs

Design storm characteristics	Storm duration	(h)	48	60	72
	Time pattern		2nd quartile - 50 % prob. level		
	Total rain depth	(mm)	411,6	459,5	502,8
	Losses	(%)	15	15	15
	Losses	(mm)	61,7	68,9	75,5
	Net rain depth	(mm)	349,9	390,6	427,3
Inflow hydrograph characteristics	Flood duration	(h)	55	67	79
	Base flow	(m^3/s)	20	20	20
	Net flood volume	($m^3 \times 10^6$)	36,4	40,6	44,3
	Total flood volume	($m^3 \times 10^6$)	40,4	45,4	50,0
	Peak discharge	(m^3/s)	570	540	480
	Time to peak	(h)	21	27	33

Table 5.16

Summarized inflow hydrographs at Steno dam site

T = 100 yrs

Design storm characteristics	Storm duration	(h)	48*	60
	Time pattern		2nd quartile - 50 % prob.level	
	Total rain depth	(mm)	238,5	269,2
	Losses	(%)	26	26
	Losses	(mm)	62,0	70,0
	Net rain depth	(mm)	176,5	199,2
Inflow hydrograph characteristics	Flood duration	(h)	85	96
	Base flow	(m^3/s)	200	200
	Net flood volume	($m^3 \times 10^6$)	113	127
	Total flood volume	($m^3 \times 10^6$)	173	196
	Peak discharge	(m^3/s)	1858	1649
	Time to peak	(h)	27	34

* Given by PPC

Table 5.17

Summarized inflow hydrographs at Kalaritikos dam site

T = 100 yrs

Design storm characteristics	Storm duration	(h)	48	60
	Time pattern		2nd quartile - 50 % prob.level	
	Total rain depth	(mm)	298,8	333,2
	Losses	(%)	22	22
	Losses	(mm)	65,7	73,3
	Net rain depth	(mm)	233,1	259,9
Inflow hydrograph characteristics	Flood duration	(h)	86	98
	Base flow	(m^3/s)	70	70
	Net flood volume	($m^3 \times 10^6$)	51	56
	Total flood volume	($m^3 \times 10^6$)	73	81
	Peak discharge	(m^3/s)	778	741
	Time to peak	(h)	25	28

Table 5.18

Summarized inflow hydrographs of intermediate basin I

(between Steno, Kalaritikos and Aghios Nikolaos dam sites)

T = 100 yrs

Design storm characteristics	Storm duration	(h)	48	60
	Time pattern		2nd quartile - 50 % prob.level	
	Total rain depth	(mm)	262,0	292,5
	Losses	(%)	32	32
	Losses	(mm)	83,9	93,6
	Net rain depth	(mm)	178,1	198,9
Inflow hydrograph characteristics	Flood duration	(h)	65	77
	Base flow	(m^3/s)	30	30
	Net flood volume	($m^3 \times 10^6$)	50	56
	Total flood volume	($m^3 \times 10^6$)	57	64
	Peak discharge	(m^3/s)	744	712
	Time to peak	(h)	26	32

Table 5.19

Summarized inflow hydrographs of intermediate basin II

(between Aghios Nikolaos and Pistiana dam sites)

T = 100 yrs

Design storm characteristics	Storm duration	(h)	48	60
	Time pattern		2nd quartile - 50 % prob.level	
	Total rain depth	(mm)	262,0	292,5
	Losses	(%)	32	32
	Losses	(mm)	83,9	93,6
	Net rain depth	(mm)	178,1	198,9
Inflow hydrograph characteristics	Flood dunation	(h)	55	67
	Base flow	(m^3/s)	20	20
	Net flood volume	($m^3 \times 10^6$)	18,5	20,7
	Total flood volume	($m^3 \times 10^6$)	22,5	25,5
	Peak discharge	(m^3/s)	320	302
	Time to peak	(h)	24	30

5.5.5 Spillway flood calculations

5.5.5.1 Assumptions and procedure

According to the Guide referred to in paragraph 5.5.1 the storm duration is considered unique for the entire basin. The recurrence interval for the storm event is considered to have the same value, T = 10.000 for all sub-basins.

According to these assumptions, the selection of the storm duration determines the inflow hydrographs for all sub-basins.

In order to estimate the routed hydrographs down to the dam sites under study (Aghios Nikolaos and Pistiana) the following considerations have been taken into account :

- The Upper Arakhthos projects (Steno and Kalaritikos) exist, so the inflow hydrographs of both basins are routed through the spillways. The routed hydrographs are then added to give the hydrograph in the beginning of the river reach between Steno, Kalaritikos and Aghios Nikoloas dam sites.
- Since the travel time in the above river reach is shorter than 1 hour (velocity 8 m/s) and the river storage volume is neglible, no lag or attenuation is applied to the above hydrograph. In order to calculate the total inflow hydrograph to Aghios Nikolaos reservoir, the ordinates of the outflow hydrographs of Steno and Kalaritikos are added to the direct inflow hydrograph for sub-basin I.
- Since the flood storage volume in Aghios Nikolaos and Pistiana reservoirs is neglible, the outflow is effectively equal to the inflow. The inflow and outflow hydrograph to Pistiana reservoir is computed by adding the ordinates of the inflow hydrograph of Aghios Nikolaos reservoir to the ordinates of the direct inflow hydrograph for sub-basin II. It is obvious that no lag or attenuation should be applied to the former hydrograph.

The procedure for the spillway flood routing calculations, according to the above assumptions, is as follows :

a) Determine the design storm duration (see paragraph 3)
b) Calculate the direct inflow hydrographs of the four sub-basins
c) Route the Steno and Kalaritikos inflow hydrographs through the corresponding spillways
d) Add the ordinates of the above hydrographs and the ordinates of the direct inflow hydrograph of the intermediate sub-basin I, to find the inflow (and outflow) hydrograph to the Aghios Nikolaos reservoir
e) Add the ordinates of the above hydrograph to the ordinates of the direct inflow hydrograph of the intermediate sub-basin II, to find the inflow (and outflow) hydrograph to the Pistiana reservoir.

5.5.5.2 Results of the calculations

The estimated design storm duration for both Middle Course reservoirs is 60 h (see paragraph 5.5.3),.

The main characteristics of the inflow and outflow hydrographs, produced by the storm with the above duration and with other characteristics as described in paragraph 5.5.4.1, are summarized in Table 5.20 below. The full hydrographs are shown graphically on Figs 5.3 and 5.4.

Table 5.20

Summarized inflow and outflow peaks for spillways

Hydrograph	Peak discharge (m^3/s)	Time to peak (h)
Steno inflow	2.918	34
Steno outflow	1.566	45
Kalaritikos inflow	1.284	28
Kalaritikos outflow	604	41
Interm.sub-basin I direct inflow	1.289	31
Interm.sub-basin II direct inflow	540	27
Aghios Nikolaos inflow and outflow	3.145	33
Pistiana inflow and outflow	3.568	30

The other storm durations examined i.e. 72 h and 48 h gave peak discharges very close to that of 60 h. The former gave a smaller peak and the latter 1% greater, confirming that the 60 h design-storm duration established using the formula mentioned in 5.5.3 is appropriate.

5.5.6 Diversion tunnel flood calculations

5.5.6.1 Assumptions and procedure

The basic assumptions for the time and area structure of the design storm are the same as for the spillway flood calculations.

The recurrence interval for the design of diversion tunnels and cofferdams is selected as 100 yrs according to PPC's instructions because both dams are likely to be embankment dams.

Since it is not yet known whether the Upper Arakhthos projects will be under construction or in operation at the time of the Middle Course project construction, two cases have been considered:

Case A

Upper Arakhthos projects under construction. In this case, in order to calculate the inflow hydrograph to the Aghios Nikolaos dam site, the inflow hydrographs of Steno and Kalaritikos sub-basins would normally be routed through the diversion tunnels. But, since the design recurrence intervals in Upper Arakhthos diversion tunnels are much shorter than 100 yrs it is evident that if the 100-year flood should occur, then the Upper Course cofferdams would overtopped, and, after a certain time, the outflow would be equal to the inflow. The conservative assumption was therefore made that the outflows from Steno and Kalaritikos dam sites equal the inflows during the whole flood duration.

According to this assumption it is evident that case A is equivalent to the case where construction of the Upper Arakhthos projects has not yet started.

Case B

Upper Arakhthos projects in operation. In this case the flood hydrographs of Steno and Kalaritikos sub-basins must be routed through the spillways.

Since the storage volumes of the Aghios Nikolaos and Pistiana cofferdams are negligible, outflow from diversion tunnels equals inflow at both sites.

Since no lag or attenuation is applied to the hydrographs to account for travel time through the river reaches, as explained in paragraph 5.5.1, the calculation procedures for the diversion tunnels are as follows :

Case A

a) Determine the design storm duration (see paragraph 5.5.3)
b) Calculate the direct inflow hydrographs of the four sub-basins
c) Add the ordinates of Steno, Kalaritikos and intermediate sub-basin I hydrographs, to find the inflow (and outflow) hydrograph at Aghios Nikolaos dam site
d) Add the ordinates of the above hydrograph to the direct inflow hydrograph of intermediate sub-basin II, to find the inflow (and outflow) hydrograph at Pistiana dam site.

Case B

a) Same as a), case A
b) Same as b), case A
c) Route the Steno and Kalaritikos inflow hydrographs through the corresponding spillways
d) Add the above outflow hydrographs to the direct inflow hydrograph of the intermediate sub-basin, to find the inflow (and outflow) hydrograph to Aghios Nikolaos dam site
e) Same as d), case A

5.5.6.2 Results of the calculations

The estimated design storm durations for both Middle Course diversion tunnels are 48 h for case A and 60 h for case B.

The results of the relevant hydrologic calculations, made by the procedure outlined in paragraph 5.5.6.1 above, are summarized in Table 5.21 and the full hydrographs are shown graphically on Figs. 5.5 and 5.6 for case A and on Figs 5.7 and 5.8 for case B.

Table 5.21

Results of the hydrologic calculations for diversion floods

Hydrograph	Case A (D=48 h)		Case B (D=60 h)	
	Peak discharge (m^3/s)	Time to peak (h)	Peak discharge (m^3/s)	Time to peak (h)
Steno inflow	1.858	27	1.649	34
Steno outflow	1.858	27	1.040	44
Kalaritikos inflow	778	25	741	28
Kalaritikos outflow	778	25	590	32
Interm. sub-basin I, direct inflow	744	26	712	32
Interm. sub-basin II, direct inflow	320	24	302	30
Aghios Nikolaos, inflow and outflow	3.310	25	2.233	33
Pistiana inflow and outflow	3.599	25	2.477	30

5.6 RESERVOIR SEDIMENTATION

According to the PPC hydrology report for the Middle Course projects, the volume of sediment entering the Aghios Nikolaos and Pistiana reservoirs during the operating life of the projects may be calculated using sediment discharge data from the Plaka measuring station. The bed load contribution is taken as 5 % as opposed to 15 % for the Upper Arakhthos because of the supposedly milder slopes of the Middle Course. The weight of sediment entering the reservoirs is investigated using an empirical method used by the U.S. Bureau of Reclamation. For calculating the unit weight and hence the rate of reservoir volume loss due to sedimentation, the classification formula proposed by the American Geophysical Union was proposed. The rate of sedimentation for the two reservoirs, as calculated by PPC, is given in Table 5.22.

Table 5.22

Rates of sedimentation for Aghios Nikolaos and Pistiana reservoirs (from intermediate catchments only)

Years of operation	Unit wt. t/m^3	Volume of incoming sediment ($m^3 \cdot 10^6$)	
		Aghios Nikolaos	Pistiana
10	1055	4,99	1,83
20	1088	9,68	3,56
50	1136	23,17	8,52
100	1173	44,89	16,50
500	1262	208,61	76,66

Most of the sediment will be deposited in the upper parts of the reservoirs, i.e. in the active storage zones. With a maximum power pool elevation of 270 m a.s.l. the total storage volume of the Aghios Nikolaos reservoir is $180 \cdot 10^6$ m³, so it is evident that the reservoir would not become fully silted up for nearly 500 years. Pistiana, with a total storage volume of $170 \cdot 10^6$ m³, would take more than 500 years to silt up. Thus it is apparent that the performance of the reservoirs will not be adversely affected by sedimentation during the 50-year economic life of the projects.

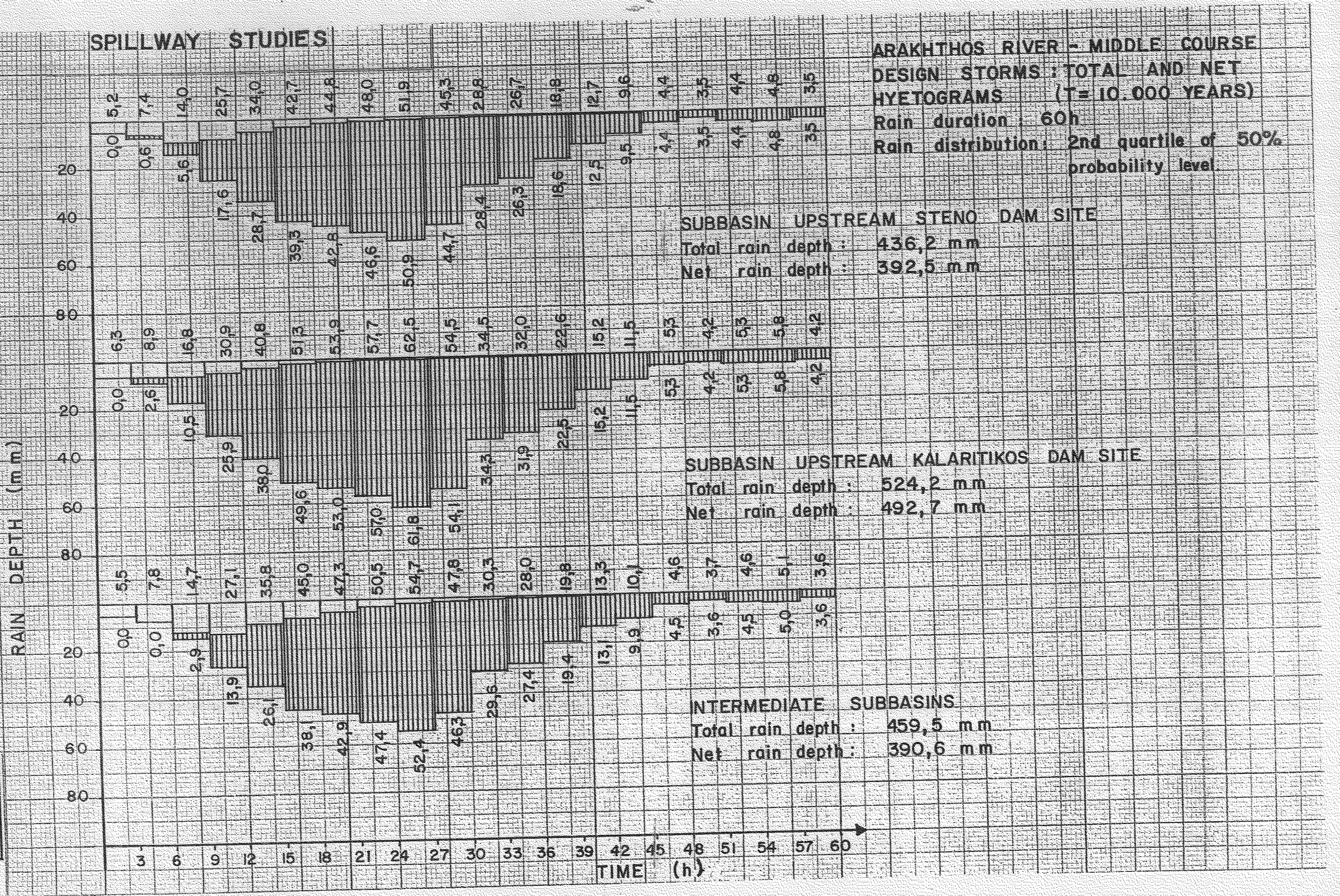

SPILLWAY STUDIES
ARAKHTHOS RIVER - MIDDLE COURSE
DESIGN STORMS : TOTAL AND NET HYETOGRAMS (T= 10.000 YEARS)
Rain duration : 60h
Rain distribution : 2nd quartile of 50% probability level
SUBBASIN UPSTREAM STENO DAM SITE
Total rain depth : 436,2 mm
Net rain depth : 392,5 mm
SUBBASIN UPSTREAM KALARITIKOS DAM SITE
Total rain depth : 524,2 mm
Net rain depth : 492,7 mm
INTERMEDIATE SUBBASINS
Total rain depth : 459,5 mm
Net rain depth : 390,6 mm
RAIN DEPTH (mm)
TIME (h)

Fig. 5.1

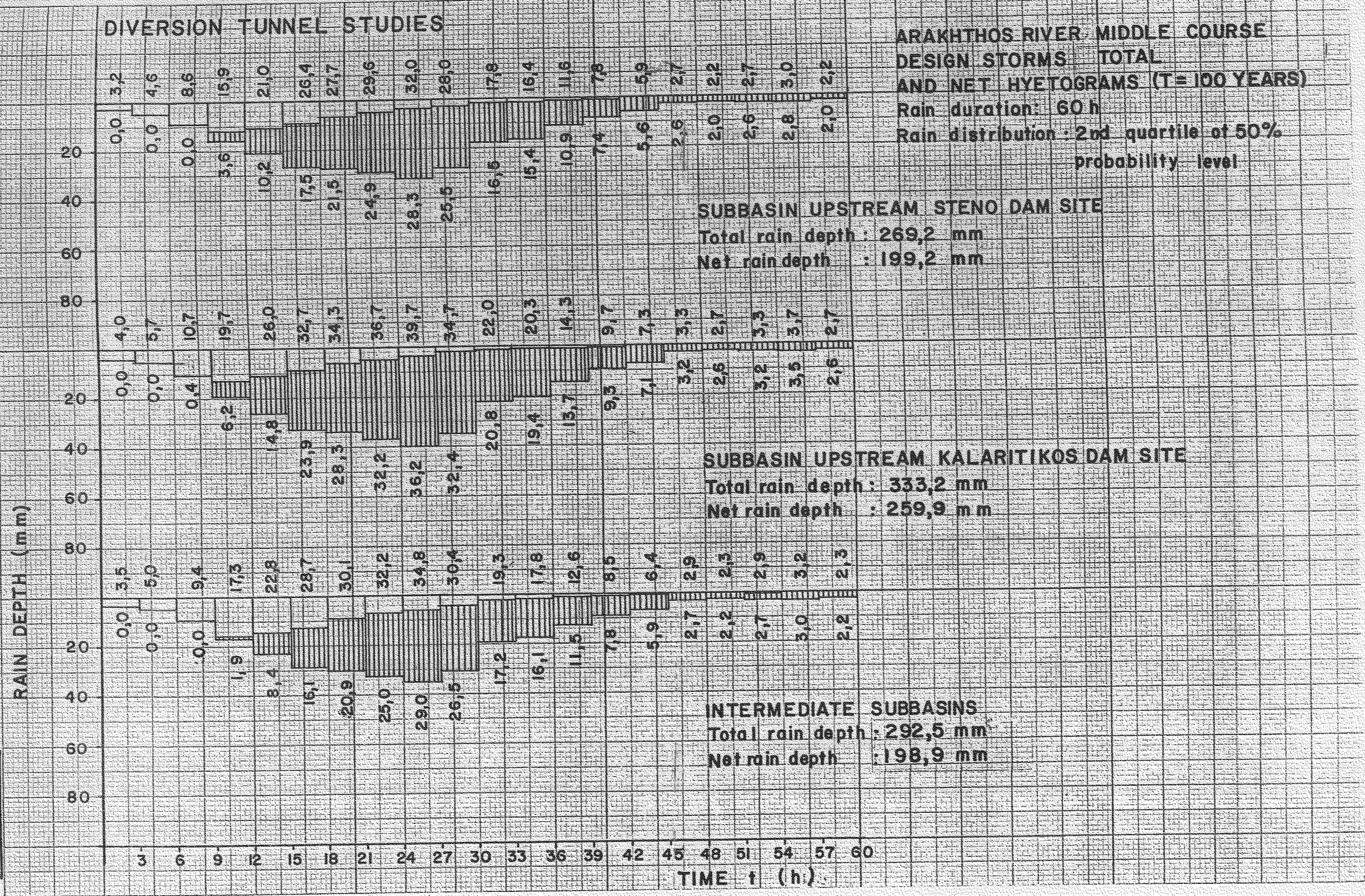

DIVERSION TUNNEL STUDIES
ARAKHTHOS RIVER MIDDLE COURSE
DESIGN STORMS TOTAL
AND NET HYETOGRAMS (T= 100 YEARS)
Rain duration: 60 h
Rain distribution: 2nd quartile of 50% probability level
SUBBASIN UPSTREAM STENO DAM SITE
Total rain depth : 269,2 mm
Net rain depth : 199,2 mm
SUBBASIN UPSTREAM KALARITIKOS DAM SITE
Total rain depth : 333,2 mm
Net rain depth : 259,9 mm
INTERMEDIATE SUBBASINS
Total rain depth : 292,5 mm
Net rain depth : 198,9 mm
RAIN DEPTH (mm)
TIME t (h)

Fig. 5.2

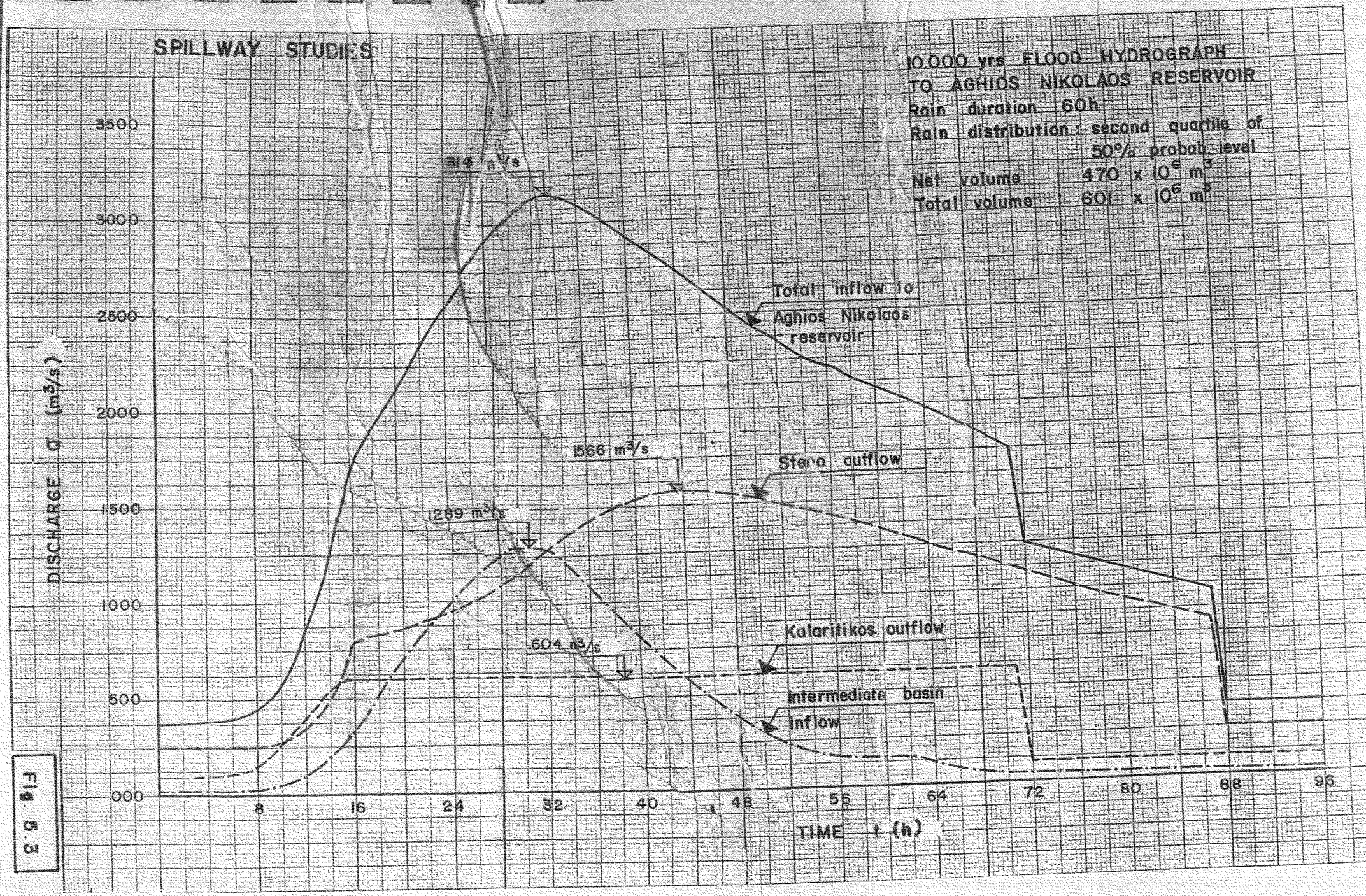

SPILLWAY STUDIES
10.000 yrs FLOOD HYDROGRAPH
TO AGHIOS NIKOLAOS RESERVOIR
Rain duration 60h
Rain distribution : second quartile of 50% probab level
Net volume 470 x 10^6 m^3
Total volume 601 x 10^6 m^3
DISCHARGE Q (m3/s)
TIME t (h)
3500
3000
2500
2000
1500
1000
500
000
8
16
24
32
40
48
56
64
72
80
88
96
314 m3/s
1566 m3/s
1289 m3/s
604 m3/s
Total inflow to Aghios Nikolaos reservoir
Stavo outflow
Kalaritikos outflow
Intermediate basin inflow

Fig. 5.3

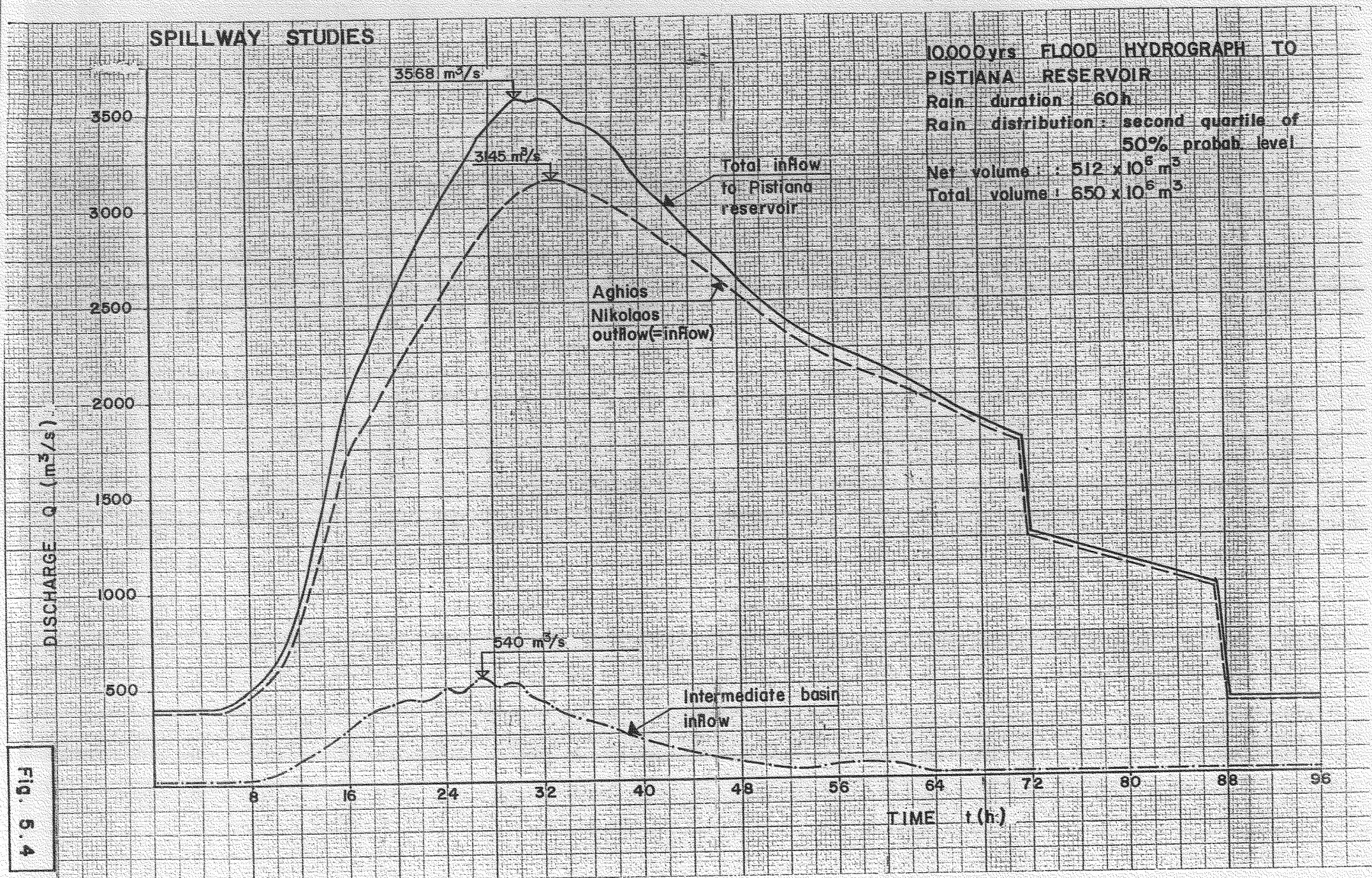

SPILLWAY STUDIES
10000 yrs FLOOD HYDROGRAPH TO PISTIANA RESERVOIR
Rain duration : 60 h
Rain distribution : second quartile of 50% probab. level
Net volume : 512 x 10^6 m^3
Total volume : 650 x 10^6 m^3
3568 m^3/s
3145 m^3/s
540 m^3/s
Total inflow to Pistiana reservoir
Aghios Nikolaos outflow(=inflow)
Intermediate basin inflow
DISCHARGE Q (m^3/s)
3500
3000
2500
2000
1500
1000
500
8
16
24
32
40
48
56
64
72
80
88
96
TIME t(h)

Fig. 5.4

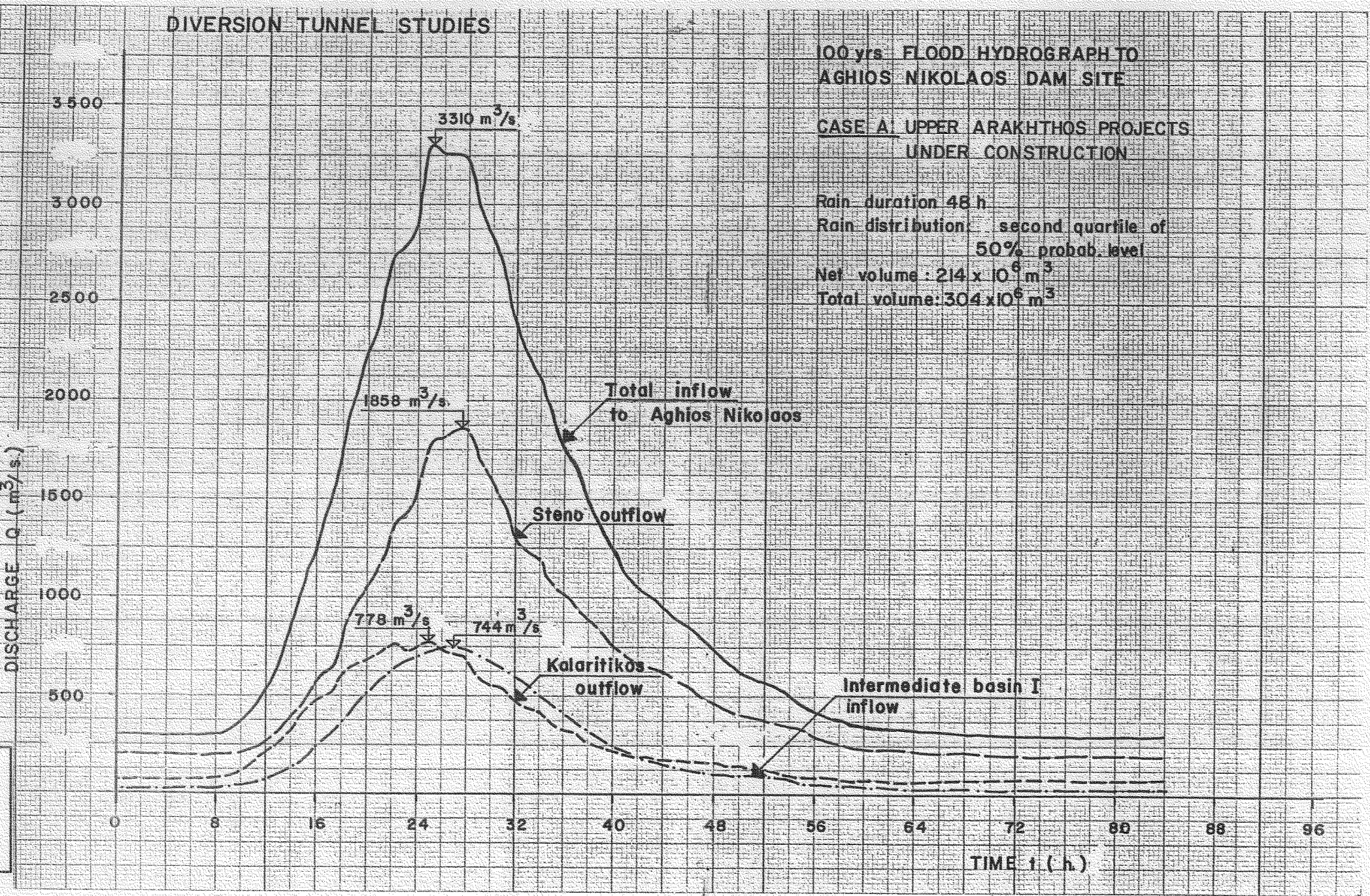

DIVERSION TUNNEL STUDIES
100 yrs FLOOD HYDROGRAPH TO AGHIOS NIKOLAOS DAM SITE
CASE A: UPPER ARAKHTHOS PROJECTS UNDER CONSTRUCTION
Rain duration 48 h
Rain distribution: second quartile of 50% probab. level
Net volume : 214 x 10^6 m^3
Total volume: 304 x 10^6 m^3
3310 m^3/s
1858 m^3/s
778 m^3/s
744 m^3/s
Total inflow to Aghios Nikolaos
Steno outflow
Kalaritikos outflow
Intermediate basin I inflow
DISCHARGE Q (m^3/s)
TIME t (h)
3500
3000
2500
2000
1500
1000
500
0
8
16
24
32
40
48
56
64
72
80
88
96

Fig. 5.5

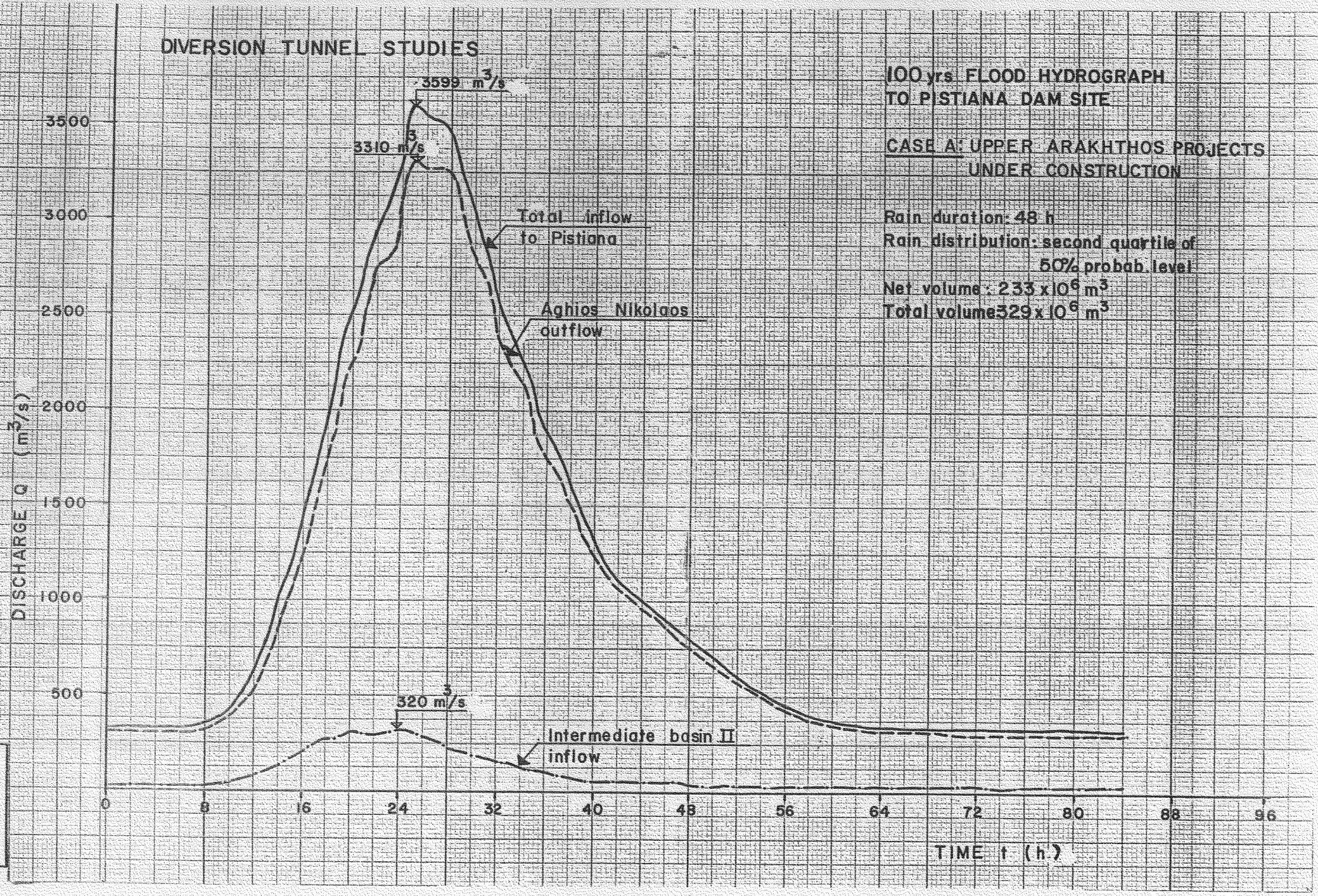
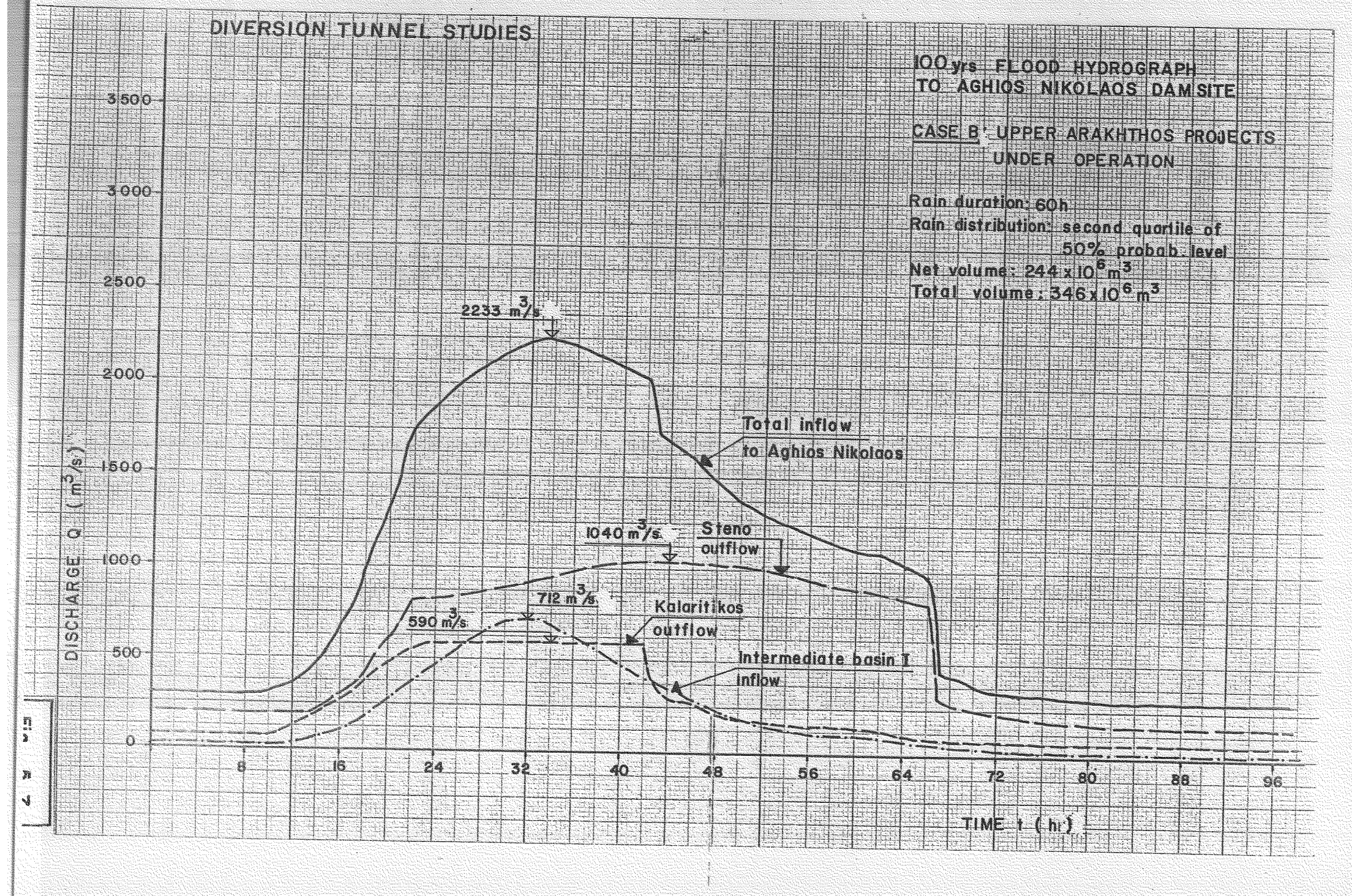
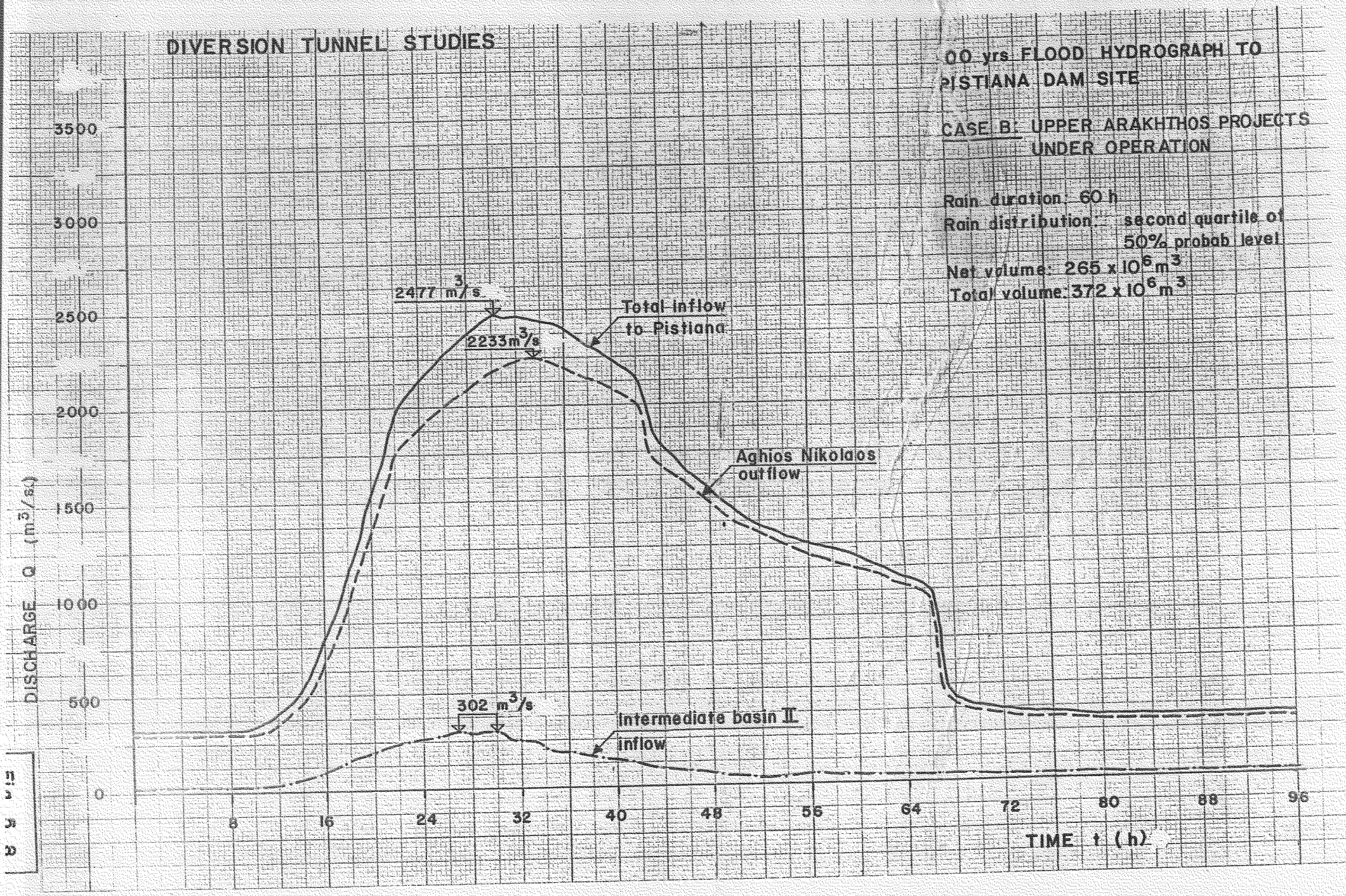

DIVERSION TUNNEL STUDIES
100 yrs FLOOD HYDROGRAPH
TO PISTIANA DAM SITE
CASE A: UPPER ARAKHTHOS PROJECTS
UNDER CONSTRUCTION
Rain duration: 48 h
Rain distribution: second quartile of
50% probab. level
Net volume: 233 x 10^6 m^3
Total volume 329 x 10^6 m^3
3599 m^3/s
3310 m^3/s
Total inflow
to Pistiana
Aghios Nikolaos
outflow
320 m^3/s
Intermediate basin II
inflow
DISCHARGE Q (m^3/s)
TIME t (h)
3500
3000
2500
2000
1500
1000
500
0
8
16
24
32
40
48
56
64
72
80
88
96

Fig. 5.6


DIVERSION TUNNEL STUDIES
100 yrs FLOOD HYDROGRAPH
TO AGHIOS NIKOLAOS DAMSITE
CASE B' UPPER ARAKHTHOS PROJECTS
UNDER OPERATION
Rain duration: 60h
Rain distribution: second quartile of
50% probab. level
Net volume: 244 x 10^6 m^3
Total volume: 346 x 10^6 m^3
2233 m^3/s
Total inflow
to Aghios Nikolaos
1040 m^3/s
Steno
outflow
712 m^3/s
590 m^3/s
Kalaritikos
outflow
Intermediate basin I
inflow
DISCHARGE Q (m^3/s)
TIME t (hr)
3500
3000
2500
2000
1500
1000
500
0
8
16
24
32
40
48
56
64
72
80
88
96


DIVERSION TUNNEL STUDIES
100 yrs FLOOD HYDROGRAPH TO PISTIANA DAM SITE
CASE B: UPPER ARAKHTHOS PROJECTS UNDER OPERATION
Rain duration: 60 h
Rain distribution: second quartile of 50% probab level
Net volume: 265 x 10^6 m^3
Total volume: 372 x 10^6 m^3
2477 m^3/s
2233m^3/s
Total inflow to Pistiana
Aghios Nikolaos outflow
302 m^3/s
Intermediate basin II inflow
DISCHARGE Q (m^3/s)
TIME t (h)
3500
3000
2500
2000
1500
1000
500
0
8
16
24
32
40
48
56
64
72
80
88
96