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Cyprus Water Planning Project

LIMASSOL - LARNACA - FAMAGUSTA
ALTERNATIVE DEVELOPMENT SCHEMES
(Preliminary Report)

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A 1 : 25000 scale map of the Limassol - Larnaca - Famagusta regions is attached to the report, showing the conveyors, dams and irrigable areas.

1. INTRODUCTION

Depending on the extension of the agricultural development of the Limassol-Akrotiri region and the construction of a desalination plant to serve the Limassol town water supply, a certain amount of water might be made available for diversion from the Khalassa, Polemidhia and Yermasoyia reservoirs, to other regions provided the cost of the diverted water is not too high.

The excess water will be diverted eastward as there is either a water shortage because of over exploitation of the Famagusta aquifer or because of the existance of more irrigable land than can be irrigated with the local available water resources in the Larnanca region. (Please see Figure 1).

After construction of the storage dams as mentioned hereafter, surface and groundwater resources will total to 73.4 MCM/a. Depending on the agricultural development and town water supply in the regions of Limassol-Akrotiri, Vasilikos-Pendaskinos, Kiti-Perivolia and the possible diversion of water to the Famagusta region, the next groups of alternatives have been studied.

Alternatives A

The main assumption is : desalination plants will be completed in the year 1985 to serve the town water supply of Limassol, Larnaca and Famagusta.

On the basis of this assumption all water will become available for agricultural purposes after 1985. The following twelve alternatives are selected for a comparative study.

Fig 1

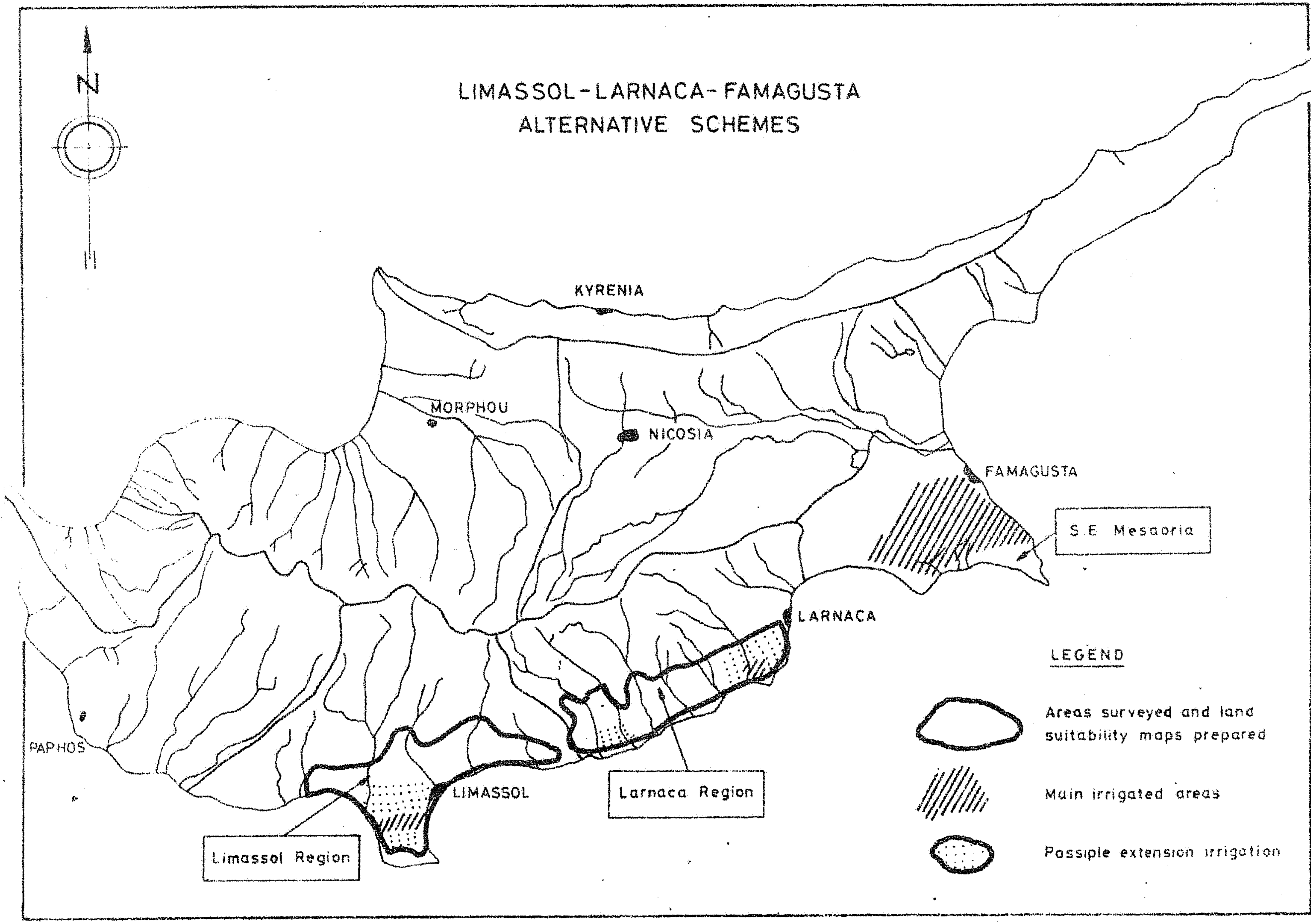

LIMASSOL-LARNACA-FAMAGUSTA
ALTERNATIVE SCHEMES
N
KYRENIA
MORPHOU
NICOSIA
FAMAGUSTA
S.E. Mesaoria
LARNACA
PAPHOS
LIMASSOL
Larnaca Region
Limassol Region
LEGEND
Areas surveyed and land suitability maps prepared
Main irrigated areas
Passiple extension irrigation

Table 1 - Alternatives "A"

	Limassol-Akrotiri region						Vasilikos-Pendaskinos region	Kiti-Perivolia region	Exported to Famagusta region	Total agricultural water consumption
	Area 1 3.3 MCM	Area 2 6.5 MCM	Area 3 4.4 MCM	Area 4 4.5 MCM	Area 5 3.6 MCM	Area 6 9.7 MCM	10.8	3 0		
AI	x	x	x	x	x		x	x	0	70.1
AII	x	x	x	x	x		x	21.3	10.7	73.1
AIII	x	x	x	x	x		9.1	22.6	14.4	73.4
AIV	x	x	x	x	x		9.1	16.6	20.4	73.4
AV	x	x	x		x		x	x	3.5	69.1
AVI	x	x	x		x		x	25.4	14.4	73.4
AVII	x	x	x		x		9.1	21.1	20.4	73.4
AVIII	x	x			x		x	x	9.6	70.8
AIX	x	x			x		9.1	25.5	20.4	73.4
AX	x	x	x	x	x	x	9.1	16.6	10.7	73.4
AXI	x	x	x	x	x	x	9.1	12.9	14.4	73.4
AXII	x	x	x	x	x	x	9.1	6.9	20.4	73.4

All figures are in llions of cubic metres. Annual
x means : full demand is supplied.

Alternatives B

For this group of alternatives, it has been assumed; no desalination plants will be constructed before the year 2000.

In this case, Limassol and Larnaca, Famagusta have to be supplied by surface water at the expense of agricultural expansion. On the assumption that, both, Limassol and Larnaca plus Famagusta need 20.0 MCM/a for town water supply, in the year 2000 only 33.4 MCM/a will become available for agricultural purposes.

The next five alternatives are selected and have been studied.

Table 2 - Alternatives "B"

Alternatives	Limassol-Akrotiri region						Vasilikos Pendaskinos region	Kiti Perivolia region	Export to Famagusta region	Total agricultural water
	Area 1 3.3MCM	Area 2 6.5 MCM	Area 3 4.4 MCM	Area 4 4.5 MCM	Area 5 8.6 MCM	Area 6 9.7 MCM	10.8	32.0		
B I	x	x	2.6		x		6.0	6.4	0	33.4
B II	x	x			x		6.0	8.4	0	33.4
B III	x				x		6.0	5.9	9.6	33.4
B IV					x		6.0	5.7	13.1	33.4
B V					x		3.0	5.0	16.8	33.4

All figures are in millions of cubic metres. Annual.

Alternatives "C"

For these alternatives, it is assumed that the Larnaca and Famagusta town water supply will be served by a desalination plant in the year 1985, while Limassol will be supplied with surface water till the year 2000.

In this group of alternatives 53.4 MCM/a of water* can be used for agricultural purposes. Depending on the water distribution over the d fferent regions, the following alternatives have been studied.

Table 3 - Alternative "C"

Alternatives	Limassol-Akrotiri region						Vasilikos-Pendaskinos region	Kiti Perivolia region	Agricultural export to Famagusta region	Total agricultural water consumption
	Area 1 3.3 MCM	Area 2 6.5 MCM	Area 3 4.4 MCM	Area 4 4.5 MCM	Area 5 8.6 MCM	Area 6 9.7 MCM	10.8	32.0		
C I	x	x	x		x		6.0	9.6	14.4	52.8
C II	xx	x			x		5.1	9.0	20.3	52.8
C III	x	x			x		6.6	13.4	14.4	52.8
C IV	x	x			x		7.4	17.4	9.6	52.8
C V	x	x			x		9.5	21.4	3.5	52.8

All figures are in million of cubic metres per year.

* This amount is still reduced by 0.6 MCM becuase only the Polemidhia and Yermasoyia reservoirs will be used to export water.

The study of these alternatives should be considered either as an alternative or as additional to the Limassol-Akrotiri Irrigation Project.

2. UNIT COSTS, ESTIMATES AND ASSUMPTIONS

2.1 Annual quantity of diverted water versus conduit capacity.

A certain relationship has to be established between the total annual diversion through a conduit and the maximum required capacity in m^3/sec of the conduit to serve the design purpose.

a. Agricultural use

When the conduit supplies water for irrigation purposes it has been assumed that water will be supplied for 24 hours per day. The peak discharge during July in this case is 0.65 l/sec/ha, while the consumptive use is given as 6000 m^3/ha. On this assumptions, the conduit capacity per 1.0 MCM/a is:

$$\frac{10^6}{6 \times 10^3} \times 0.65 \times 10^{-3} = 0.1083 \text{ m}^3/\text{sec}$$

b. Town water supply

Then the diversion conduit supplies water for town water supply systems (Alternative B), the water will be supplied at a constant rate throughout the year. The diversion conduit capacity per 1 MCM/a is:

$$\frac{10^6}{31.5 \text{ c } 10^6} \times 0.0317 \text{ m}^3/\text{sec}$$

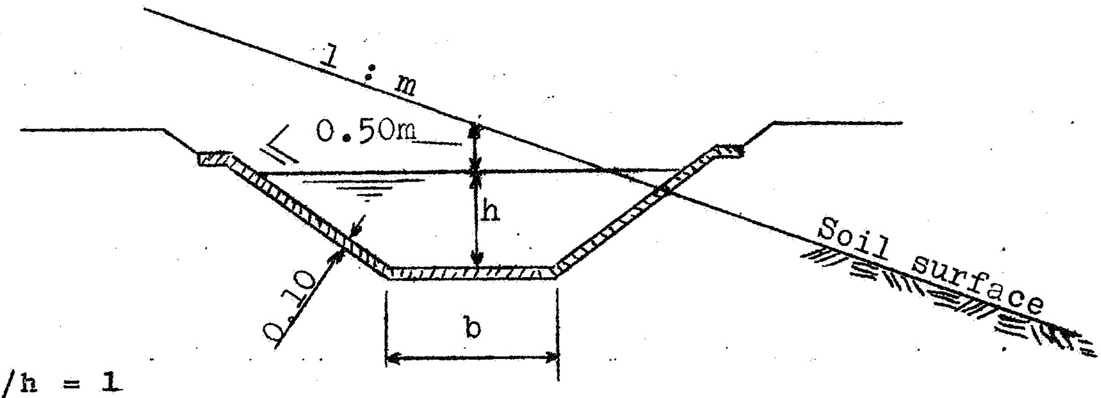
The diversion of water can be done by different means, for example :

a. Open canal with gravity flow
b. Pipe line with gravity flow
c. Pipe line with pumping station(s) or any combination of a, b and c.

Different factors, which influence the cost of these diversion conduits are described in the following sections:

2.2 Open Canal

We adopt the concrete lined canal shown of the section



b/h = 1

Mannings "n" = 0,016

For various water depths "h" and different side slopes, 1:m, the total construction cost of the canal per metre length has been calculated.

In these calculations the following estimates and prices are used :

Bxcavation:

	rate per m³, £	cost £
20% in rock	1,300	0.260
20% by handwork	0.520	0.104
60% mechanical	0.300	0.180
	per m^3 £	0.544

Used : £0.550 per m^3.

Concrete lining :

The basic rate for mass concrete is £7,500 per m^3, with 250 kg cement per m^3. To meet the difficult working conditions, curves in the canal, transport and handwork this cost is increased with about 25%, to say £9,500 per m^3 concrete lining.

Trimming of earth surface :

£0.150 per m^2

From local experience with joints over 12 feet apart cracks appear in small canals	Joints:	£0.150 per m^3 concrete

Land acquisition : £0.100 per m^2, which cost may rise sharply in the cultivated areas.

Non irrigated land £ 25-30 per donum

Irrigated land £250-500 "

The results of these calculations are represented in figure 2, showing the construction cost in pounds per metre for different design depths and side slopes of the ground surface perperdicular to the center line of the canal.

The open canal is aligned in an area with undolating and hilly topography. The average side slopes 1:m are estimated from the 1:25ooo maps from the Khalassa reservoir to the Famagusta region as shown below :

Table 4 - Distribution of side slopes

side slopes 1:m	% of total length
1 : 1.5	4
1 : 2	12
1 : 3	17
1 : 4	27
1 : 10	30
1 : 01	10
	Total 100%

This distribution of side slopes is assumed to be approximately the same for each canal section.

The capital investment in an open canal section is calculated as follows :

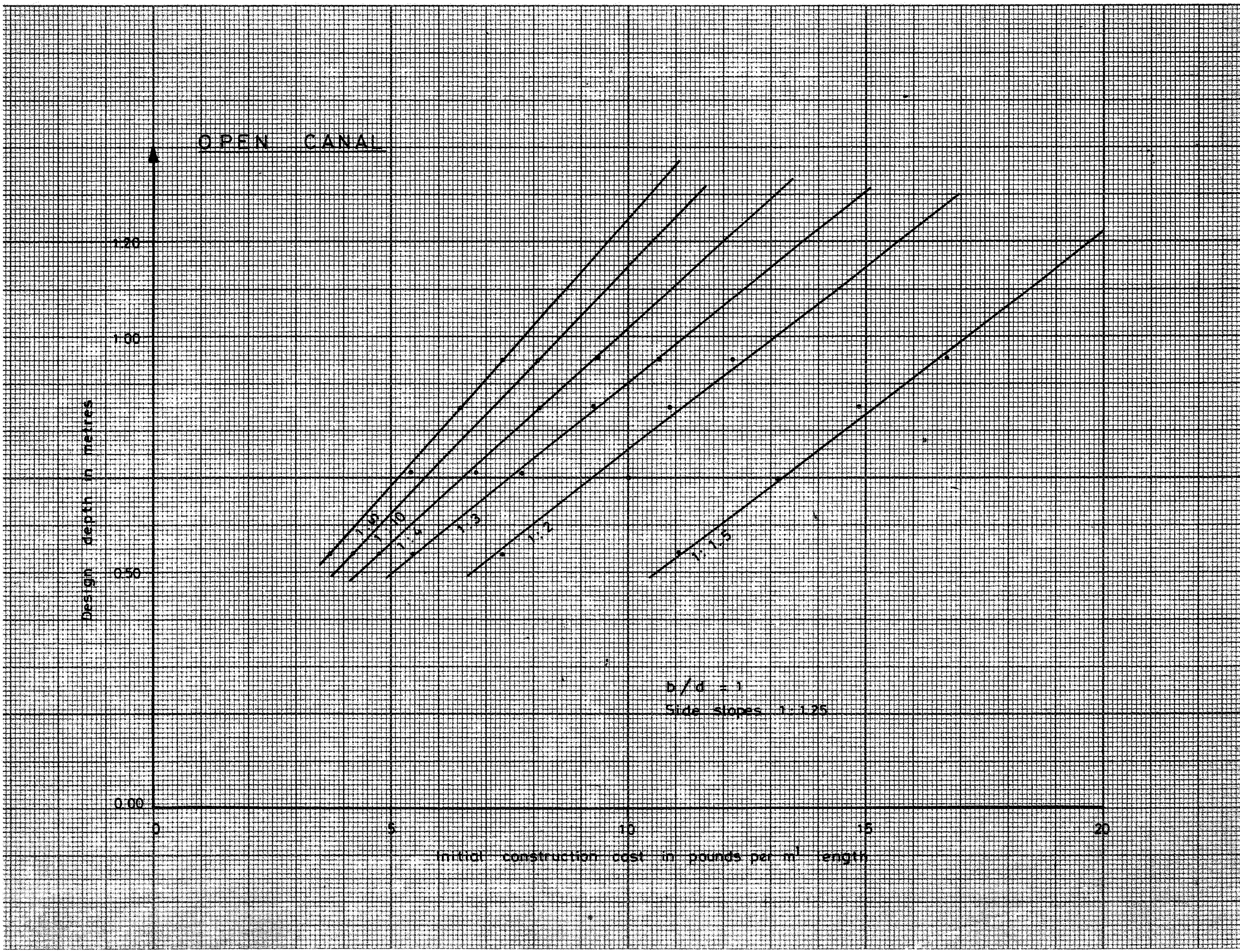

OPEN CANAL
Design depth in metres
1.20
1.00
0.50
0.00
0
5
10
15
20
Initial construction cost in pounds per m¹ length
1:6
1:10
1:4
1:3
1:2
1:1.5
b / d = 1
Side slopes 1:1.25

Fig. 2

Estimated construction cost	100 units
camps, roads, etc. 5%	5 "
work not foreseen 10%	10 "
Total direct cost :	115 units
engineering plus supervision 10%	11,5 "
Total capital investment	126,5 units

As shown above the estimated initial construction cost has to be multiplied by a factor 1.265 to find the total capital investment.

2.3 Asbest Cement pipe line

For the calculation of construction-installation cost capital investment and annual costs the following rates etc. are used :

Table 5 - Installation cost AC pipe per metre

Asbest cement pipe line class 'B'	
Internal Ø mm	Installation cost £
500	8.000
600	10.600
700	14.000
800	18.300
900	22.600
1000	27.800
1100	33.500
1200	39.100
1300	44.600

These installation costs are the prices per metre C.I.F. Famagusta, increased by about 50% to meet the cost of insurance, transport, trenching, laying and testing for use plus the filling in of the trench.

The cost of air valves, gates and wash-outs is not included in these prices. However, on the large quantities of pipe line a discount of about 10% can be obtained on the CIF prices with which these items can be purchased, or constructed.

The capital investment in a pipe line is calculated as follows :

Estimated installation cost		100 units
camps, roads, etc.	3%	3 "
Work not foreseen	10%	10 "
Total direct cost		113 units
engineering + supervision 5%		5.65 "
Total capital investment		118.65 units

The estimated installation cost has now to be multiplied by the above factor 1.1865 to find the total capital investment.

Table 6 - Capital investment AC pipe

Internal Ø mm	Total capital investment per kilo-metre AC pipe line. £
500	9,490
600	12,580
700	16,610
800	21,710
900	26,820
1000	32,990
1100	39,750
1200	46,490
1300	52,920

These values are used in the calculations for the estimated capital investments.

When a longitudinal profile of the pipe line will be worked out, it will show a prohibitive high working pressure for class B pipes in certain sections. In these sections class C pipe has to be used. This affects the cost of the pipe CIF Famagusta only and not the other costs. In this study no longitudinal profiles have been prepared and to simplify the calculations the whole pipe line has been calculated as if class B pipe will be used.

2.4 Installation cost of pumping station(s)

The construction cost of a building and the purchase and installation cost of all mechanical and electric items in a pumping station, has been expressed in £ per KW installed.

This cost has been determined from the recent reports no 19 and 20 by Mr. B. M. Millinusic, being £ 35.- per KW installed.

The total cost of a pumping station has been calculated on the assumption that pumping efficiency will be 65%. The power needed by the station is calculated with using the formula :

$$15 \times Q \times h = \ldots\ldots\ \text{KW.}$$

where,

Q = max. capacity in m^3/sec.

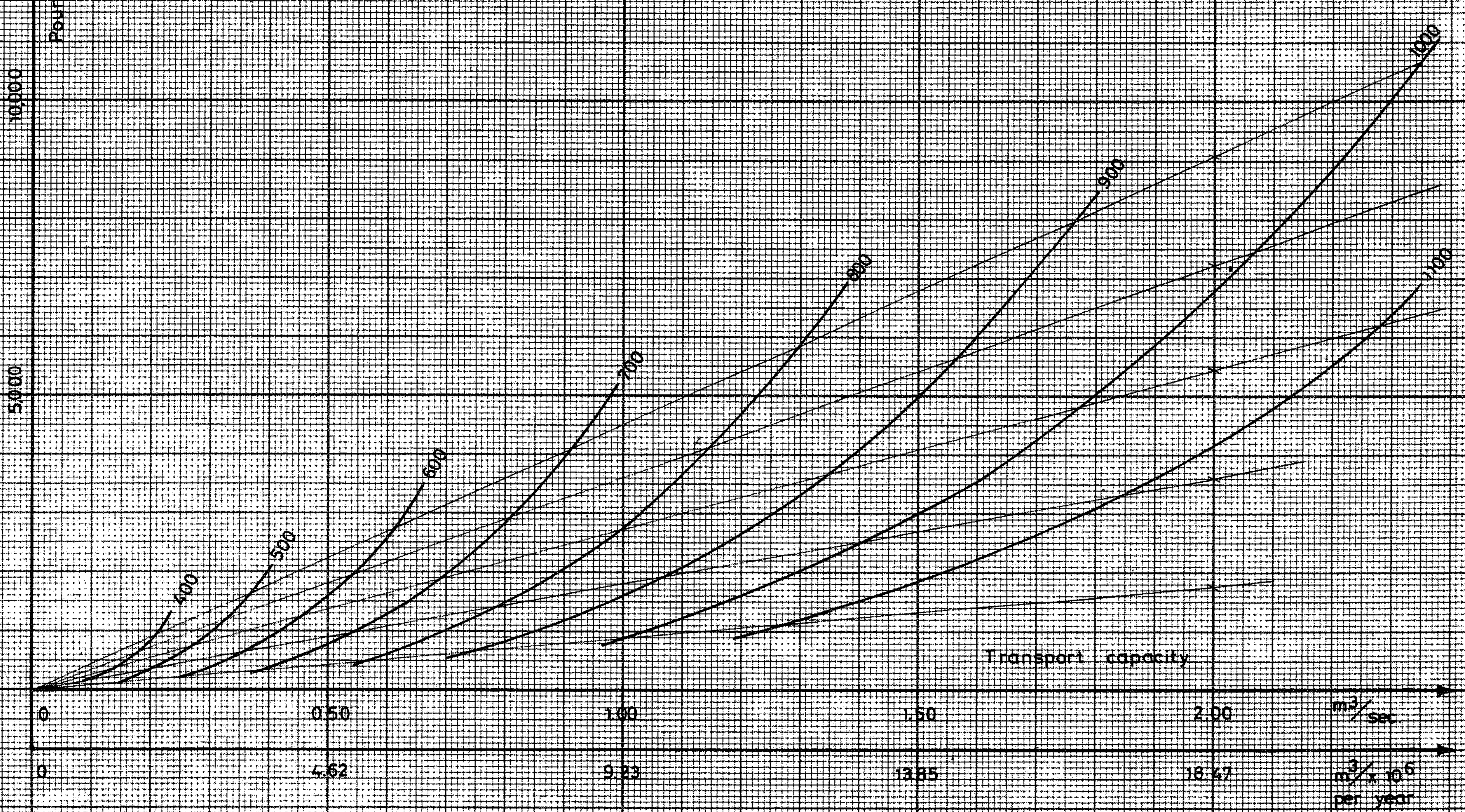
h = max. lift in metre.

Furthermore, it has been assumed that 25% of the power needed, will be installed as a stand by unit.

The total capital investment in a pumping station is in all cases calculated as follows :

Cost per KW power needed	100 units
Stand-by power	25 "
Total installed power	125 "
Work not foreseen 10%	12.5 "
Total direct cost	137.5 units
Engineering plus supervision 10%	13.75 "
Capital investment	151.25 units

CAPITAL INVESTMENT FOR PUMPING STATIONS ON A ASBEST - CEMENT PIPELINE OF 1km LENGTH



Note:
Entrance and exit level are the same.
A correction should be made for all differences

Fig 3

As shown, the actual capital investment per KW of power needed is 1.5125 x £35.- or £55.- per KW of power.

For different pipe diameters and discharges these capital investments have been calculated and are shown on figure No. 3.

2.5 Amortization rates and percentages for operation and maintenance cost

In the comparative calculations on the annual costs and in the calculations of the internal rate of return of each alternative scheme, the following figures are used.

Table 7 - Replacement and annual cost

Item	Replacement after years	Operation and maintenance
Open canal	50	2%
Pipe line A.C.	40	0.5%
Pumping stations 75%	15	4.0%
15%	30	1.0%
Dams	50	0.23%
Distribution system	40	2.5%
Farm equipment	15	4.0%

The factors by which the capital investments have to be multiplied, to calculate the total annual cost, will have the following values :

Table 8 - Annual cost factors

Item	Amortization	O + M	Total
Open canal	0.0634	0.0200	0.0834
Pipe line AC	0.0665	0.0050	0.0715
Pumping station	0.0954	0.0325	0.1279*

* Annual energy cost not included.

In case of the A.C. pipe line, the capital investments have been multiplied with the factor 0.0715 to find the annual cost for different pipe diameters.

Table 9 - Annual O + M, A.C. Pipeline

Internal Ø mm	Annual cost in pounds per Km pipe line
500	680
600	900
700	1190
800	1550
900	1920
1000	2360
1100	2840
1200	3320
1300	3780

2.6 Energy consumption of pumping stations and its favourable combination with a pipe.line.

Annual energy consumptions are calculated on the assumption that the pumping station is working at 65% efficiency and the cost of energy is 8 mils per KWh. To lift 1 MCM of water 1 metre the energy needed is :

$$\frac{10^9 \text{ kg} \times 1 \text{ m}}{0.65} = 1.54 \times 10^9 \text{ kgm}$$

$$\text{or} \quad \frac{1.54 \times 10^9}{3.67 \times 10^5} = 4.2 \times 10^3 \text{ KWh}$$

This amounts to a cost of £33.600 per 1.0 MCM per m^1 lift.

The total annual cost of the pumping station will be

$$15 \times Q_{sec} \times h \times 0.1279 \times 55.0 \quad £$$

$$\text{plus } 33.6 \times Q_{annual} \times h \quad £$$

Where,

Q_{sec} = capacity in m^3/sec.

Q_{annual} = annual pompage MCM/A

ANNUAL COST PER 1 Km AC - PIPE LINE PLUS PUMPING STATION

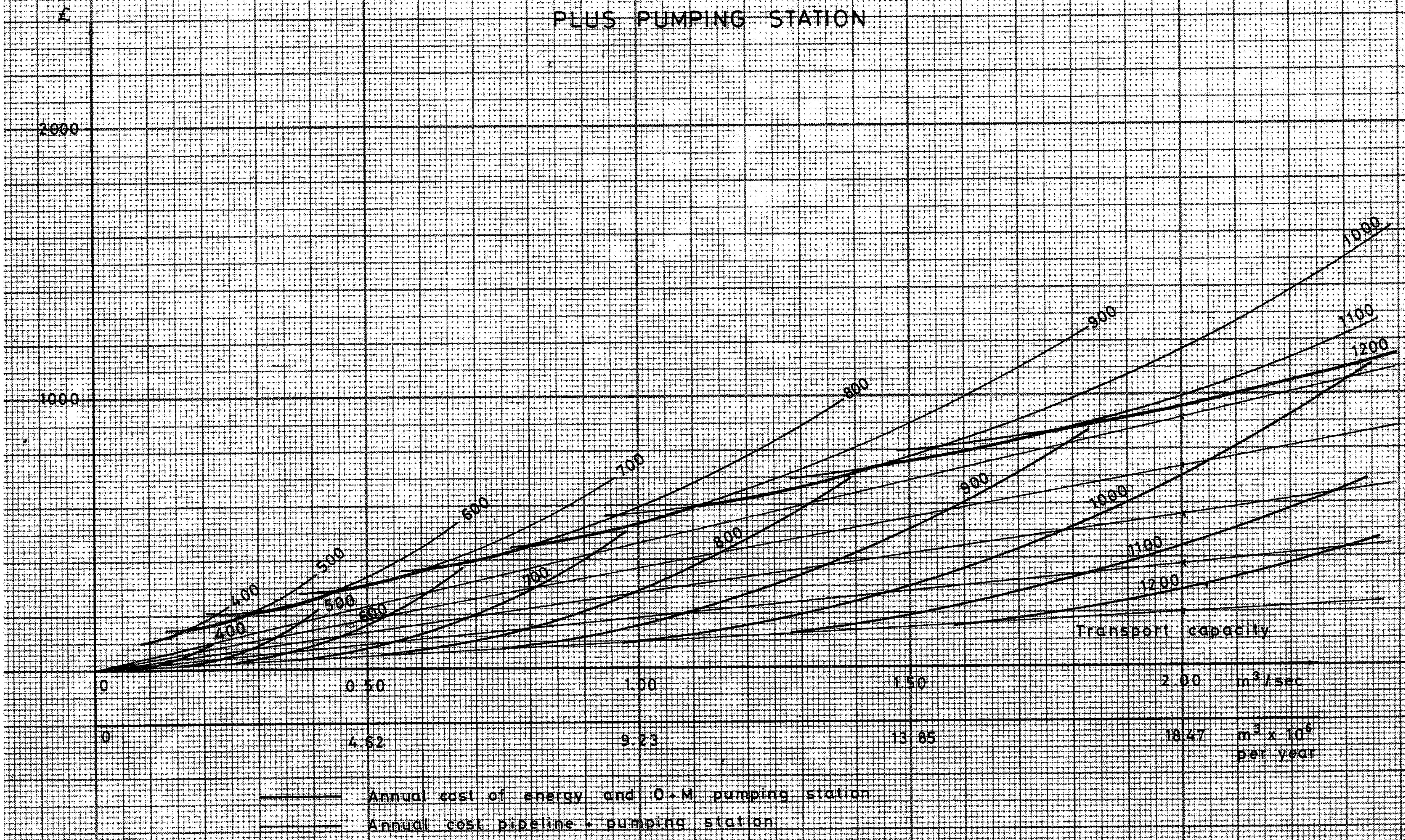


Fig. 4

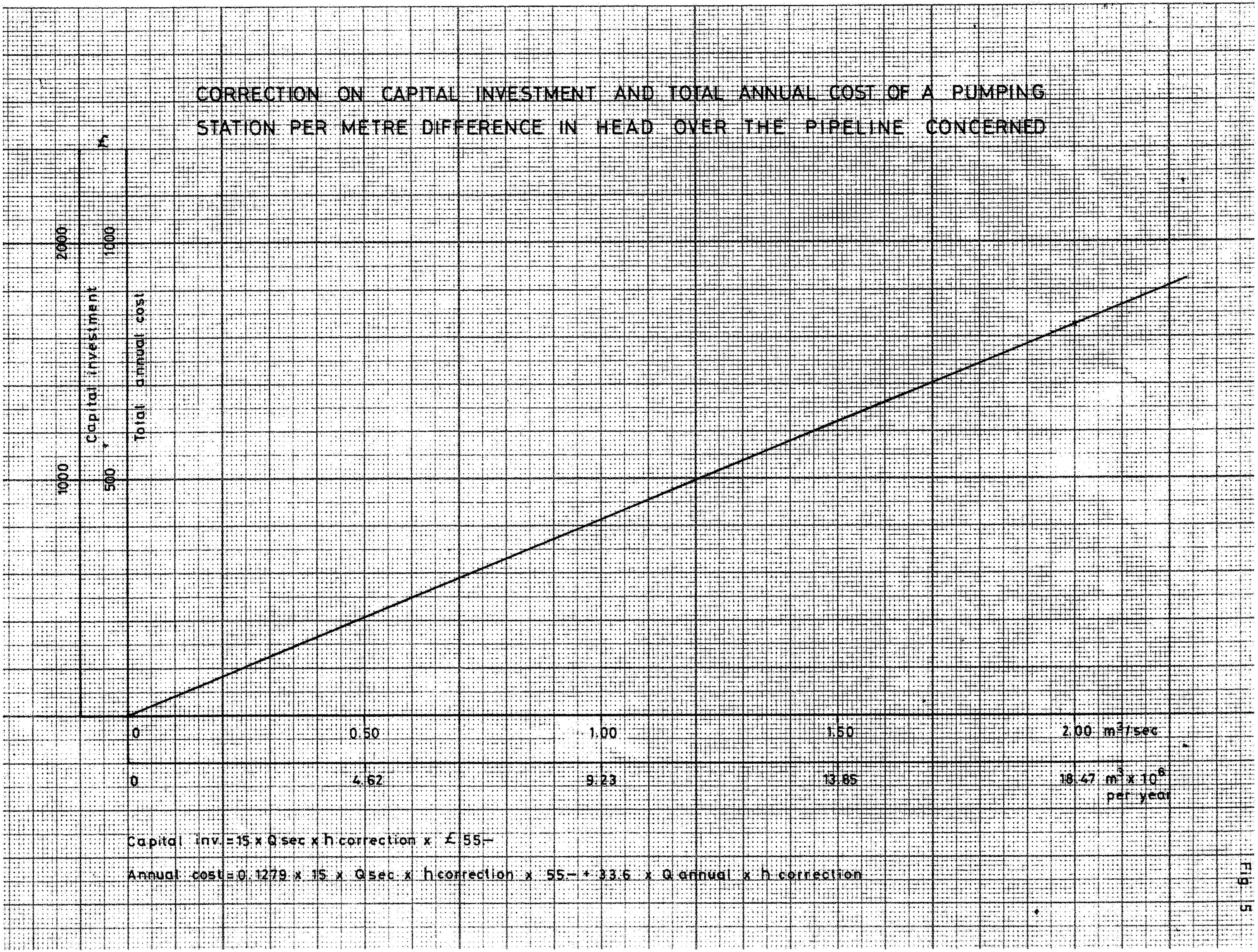

CORRECTION ON CAPITAL INVESTMENT AND TOTAL ANNUAL COST OF A PUMPING STATION PER METRE DIFFERENCE IN HEAD OVER THE PIPELINE CONCERNED
£
2000
1000
Capital investment
1000
500
Total annual cost
0
0.50
1.00
1.50
2.00 m³/sec
0
4.62
9.23
13.85
18.47 m³ x 10⁶ per year
Capital inv. = 15 x Q sec x h correction x £ 55.–
Annual cost = 0.1279 x 15 x Q sec x h correction x 55.– + 33.6 x Q annual x h correction

Fig. 5

h = loss of head over pipe line increased by 10% to meet all additional losses.

For different capacities in m^3/sec and in MCM/A for various pipe diameters these annual costs have been calculated per km length of pipe line and are shown in figure 4.

To find the annual cost of the combined pipe line and pumping station(s), both annual costs have to be added. This has been done on the graph in figure 4.

Figure 4 shows the capacities where the pipe diameter has to be varied to achieve the most economical conveyance cost. This minimum annual conveyance cost is shown by a line on figure 4, and will be used in following comparative calculations.

Note:

Figure 4 shows, in general a loss of head of 2.00 m + 10% = 2.20 m/km which is the most economical. It is usually better to overdesign the pipe rather than to use a diameter which is too small.

Correction of energy consumption :

In practice there will be a difference in elevation between the intake and the end of a pipe line.

This difference gives either a saving in the capital investment of the pumping station of

$$15 \times Q \times h \times £55.$$

or an extra cost whenever the intake of the pipe line is lower than its end. (See fig. 5)

On the annual cost of the pumping station a correction has to be made of

$$0.1279 \times 15 \times Q_{sec} \times h_{corrected} \times 55.- \quad £$$

with regard to the capital investment. The cost of energy consumption has to be corrected by

$$33.6 \times Q_{annual} \times h_{corrected} \quad £$$

For $h_{corrected}$ = 1,00 m for various Q_{sec} and Q_{annual} the annual correction is given in figure 5.

2.7 Cost and dependable yield of storage dams

With the help of a computer, reservoir operation studies have been made for each dam with variable storage capacity and dependable yield. The following dependable yields have been selected:

Table 10 - Storage capacities and dependable yields

Name of dam	Storage cap. m^3	Dep. Yield m^3/year
Khalassa	60.0 $\times 10^6$	32.0 $\times 10^6$
Polemidhia *	3.85 $\times 10^6$	2.5 $\times 10^6$
Yermasoyia *	13.5 $\times 10^6$	6.5 $\times 10^6$
Yermasoyia after raising	22.0 $\times 10^6$	9.5 $\times 10^6$
Kalavassos	8.0 $\times 10^6$	3.0 $\times 10^6$
Khirokitia	6.0 $\times 10^6$	2.5 $\times 10^6$
Lefkara	13.4 $\times 10^6$	6.2 $\times 10^6$
Dhipotamos	5.0 $\times 10^6$	4.0 $\times 10^6$

On the Maroni river, a second dam is proposed mainly as a regulator. This dam, called Psematosmanos, gives a storage capacity of 1.5 x 10^6 m^3. By itself and before construction of the Khirokitia dam, this reservoir has a dependable yield of 1.15 x 10^6 m^3. After completion of the Khirokitia dam, it can serve to impound the spills of the Khirokitia and Kalavassos reservoirs, besides it principal function of regulating the water to be supplied to the Vasilikos - Pendaskinos agricultural region.

The Polemidhia and Yermasoyia dams have been already constructed. In the computation of the internal rate of return, the costs of these dams have been corrected with a compound interest of 6% per annum for the year 1974.

The construction costs of the dams over the different years of construction are shown below and are used in the expenditure estimates.

*excisting dams

Table 11 - Capital investments dams £x10^3

construction year / name of dam	1st or 1974	2nd	3th
Khalassa	790	2160	1600
Polemidhia) Yermasoyia)	1850		
Raising of Yermasoyia	151	300	69
Kalavassos	346	755	25
Khirokitia	261	833	114
Psematismenos	143	281	12
Lefkara	380	750	120
Dhipotamos	230	407	14

Total amount of money to be invested in storage dams is: £11.436.000

O + M being 0.23 % is £ 26.300

annuity at a rate of 6% ; 50 years 0.0634 £725.000

= Annual cost of all dams £751.000

Annual dependable yield in total 59.7×10^6 m^3

Average initial cost per m^3 of water

$$\frac{751.000.000}{59.700.000} = \underline{\underline{12.58 \text{ Mils/m}^3}}$$

2.8 Groundwater resources

In furure, the agricultural water demands in each area considered in this study will be supplied with local available water, supplemented with water from the storage dams mentioned previously. The local groundwater resources are estimated as shown below :

Table 12 - Available groundwater

Area	Dependable yield in m^3 per year
Limassol - Akrotiri	7.0×10^6
Vasilikos - Pendaskinos	1.7×10^6
Kiti - Perivolia	5.0×10^6 *

2.9 Distribution system and farm equipment

The extention of the agricultural area in the Limassol - Akrotiri region has been studied in detail. From this study, the costs of the distribution system and on farm equipment have been used in the expenditure computations in this region.

For the Vasilikos - Larnaca region, however, no detailed study has been made. The capital investment on these items are assumed to be, on the average the same as in the Limassol - Akrotiri region, and are

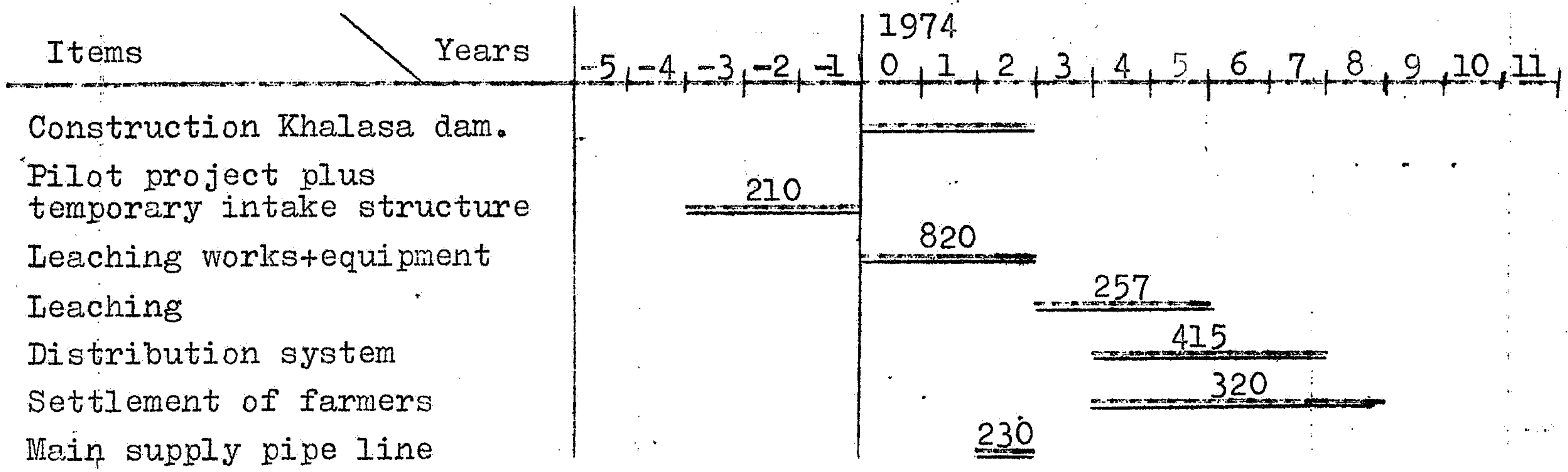
Distribution system	£250 per ha
Farm equipment	£166 per ha

2.10 Reclamation of Akrotiri salt lake

In three of the alternatives studied, it has been assumed, area 6 of the Akrotiri salt lake will be reclaimed. A semi-detailed study has been made by Mr. B. M. Milinusic on the estimated cost of this scheme. After some revision, the following schedule of construction and expenditure is used hereafter.

* including yield from Kiti reservoir

Schedule of development and expenditure of area 6



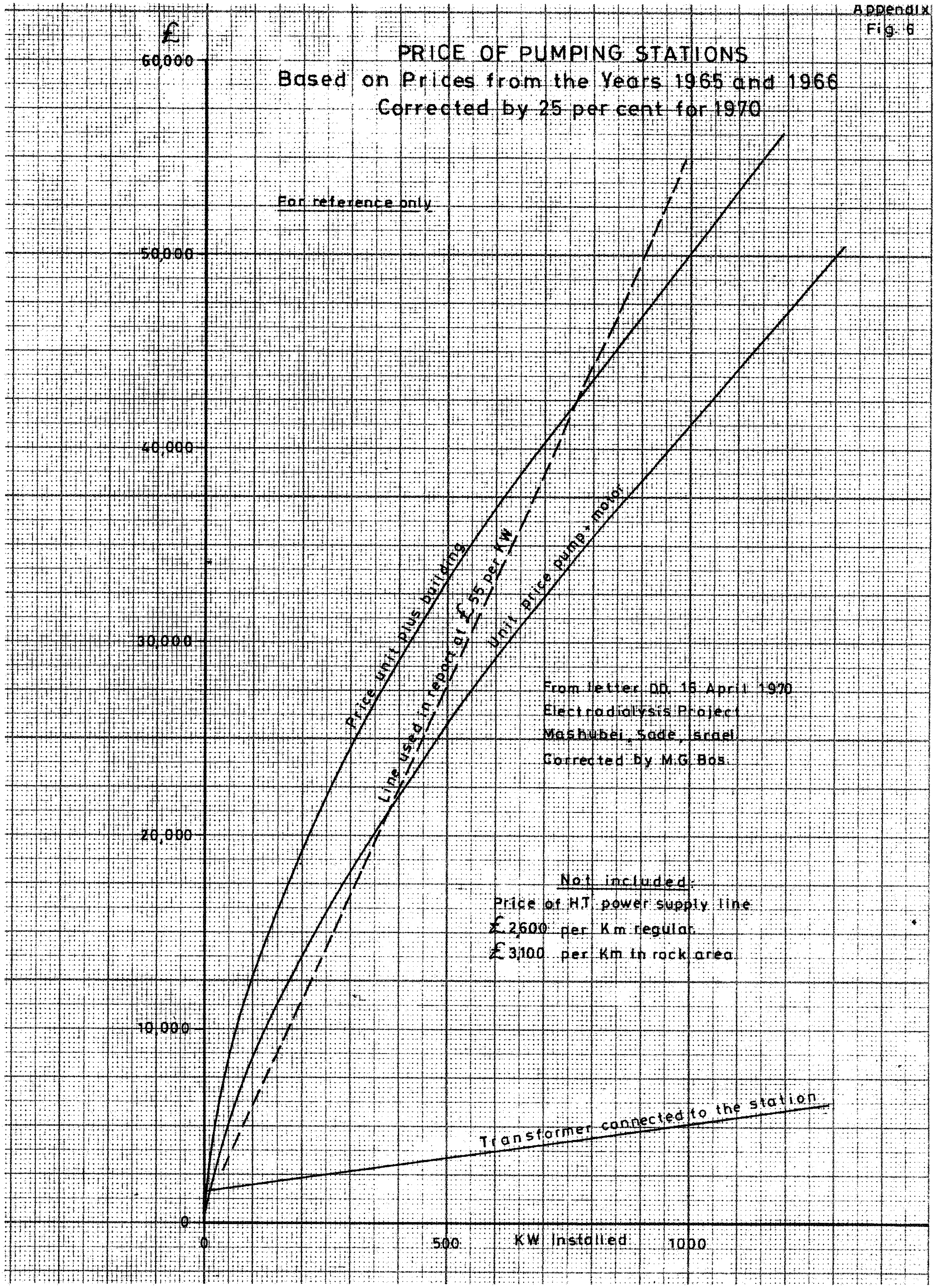
Expenditure in £ x 10^6

2.11 Price of a pumping station

After completion of the calculations in the report, a letter has been received d.d. 16 April 1970, from Mr. J. R. Olie, Project Manager of the Electrodialysis Project - Mashadei Sade, Israel, UNDP. SF. In this letter a graph was enclosed giving pump unit prices is Israel pounds varsus HP. installed. These prices have been corrected by plus 25% and converted to Cyprus pound and KW at a rate of 1 IL = 0.116 C£ and 1 HP = 0.735 KW respectively.

As shown in the graph, the pump unit prices plus building do not differ to a great extend from the prices used in the report, taking into consideration that nearly all pump units are in the 500 to 1000 KW range.

For any further study the use of this new graph is recommanded, as it gives a more reasonable cost estimate at the rate of 55 £ per KW installed than, used before.



PRICE OF PUMPING STATIONS
Based on Prices from the Years 1965 and 1966
Corrected by 25 per cent for 1970

Table 13 - Dimensions open canal

Capacity Q : m^3/sec	0.45	0.90	1.35	1.80
Canal slope "S"	0.00055	0.00055	0.00055	0.00055
b = h in metre	0.54	0.71	0.85	0.93
Water area A:m^2	0.657	1.138	1.629	1.950
$\bar{V}$ m/sec	0.685	0.791	0.830	0.923

The initial construction cost of the canal has been calculated with the given side slope (table 4) and the construction costs per metre as shown in figure 2.

This construction cost is calculated in table 14 for the four different canal capacities :

Because of the unfavourable topography, the many rivers, streams or valleys to be crossed and the trucks and roads in the area, high costs are involved by the construction of culverts, siphons, aquaducts, road culverts/bridges and sections with pipe lines to cross village areas.

3. COMPARISON OF PIPE LINE VERSUS OPEN CANAL AS A CONVEYOR

3.1 General

To enable the choice between different means of conveying water, comparative calculations have been made of the capital investment and annual costs of :

a. Open concrete lined canal

b. Pipe line with gravity flow

c. Pipe line with pumping stations.

For this reason the alignment of an open canal and a pipe line has been traced on 1:25.000 scale maps to transport water from the Khalassa reservoir to a selected delivery point near Avgorou in the Famagusta region (WD 746, 760).

Supply head at Khalassa dam has been determined in previous reports at 168.00 m. The demanded head near Avgorou is 50.00 m. A large irrigation area is commanded by this supply level. The available head for the conduit is

$$168.00 - 50.00 = 118.00 \text{ m}$$

3.2 Open canal with gravity flow

The estimated length of the graded contour canal is about 190 km. The available loss of head will be

$$118/190 = 0.621 \text{ m/km}$$

If we allow 0.071 m/km (about 10%) loss of head in siphons, aquaducts, curves etc., there is 0.55 m/km left for the gravity flow in the open canal. An extra head of 190 x 0.071 = 13.50 m is available for losses, other than the loss of 0.55 m/km.

The shape and different dimensions of the canal of various capacities are :

Table 14 - Estimated construction cost - Open Canal

Side Slopes	length of section in km	Unit Cost in £ Per Metre				Total Cost in £ Per Section			
		0.45	0.90	1.35	1.80	0.40	0.90	1.35	1.80
1:1.5	8	11.1	13.2	15.2	16.6	88,800	105,700	121,600	132,900
1:2	23	7.2	9.4	11.3	12.5	165.600	216.200	259,900	287,500
1:3	32	5.4	7.7	9.4	10.7	172.800	246.400	300,800	342,400
1:4	51	4.7	6.7	8.1	9.3	239.700	341.700	413,100	474,300
1:10	57	4.2	5.8	7.1	8.1	249,400	330,600	404,700	461,700
1.∞	19	3.7	5.3	6.5	7.1	70,300	100,700	123,500	134,900
Totals	190km					£986,600	1,341,300	1,623,600	1,833,700

The number of structures are estimated from the 1:25.000 map and are listed below :

Table 15 - Number of structures

Type of structure	Approximate amount
Culverts	140
Road culverts/bridges	110
Aquaducts	35
Siphons	13 (± 4 Km)
Length of pipe line	5000 m

Unit prices for these items for the different canal capacities are estimated on the basis of previous studies, as shown below :

Table 16 - Construction cost structures : £

Q m^3/sec	0.45	0.90	1.35	1.80
Culvert	350	375	400	425
Road crossing	300	500	650	800
Aquaduct	800	1,000	1,200	1,400
Siphon : lump sum	56,000	111,200	134,000	156,400
Extra cost pipe lines	9.0	21.0	25.5	29.7

The total initial construction cost involved for these structures is shown in table 17.

Table 17 - Total initial construction cost structures

Q m^3/sec	0.45	0.90	1.35	1.80
Culverts	49.000	52.500	56.000	59.500
Road crossings	33.000	55.000	71.500	88.000
Aquaducts	28.000	35.000	42.000	49.000
Siphons	56.000	111.200	134.000	156.400
Pipe lines	45.000	105.000	127.500	148.500
Sub total in £	211.000	358.700	431.000	501.400

The initial cost of the canal has been calculated in table 14. The total capital investment in the canal and related structures is :

Table 18 - Total capital investment open canal

$Q\ m^3/sec$	0.45	0.90	1.35	1.80
Canal only	986.600	1.341.300	1.623.600	1.833.700
Related structures	211.000	358.700	431.000	501.400
Sub Total	1.197.600	1.700.000	2.054.600	2.335.100
Use factor 1.265 for Capital investment	1.515.000	2.150.500	2.599.100	2.953.400

These are the total capital investments for a 190 Km long open canal. The figures are represented in figure 7.

Evaporation from an open canal :

The water surface of an open canal is exposed to the atmosphere. The water has a velocity of flow and in the case of wave action the concrete lined freeboard is continually westted. This gives a certain loss of water by evaporation, and represents an annual operation loss.

The water supplied to the Famagusta region has been estimated to cost about 30 Mils per m^3. The total annual loss in pounds is :

Table 19 - Evaporation losses

$Q\ m^3/sec$	0.45	0.90	1.35	1.80
Top width canal plus 10% in metre	2.15	2.75	3.25	3.60
Total surface in m^2	390.000	500.000	590.000	660.000
Total evaporation 1500 mm	585.000	750.000	885.000	1.000.000
Losses in £ per year	17.600	22.500	26.500	30.000

Fig. 7

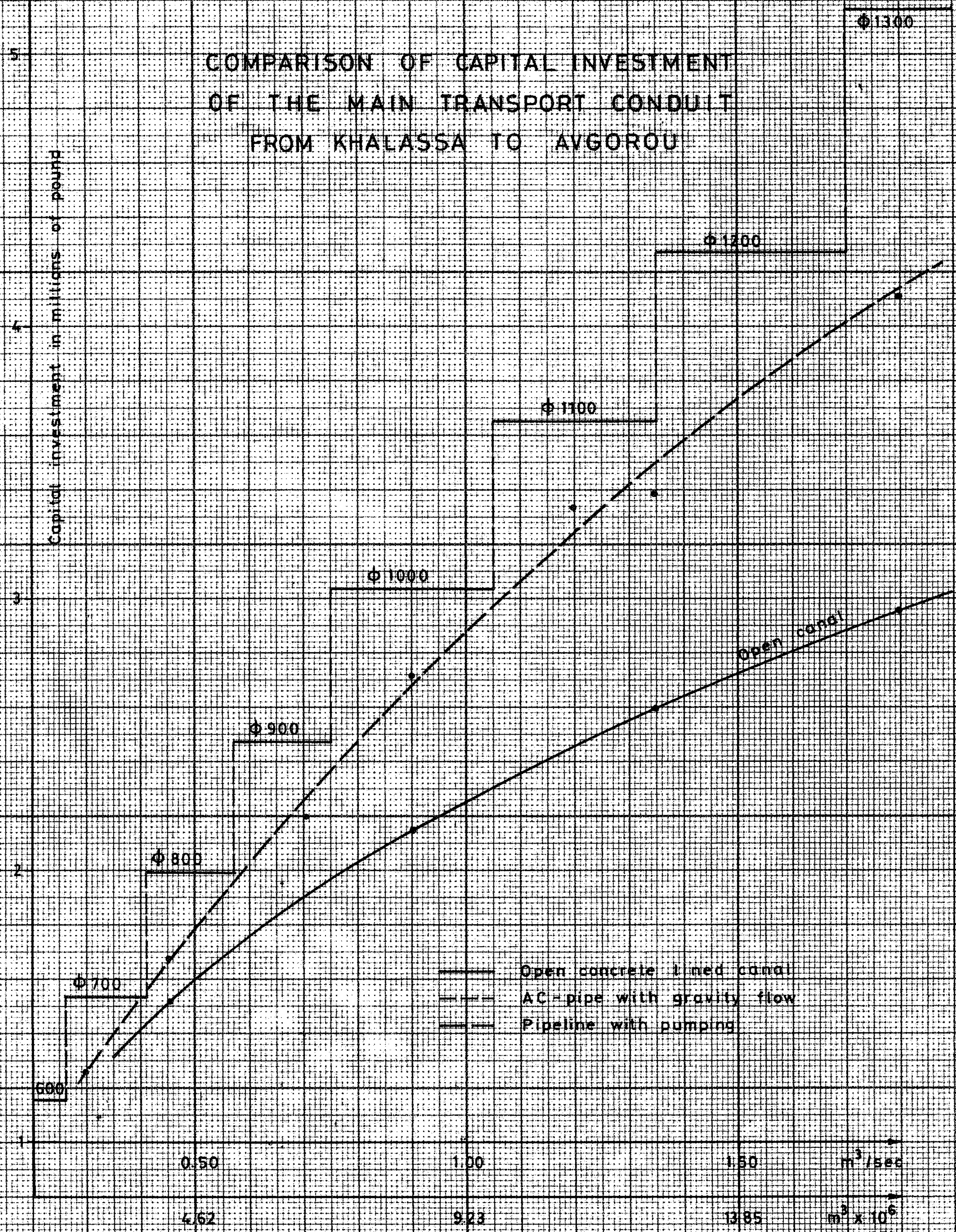

COMPARISON OF CAPITAL INVESTMENT
OF THE MAIN TRANSPORT CONDUIT
FROM KHALASSA TO AVGOROU
Capital investment in millions of pound
5
4
3
2
1
Φ1300
Φ1200
Φ1100
Φ1000
Φ900
Φ800
Φ700
600
Open canal
Open concrete lined canal
AC-pipe with gravity flow
Pipeline with pumping
0.50
1.00
1.50
m³/sec
4.62
9.23
13.85
m³ x 10⁶ per year

Fig.8

COMPARISON OF THE ANNUAL COST OF THE MAIN TRANSPORT CONDUIT FROM KHALASSA DAM TO THE AVGOROU DELIVERY POINT

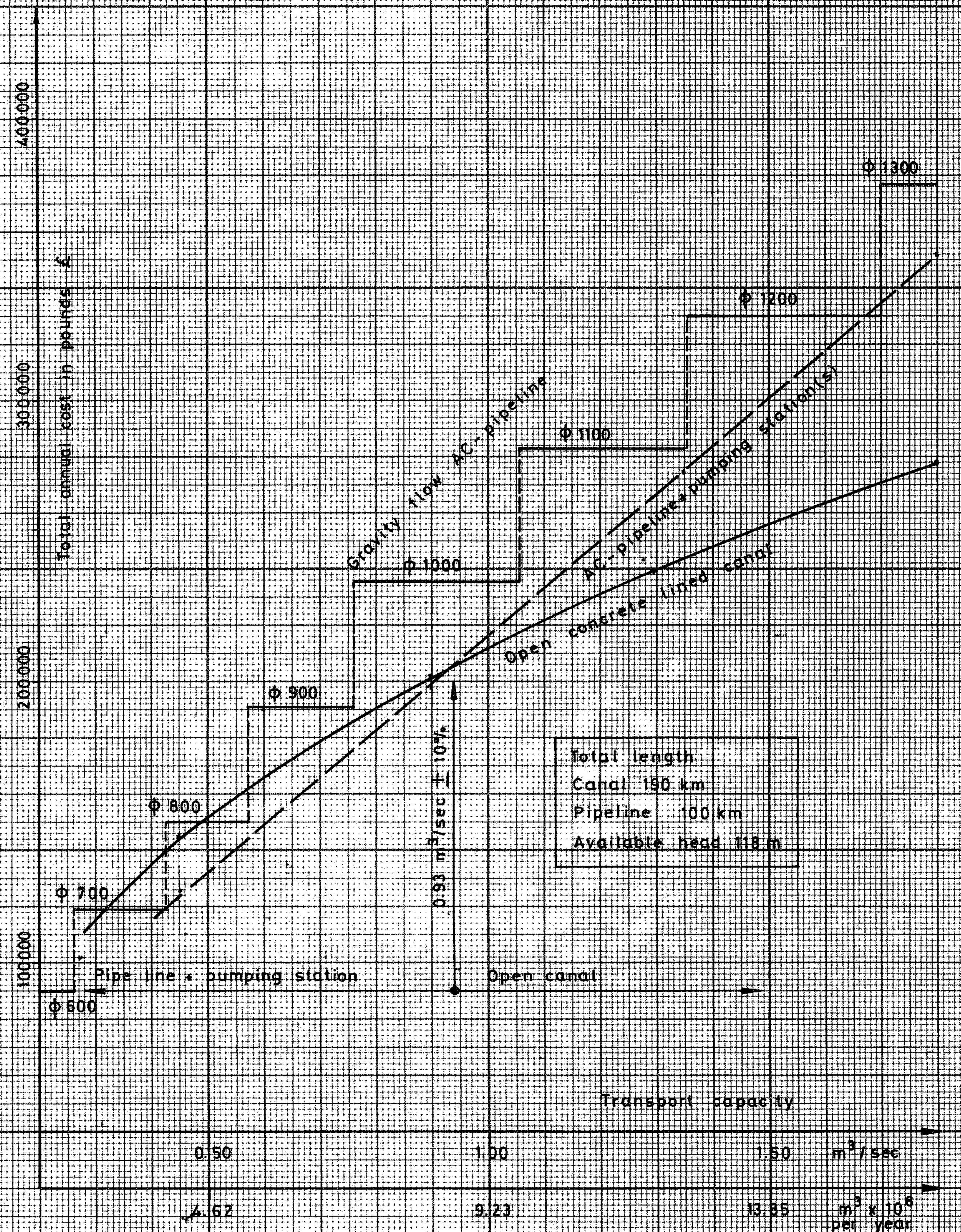
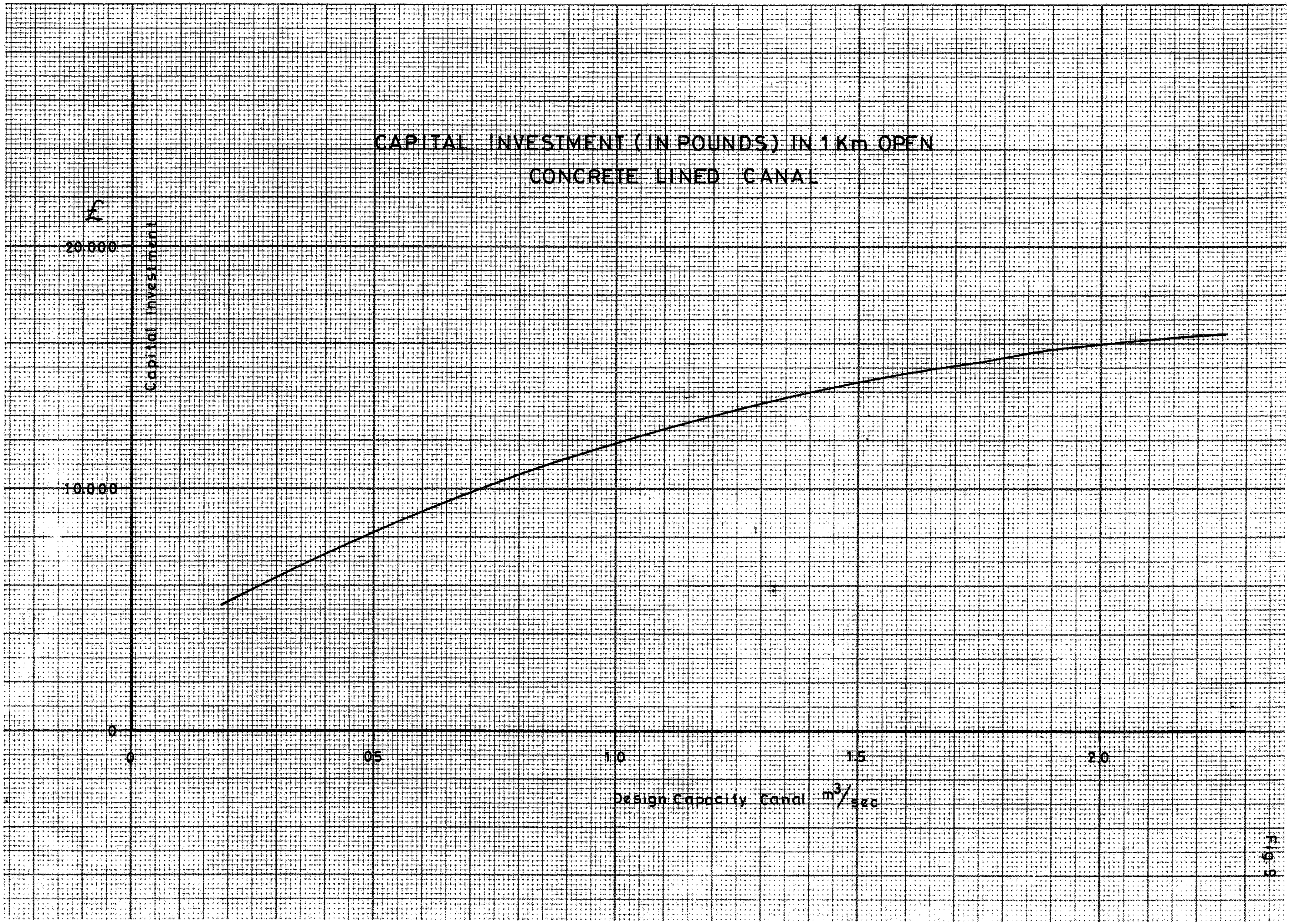
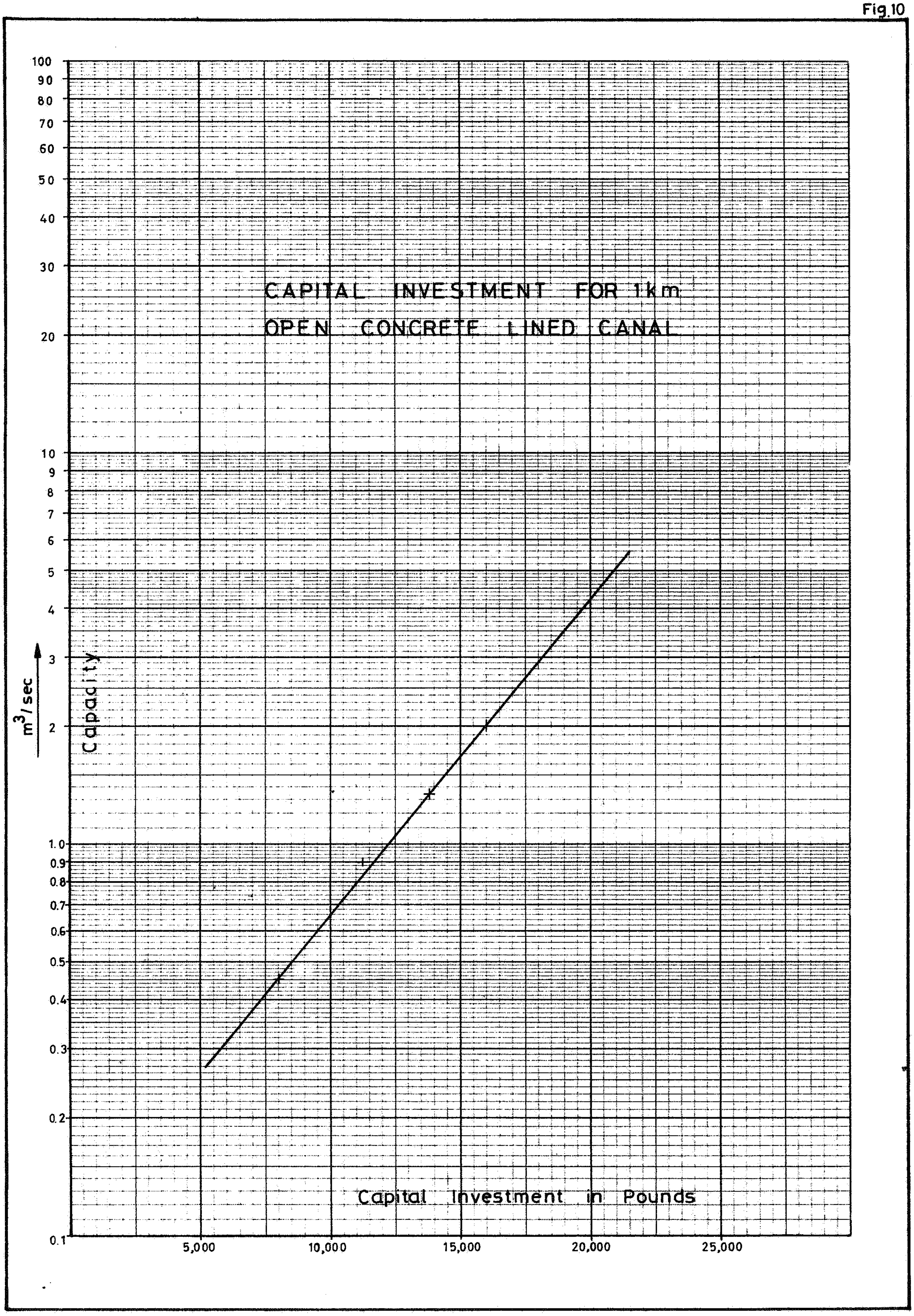


Fig. 9



CAPITAL INVESTMENT (IN POUNDS) IN 1 Km OPEN
CONCRETE LINED CANAL
£
20.000
10.000
0
Capital Investment
0
0.5
1.0
1.5
2.0
Design Capacity Canal m3/sec

Fig.10



CAPITAL INVESTMENT FOR 1 km
OPEN CONCRETE LINED CANAL
Capacity
m³/sec
Capital Investment in Pounds
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
5,000
10,000
15,000
20,000
25,000

This loss has to be added to the operation, maintenance and amortization costs, which total 8.34% of the capital investment.

Annual cost open canal :

The total annual cost is composed of two items as shown below :

Table 20 - Annual cost open canal

Q m^3/sec	0.45	0.90	1.35	1.80
Evaporation	17.600	22.500	26.500	30.000
Operation+maintenance+amortization 8.34%	126.400	179.400	216.800	246.300
Total annual cost £	144.000	201.900	243.300	276.300

These annual costs are represented in figure 8.

The total capital investments for 1 Km of open canal, under the conditions mentioned, can be found by divieion of the calculated costs by 190 Km.

The results are represented in figure 9 and 10.

3.3 Pipe line with gravity flow

From the Khalassa dam to the Avgorou delivery point, a head of 118.00 m is available for gravity flow.

The total length of the pipe line to a delivery point (WD 746, 760) is determined from the 1:25.000 maps and is about 100 km.

Available head per Km is 118/100 = 1.18 m/km. When we assume about 10% losses in valves etc., there is 1.06 m/Km left for gravity flow.

With this head AC-pipes of different diameter can handle the discharges as listed in table 21.

The total capital investment and the annual cost of the pipe line can be calculated by the use of table 6 and 9 and are shown in table 21.

Table 21 - Gravity pipe line (100 Km)

Internal ∅ mm	Discharge by gravity m^3/sec	Total Capital investment	Total O + M
500	0.17	949,200	68.000
600	0.26	1,257,700	90.000
700	0.41	1,661,100	119.000
800	0.57	2,171,300	155,000
900	0.75	2,681,500	192,000
1000	1.05	3,298,600	236.000
1100	1.35	3,974,700	284.000
1200	1.70	4,649,200	332.000
1300	2.05	5,291,800	378.000

This capital investments and annual costs are represented on figure 7 and 8 respectively.

3.4 Pipe line with pumping station(s)

It can be considered to decrease the diameter of the pipe line in order to save on the capital investment. To convey the same discharge through a smaller diameter pipe, a greater loss of head per Km is required. The most economical way to transport water through a pipe is shown in figure 4.

Total capital investments in the pipe line plus pumping stations are found by adding the costs of both items.

The costs of the pipe line are shown in table 21. The installation cost of a pumping station can be found from figure 3, while the correction for available head has been taken from figure 5.

Table 22 - Capital investment 100 Km pipe + pump

m^3/sec	Ø pipe mm	pumping station	pipe line	correction (minus)	Total capital investment
0.30	600	40.000	1.257.700	29.200	1.260.400
0.45	700	60.000	1.661.100	44.100	1.668.900
0.70	800	95.000	2.171.300	68.700	2.197.600
0.90	900	121.000	2.681.500	88.400	2.714.100
1.20	1000	161.000	3.298.600	117.800	3.341.800
1.35	1000	223.000	3.298.600	132.500	3.389.100
1.80	1100	310.000	3.974.700	176.700	4.108.000

These values are represented as a broken line in figure 7.

The annual costs of the pipe line plus pumping stations can be calculated with the help of figures 6 and 9.

Table 23 - Total annual cost pipe line + pumping stations

m^3/sec	Initial cost £	Correction for elevation (118 m)	Final annual cost
0.45	147.000	- 21.900	125.100
0.90	241.000	- 43.900	197.100
1.35	342.000	- 66.300	275.700
1.80	440.000	- 87.900	352.100

These costs are represented in figure 8.

3.5 Conclusions

As a result of these comparative calculations, the following conclusions can be drawn :

1. When the capacity of the conduit is less than 0.93-10% m^3/sec, a pipe line with a pumping station is the most economical solution.

2. When the capacity of the conduit is greater than 0.93 + 10% m^3/sec, an open concrete lined canal is advised.

3. In the area 0.93 ± 10% m^3/sec an open canal is advised to provide greater flexibility in operation and low sensibility to a change in the annual volume of water conveyed.

4. The quantity conveyed in MCM/A does not influence the annual cost of the gravity flow canal, while the annual energy consumption of the pumping station is linear with the quantity conveyed, and so is the cost.

   For town water supply an open canal is used whenever $Q_{annual} > 9 \times 10^6$ m^3.

5. Because of its flexibility, a pipe line with pumping stations is usualy preferable above a pipe with gravity flow.

3.6 Export of water from Khalassa or Yermasoyia reservoirs

If it were decided to convey large quantities of water from the Limassol region, a question would be raised; which reservoir should be used for export purposes?

The utilization of the Khalassa reservoir requires the construction of an additional 32 Km open canal (from Khalassa dam to the point where the diversion canal crosses the Yermasoyia river), but it allows, owing to the elevation of the dam outlet, a diversion by gravity up to the delivery point. (+)

+) An alternative solution with a 23 km pipe line and pumping stations was found to be more expensive when the annual volume of water diverted is 6.5 MCM annual (present yield of the Yermasoyia reservoir) and the peak discharge is 0.70 m^3/sec.

In addition it is necessary to construct a conveyor from the Yermasoyia reservoir to supply the lower section of the Kouris irrigation project, thus creating complicated problems of operation. This conveyor has an estimated length of 16 km and has to cross the town of Limassol if gravity flow is to be used. It should be noted that the crossing or by-passing of the Limassol town area is not an easy matter. On the other hand, the utilization of the Yermasoyia reservoir for export, implies additional annual cost for pumping water into the diversion canal at the point where the latter crosses the river, which is located 1.9 km downstream of Yermasoyia dam.

An economic comparison of both solutions has been made assuming two values of the annual quantity of water diverted to the Larnaca and Famagusta regions, namely 6.5 and 9.5 million cubic metres per year, which are the yields of the Yermasoyia reservoir before and after possible raising of the dam.

The conclusions of the comparative study are shown in table 24.

Table 24 - Diversion from Khalassa or Yermasoyia reservoirs

Conditions Yermasoyia dam	Before raising $6.5x10^6$ m^3/year		After raising $9.5x10^6$ m^3/year	
source of water to be diverted	Khalassa	Yermasoyia	Khalassa	Yermasoyia
Required capacity of diversion conduit m^3/sec	0.70	0.70	1.05	1.05
Type of conduit	canal	pipe+pump	canal	pipe+pump
Annual cost £	30.100	30.800	36.300	44.600
Capacity of 16 km pipe line in m^3/sec. from Yermasoyia to Limassol region	0.90		1.30	
Required pipe diameter ∅ mm if available head 1.10 m/km	1000		1100	

Table 24 - continued

Conditions Yermasoyia dam	Before raising $6.5x10^6$ m^3/year		After raising $9.5x10^6$ m^3/year	
source of water to be diverted	Khalassa	Yermasoyia	Khalassa	Yermasoyia
Annual cost pipe line in £	37.700		45.500	
Annual cost per combination £	67.800	30.800	81.800	44.600

It appears to be clear that diversion from the Yermasoyia reservoir is preferable to a diversion from the Khalassa reservoir combined with the local use of Yermasoyia water.

For the same reasons it is preferable to divert water from the Polemidhia reservoir instead of from the Khalassa reservoir. An additional advantage of exporting the water from the Yermasoyia reservoir is that as soon the water is in the main diversion canal it can serve the entire Larnaca region by sprinkler irrigation if required, while all water at the end of the 16 km supply pipe line has to be pumped (over 3 atm. minimum) to use it for this purpose.

4. SUPPLY CONVEYORS INTO THE MAIN CONVEYOR CONDUIT

4.1 Different sections of the main conduit

Whenever a reservoir is supplying water into the main conveyor canal or pipe line, the capacity of the conduit will change in accordance with the capacity of the feeder conveyor.

The sections in between this points have a constant capacity and the following lengths :

Table 25 - Section lengths in Km

Name of supply reservoir or outlet	Open canal	Pipe-line
Khalassa		
	18	14
Polemidhia		
	14	9
Yermasoyia		
	42	23.5
Kalavassos		
	11	5
Khirokitia) Lefkara) Psematismenos Dhipotamos)		
	43.5	27.5
Kiti night storage		
	63.5	32
Avgorou		

4.2 <u>Supply canals from the reservoirs into the main conveyor conduit</u>

Canals or pipe lines with or without pumping stations have to be constructed to supply water from the storage reservoirs at a certain rate.

The different conduits are described below :

Table 26 - Polemidhia conduit

Description	Agricultural use	Town water supply
Maximum water level in reservoir	137.75 m	
Minimum water level	110.40 m	
Average level (estimated)	124.00 m	
Blevation of main conduit	158.00 m	
Maximum head to be pumped	47.60 m	
Average lift (energy)	34.00 m	
Storage capacity reservoir	3.78 MCM	
Dependable yield "	2.5 MCM	

Table 26 - continued

Description	Agricultural use	Town water supply
Capacity of supply conduit	0.27 CM/S	0.08
Required capacity of pumping station $15 x Q x h_{max}$ KW	198	59
Capital investment unit pump plus building (see appendix I) £	19.200	9.400
Internal diameter pipe line; mm	500	400
Capital investment pipe line; £	4.700	2.200
Annual energy consumption, £	2.900	2.900

Table 27 - Yermasoyia conduit

Description	Agricultural use	
	Before raising	After raising
Maximum water level reservoir	85.50	
Minimum water level reservoir m	56.50	56.50
Dependable yield reservoir m^3	$6.5x10^6$	$9.5x10^6$
Elevation of main canal m	148.60	
Maximum lift m	92.10	
Average head to be pumped m	72.60	
Maximum required capacity of conveyor conduit CM/Sec	0.70	1.03
Initial capacity of pumping station : 15 x Q x h KW	970	
Extra pumping station to be installed after raising KW		456
Estimated cost pumping stations, £	49.400	23.400 (extra)
Internal diameter of pipe line if dam will be raised, mm	900	900
No raising planned, mm	800	-
Capital investment for 1.9 Km AC - pipe line ∅ 900 mm	51.000	
∅ 800 mm	41.000	
Annual energy consumption £	29.000	13.000 in addition

Table 27 - continued

Description		Town water supply	
		Before raising	After raising
Conveyor conduit capacity	m^3/sec	0.21	0.30
Capacities pumping stations	KW	290	plus 134
Capital investments	£	24.000	15.000
Investment pipe line : ∅ 500 mm for both cases		18.000	
Annual cost of energy		29.000	plus 13.000

Table 28 - Kalavassos conveyor

Description		Diversion of	
		Regulated flow	Winter spills
Supply level to main canal		124.00	124.00
Maximun water level		156.50	156.50
Conduit capacity required, m^3/sec		0.33	0.90
Internal diameter pipe line : mm		700	700
Loss of head in m/km		0.80	5.30
Maximum flow velocity m/sec		0.85	2.15
Estimated length of the pipe line :	Km	6	
Capital investment	£	99.700	
Extra cost energy dissipator		1.300	
Total capital investment	£	101.000	

Table 29 - Khirokitia conveyor

Description		Diversion of Regulated flow	Diversion of Winter spills
Main conduit water level	m	117.00	117.00
Maximum reservoir level	m		272.00
Minimum reservoir level	m	231.oo	
Available head over conduit	m	114.00	155.00
Required conveyor capacities	m^3/sec	0.27	0.44
Length of pipe line :	Km	7	7
Selected pipe diameter	Ø mm	400	400
Maximum flow velocity	m/sec		2.75
Capital investment pipe line		43.600	
" " energy dissipator		900	
Total capital investment		44.500	

Table 30 - Lefkara conduit

Description		Diversion of regulated flow
Dependable yield reservoir	m^3	$6.2x10^6$
Required capacity of conduit	m^3/sec	0.65
Estimated length of pipe line up to Dhipotamos damsite	Km	8
Minimum level at Lefkara	m	290.00
Delivery level at Dhipotamos	m	163.00
Available head	m	127.00
Selected pipe diameter	mm	500
Maximum velocity	m/sec	2.55
Capital investment pipe line	£	75.900
id. energy dissipator	£	1.100
Total capital investment	£	77.000

Table 31 - Dhipotamos conduit

Description		Diversion of regulated flow
Dependable yield of Lefkara and Dhipotamos reservoirs	m^3	$10.2x10^6$
Required conduit capacity	m^3/sec	1.10
Water level at main canal		112.00
Minimum supply level at reservoir		134.00
Available head over canal		22.00
Available head in m/Km		1.40
Estimated capital investment 14 Km canal	£	153.400

The capital investments and annual costs have been used in the computation of expenditures for each alternative.

4.3 Kiti night storage reservoir

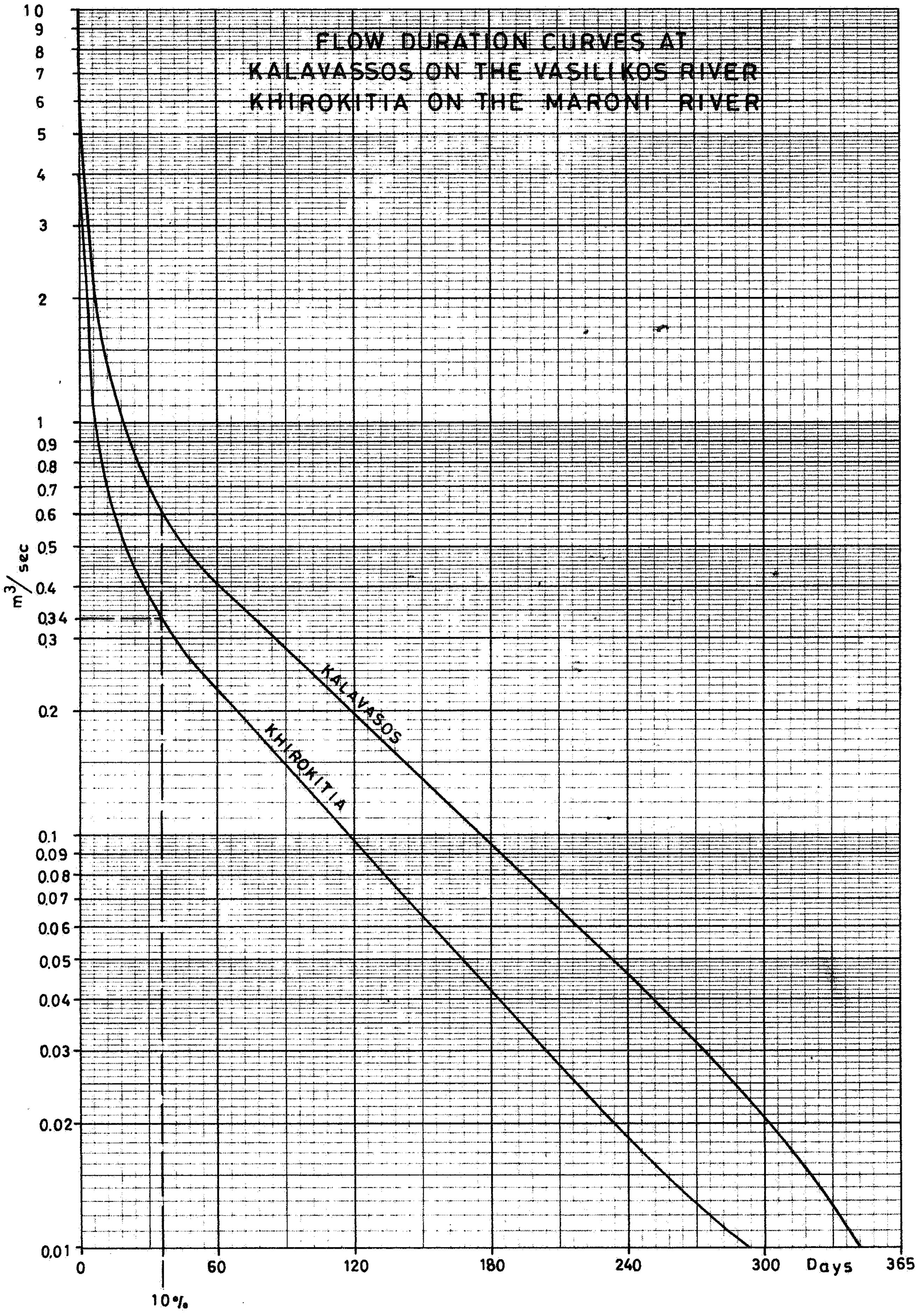
The main transport canal will operate 24 hours per day, while the farmers are supposed to irrigate for 16 hours per day. Water supplied during the other 8 hours (+ a 25%factor of safety) has to be stored in a night storage reservoir. The capacity of this reservoir has to be :

$$36000 \times Q_{sec.} \text{ supplied max.}$$

After some preliminary study, it has been assumed, the cost of the reservoir will be £1,5 per m^3 , of the required storage capacity.

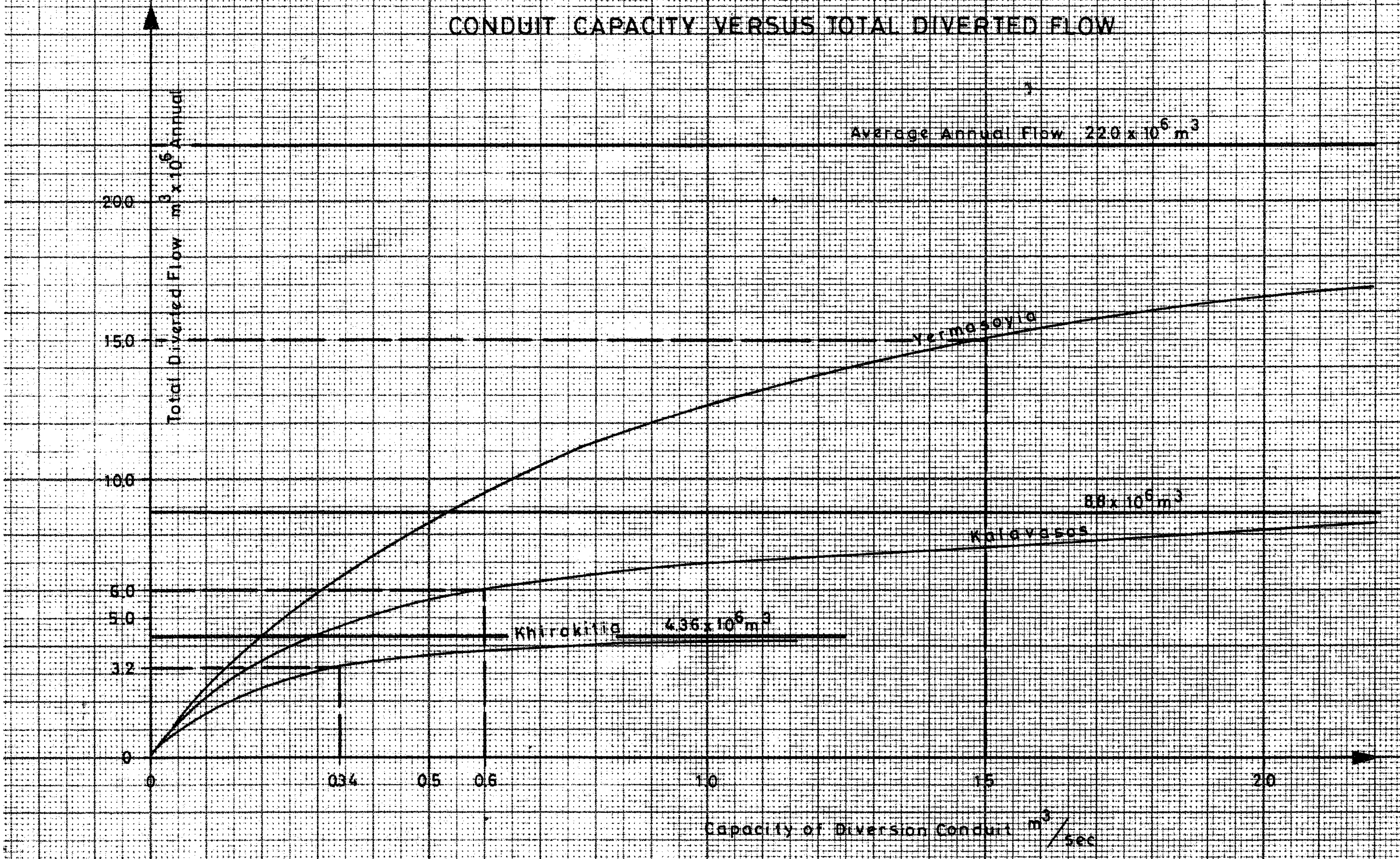
4.4 The diversion of winter flows

All storage dams in the area have carried over storage and can supply irrigation water over after a period of two consecutive years of severe drought. In more normal year, however, the inflow into the reservoir is often greater than the total storage capacity and more often greater than the volume needed to fill the reservoir.



FLOW DURATION CURVES AT
KALAVASSOS ON THE VASILIKOS RIVER
KHIROKITIA ON THE MARONI RIVER
m³/sec
10
9
8
7
6
5
4
3
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.34
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
60
120
180
240
300
Days
365
10%
KALAVASOS
KHIROKITIA

Fig. 12



CONDUIT CAPACITY VERSUS TOTAL DIVERTED FLOW
Average Annual Flow 22.0 x 10^6 m^3
8.8 x 10^6 m^3
4.36 x 10^6 m^3
Yermasoyia
Kalavasos
Khirakitia
Total Diverted Flow m^3 x 10^6 Annual
Capacity of Diversion Conduit m^3/sec
0
3.2
5.0
6.0
10.0
15.0
20.0
0.34
0.5
0.6
1.0
1.5
2.0

Whenever the reservoirs fill, water will be spilled and flow down to the sea, as waste unless measures are taken to use the spills.

In order to use the spillway flow of water, consideration should be given to diverting water from the reservoir in a good year when it fills or is expected to fill. The water can be supplied into the main conveyor canal and be used to recharge the overexploited aquifers in the Famagusta region.

The spills of the reservoirs will be used for different pusposes. Khalassa reservoir spills will be used to recharge the Limassol aquifer. Those from Polemidhia can be pumped into the canal via the proposed pipe line plus pumping station. Those from Yermasoyia which are considerable can either be diverted upstream of the reservoir and supplied by gravity into the main canal or the proposed pipe line and pumping station can be used to divert flows. The Kalavassos and Khirokitia spills can be diverted via the proposed pipe line which conveys the reservoir regulated flow, while the spills of the Lefkara reservoir are impounded in the proposed Dhipotamos dam.

Flow duration curves are available for Kalavassos on the Vasilikos river and Khirokitia on the Maroni river (figure 11). For the Yermasoyia river, no flow duration curve is available. In the upstream and most important area, however, the Vasilikos and Yermasoyia watersheds have a common boundary. For this reason it is assumed, the shape of the duration curve of the two rivers will be about the same. The average annual discharge on the Vasilikos and Yermasoyia rivers at the proposed damsites is 8.8 and 22.0 million m^3 respectively.

On the basis of the flow duration curves a set of curves have been drawn, giving the total average annual divertion flow versus the capacity in CM/S of the diversion canal. (See figure 12).

With the help of figures 11 and 12 a capacity of the conduit can be selected for the most economical diversion. This conduit capacity is the capacity which can handle a discharge that occurs during about 10% of the year on the average. The following volumes can be diverted when no storage reservoir is taken into consideration.

Table 32 - Diversion of winter flow

Name of dam	Yermasoyia	Kalavassos	Khirokitia
Storage capacity CM	$13.5x10^6$	$8.0x10^6$	$6.0x10^6$
Average annual runoff "	$22.0x10^6$	$8.8x10^6$	$4.36x10^6$
Dependable yield CM	$6.5x10^6$	$3.ox10^6$	$2.5x10^6$
Average annual spill " (including evaporation)	$15.5x10^6$	$5.8x10^6$	$1.9x10^6$
Capacity diversion conduit CM/Sec	1.5	0.60	0.34
Maximum annual average diverted flow CM	$15.0x10^6$	$6.0x10^6$	$3.2x10^6$

It is difficult ot forecast, which part of the flow will fill the storage reservoir and which part can be diverted afterwards. If we assume that 2/3 of the dependable yield is supplied by water that could be diverted, the actual diverted volume will be the maximum possible diverted volume less 2/3 of the dependable yield, being

	Yermasoyia	Kalavassos	Khirokitia
2/3 x dependable yield	$4.3x10^6$	$2.0x10^6$	$1.7x10^6$
estimated diverted flow	$10.7x10^6$	$4.0x10^6$	$1.5x10^6$

The total average annual yield from the winter diversion schemes totals to about $16x10^6$ m^3. (rough estimate only).

If these winter flows have to be diverted at the rates discussed above, in several of the alternative schemes canal sections have to be designed with a higher capacity than required for the regulated flow.

As indicated above, the capacity of the different canal sections have to be as follows:

Yermasoyia - Kalavassos	1.50 m^3/sec
Kalavassos - Psematismenos	2.10 "
Psematismenos - Avgorou	2.40 m^3/sec

In addition to this, the supply conveyors from the dams to the main canal have to be adopted to the diversion capacities as required.

As indicated in tables 28 and 29 the capacity of the pipe lines from the Kalavassos and Khirokitia reservoirs are adequate due to the extra available head on the pipe line, and because of the difference in water level in the reservoir.

For the diversion of winter flow from the Yermasoyia river, the question can be raised which solution is prefarable.

a) Utilize the proposed pumping station and pipe line as used for the diversion of the regulated flow. The head to be gained by pumping is less than for the regulated flow and thus the capacity of the system has increased :

Table 33 - Flood diversion Yermasoyia

Situation of the dam	Unraised	raised
Power in the proposed pumping station less 25% stand by; KW	970	1426
Head to be gained : m	65	62
Capacity of system KW = 15 x Q x h; m^3/sec	1.00	1.54

After raising of the Yermasoyia dam the capacity is sufficient. The O + M and annual costs have been charged against the regulated flow. In this case only the energy, used for winter spill diversion has to be paid for. This will cost about 2.2 mils per cubic metre.

b. A diversion dam can be build on the eastern tributary upstream of the reservoir. This tributary supplies about 90% of the average annual runoff. An open canal of about 13 km has to be constructed on relatively steep slopes. For this reason construction costs will be 10% higher than used previously. The total capital investment and annual cost of the system is estimated as follows :

Table 34 - Diversion dam on Yermasoyia

Description	Capital investment	Total annual cost
Open diversion canal 13 Km	196.000	16.300
Diversion dam, lump sum	35.000	3.000
Totals	231.000	19.300

The diversion canal has a capacity of 90% of the proposed capacity of the 1.50 CM/S canal required at the storage dam. For this reasons, not more than 90% of the estimated volume in table 32 can be expected to be diverted in an average year, amounting to 9.6×10^6 m^3.

The estimated cost per m^3 is 2.0 mils.

Summary and conclusion :

1. The cost per m^3 is slightly less when a diversion dam is used. However, 1.1×10^6 m^3 less can be diverted, which gives a considerable loss in benefit.

2. When the Yermasoyia reservoir is used for flood routing on the basis of probability calculations, the annual diverted winter flow can be increased considerably by the effective use of the pumping station.

3. No extra investment has to be made if the pumping station is used, while the diverted water is relatively free from sedements and more suitable for recharge purposes.

Diversion of winter flow via the proposed pumping station and pipe line is recommended.

For each of the 22 alternatives, as described previously, some modifications have to be made on the conveyor system in order to handle the winter spills at the discharge rates quoted already.

Capital investments, involved with the "over design" of certain canal sections are listed in table 35 for each alternative studied.

Table 35 - Capital investment on main canal for winter flow diversion in pounds.

Alternative	Pounds £
A I	1.064.000
A II	289.000
A III	125.000
A IV	24.000
A V	594.000
A VI	187.000
A VII	22.000
A VIII	289.000
A IX	35.000
A X	289.000
A XI	124.000
A XII	29.000
B I	1.700.000
B II	1.551.000
B III	589.000
B IV	326.000
B V	218.000
C I	241.000
C II	43.000
C III	134.000
C IV	299.000
C V	609.000

These costs might well influence the selection of a alternative

5. THE ALTERNATIVE SCHEMES

5.1 Description of the various alternatives in the Limassol region

The availability of water, in the Limassol region, before and after implementation of the Khalassa dam is shown on figure 13. On the same figure several curves have been plotted for comparison purposes, showing the increasing agricultural and non-agricultural water

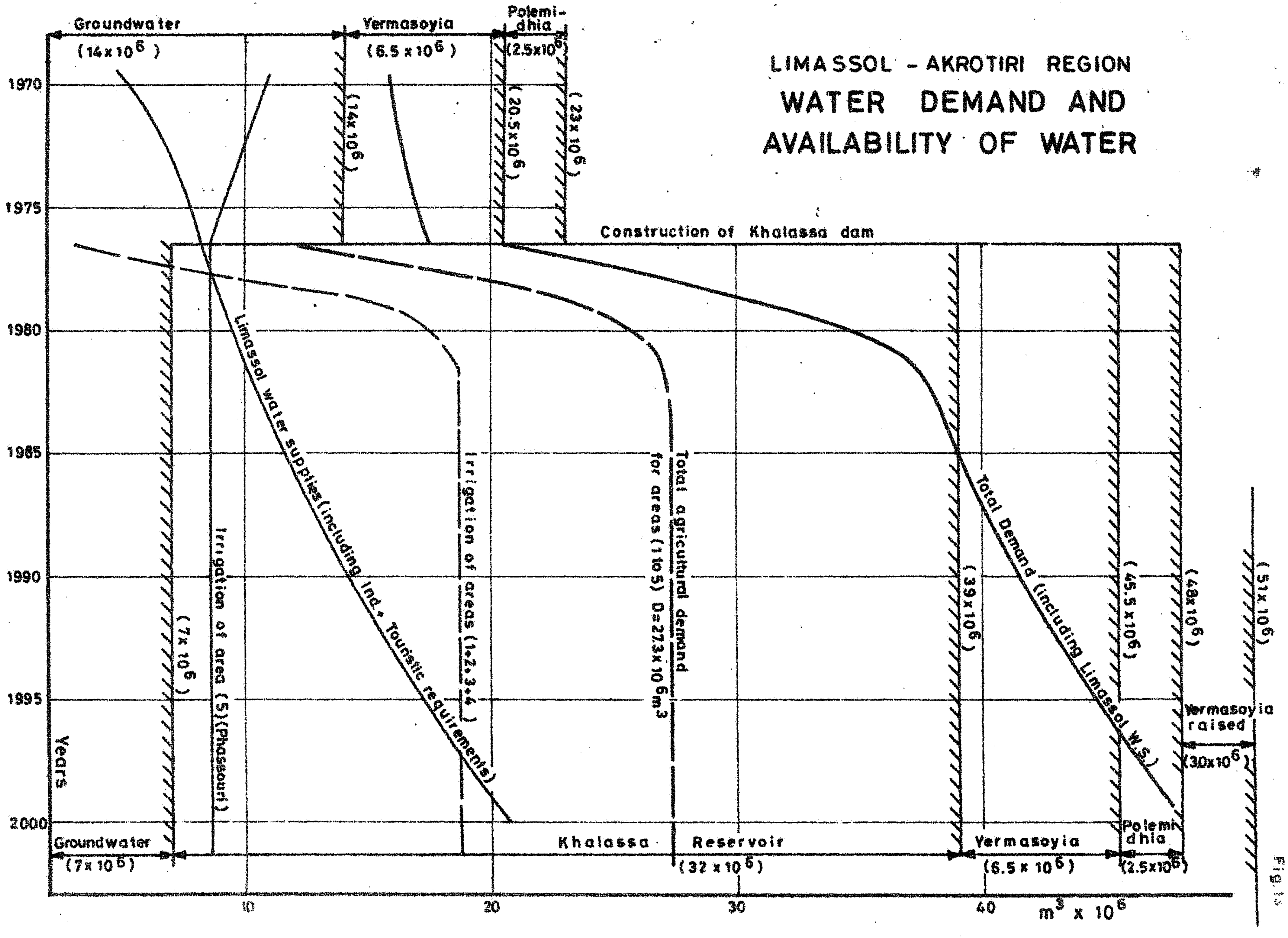

LIMASSOL - AKROTIRI REGION
WATER DEMAND AND
AVAILABILITY OF WATER
Groundwater
(14x10^6)
Yermasoyia
(6.5x10^6)
Polemi-dhia
(2.5x10^6)
(14x10^6)
(20.5x10^6)
(23x10^6)
Construction of Khalassa dam
Limassol water supplies (including Ind. + Touristic requirements)
Irrigation of areas (1+2+3+4)
Total agricultural demand
for areas (1 to 5) D=27.3x10^6 m^3
Total Demand (including Limassol W.S.)
Irrigation of area (5) (Phassouri)
(7x10^6)
(39x10^6)
(45.5x10^6)
(48x10^6)
(51x10^6)
Yermasoyia raised
(3.0x10^6)
Groundwater
(7x10^6)
Khalassa Reservoir
(32x10^6)
Yermasoyia
(6.5x10^6)
Polemidhia
(2.5x10^6)
Years
1970
1975
1980
1985
1990
1995
2000
10
20
30
40
m^3 x 10^6

Fig. 15

demands from 1970 up to the year 2000. The total water demands of the Limassol region can be met up to the end of the century provided improved water use methods are applied within are 5 and the salt lake is not reclaimed. An additional amount of 3 MCM/A could be made available by raising the Yermasoyia dam. These additional water resources may be diverted for use in the Larmaca and Famagusta regions.

Other ways of increasing the amount of water available for diversion is to construct a desalination plant to serve Limassol town water supply in the year 1985, (alternative A), or to reduce the irrigated area in the Limassol region and use the water saved in the Larnaca and /or Famagusta regions.

The following have been studied as distinct area's in the report on the Kouris Irrigation Project :

Table 36 - Sub-area's in Limassol region

Number of area and name	Net irrigable area in ha	Annual water demand MCM
Area :		
1 Episkopi	515	3.3
2 Kolossi	1014	6.5
3 Ypsonas	706	4.4
4 Polemidhia-Berengeria	836	4.5
5 Fassouri - Zakaki	1348	8.6
6 Salt lake	1989	9.7
Totals :	6407	37.0

The Limassol region has been studied for the following additional agricultural development :

Li 1 : All the areas 1 to 5 will be developed.

Li 2 : The areas 1,2,3 and 5 will be developed.

Li 3 : The areas 1,2 and 5 will be developed.

Li 4 : All areas 1 to 6 will be developed in future.

Li 5 : Only area 5 which is already developed will be supplied with water.

Furthermore distingtion has been made with regard to :

a. The year of construction of a desalination plant serving Limassol.

b. The development rate of the agricultural areas, between a rapid (6 years) and a slow rate (11 years).

c. The rate at which water will be sold at the dam for agricultural use, being 10 and 15 mils per CM.

d. The rate at which water is sold to Limassol town is kept constant at 35 mils per CM at the dam.

This results in the selection of the following combinations, wich have been studied :

Table 37 - Limassol combinations

Name of alternative	Desalination plant in	Development rate	Diverted water mils/m^3
Li 1 a	1985	rapid	10
b	1985	slow	10
c	1985	rapid	15
d	1985	slow	15
Li 2 a	1985	rapid	10
b	1985	slow	10
Li 3 a	1985	rapid	10
b	1985	slow	10
c	2000	rapid	10
Li 4 a	1985	slow	10
Li 5 a	2000	none	10

On the basis of the findings of a FAO/IBRD mission, which visited Cyprus in November 1969, a construction schedule was prepared for the construction of the Khalassa dam, Construction could start in 1974 and be completed by the end of 1976. The first year when water from the reservoir can be used will be 1977.

Region : Limassol
Project : Limassol-Larnaca-Famagusta Schemes
Alternative : Lila and C
Main assumptions : Rapid development rate.

Year of Project	Investments							Operation Maintenance, and Annual Costs							
	Yermasoyia and Polemidhia	Khalassa dam	Main canal	Pipe area 5	Distribution system	On farm equipment	Total investment		Yermasoyia Polemidhia	Kalavasos	Canal	Pipe 5	Distribution system	Farm equipment	Total O + M
0 1974	1850	790	75				2715		4.3	1.8	1.5				8
1		2160	175	115	235		2635		4.3	6.8	5.0	0.6	5.9		23
2		1600	150		344	88	2182		4.3	10.5	8	0.6	13.8	3.5	41
3					237	117	354		4.3	10.5	8	0.6	19.3	8.2	51
4					128	150	278		"	"	"	"	22.2	14.2	59
5						100	100		"	"	"	"	"	18.2	63
6 1980						33	33		"	"	"	"	"	19.5	64
7						22	22		"	"	"	"	"	20.4	65
8									"	"	"	"	"	20.4	65
9									"	"	"	"	"	"	"
10									"	"	"	"	"	"	"
11									"	"	"	"	"	"	"
12									"	"	"	"	"	"	"
13									"	"	"	"	"	"	"
14									"	"	"	"	"	"	"
15									"	"	"	"	"	"	"
16									"	"	"	"	"	"	"
17						88	88		"	"	"	"	"	"	"
18						117	117		"	"	"	"	"	"	"
19						150	150		"	"	"	"	"	"	"
20						100	100		"	"	"	"	"	"	"
21						33	33		"	"	"	"	"	"	"
22						22	22		"	"	"	"	"	"	"
23									"	"	"	"	"	"	"
24															
25															
26 2000															
27															
28															
29															
30															
31															
32						88	88								
33						117	117								
34						150	150								
35						100	100								
36						33	33								
37						22	22								
38															
39															
40															
41				115	235		350								
42					344		344								
43					237		237								
44					128		128								
45															
46															
47						88	88								
48						117	117								
49						150	150								

The inception year of the project (1974) will be called here after zero (O) year.

On the basis of the report on the "Kouris Irrigation Project", for each of the listed "Li" sub-alternatives, tables have been prepared giving the annual capital investments and operation plus maintence costs over a 50 - year period. As an example the sheet for the sub-alternatives Li 1 a and 1 c is produced as table 38. Sheets for the other sub-alternatives can be found in the filing system of the Water Development Department.

In respect of benefits areas 1 to 4 will receive an increase and area 6, if it is developed, full benefits. No benefits of area 5 have been included. However, a pipe line serving the area 5 has been included in the expenditure (£115.000 in year 1) while 1.6 MCM is supplied annually to releve the aquifer and prevent seawater intrusion.

The agricultural benefits have been calculated on the basis of the report on the Kouris irrigation project. The non-agricultural benefits have been calculated on the basis of the selling rates per cubic metre as discussed previously.

Tables with the annual agricultural and non agricultural benefits have been prepared for each alternative and can be found in the W.D.D. filing system.

These two sets of data were processed in into a computer, and gave the internal rate of return for each sub-alternative.

Furthermore, the total capital investments have been calculated for each scheme. From these values the annual costs were computed, assuming an interest rate of 7%, the total cost to be amortized over 40 years on the average. The operation, maintenance and energy costs have been calculated for each alternative, while a lump sum of £10.000 per year has been added for administration costs, extension and miscellanous services. Under these conditions the total annual costs have been calculated for each alternative.

On the other hand we know the annual amount of surface water developed and the following items have been calculated for each alternative :

a. Cost of water in mils per m^3. It should be noted that not the entire quantity developed is used in the region, and this accounts for the low figures.

b. Annual benefits due to the project when full production is reached (about 1997).

c. Benefit cost ratio.

All the figures mentioned are given in table 39.

Table 39 - Limassol alternatives

Alternative	Total capital investment	Total annual cost	Surface water developed $10^6 m^3$	Cost of water mils/m^3	Annual benefits due to Project	Benefit/cost ratio	Internal rate of return %
Li 1a	8319	700	41	17	3222	4.6	13.6
1b	8310	700	41	17	3221	4.6	12.6
1c	8319	700	41	17	3322	4.6	14.1
1d	8310	700	41	17	3321	4.6	13.1
Li 2a	7899	655	41	16	2626	4.0	12.6
2b	7890	655	41	16	2626	4.0	12.1
Li 3a	7514	620	41	15	1919	3.1	11.4
3b	7566	630	41	15	1919	3.1	10.9
3c	7514	620	41	15	2449	4.0	12.4
Li 4b	10562	900	41	22	4016	4.6	12.6
Li 5a	6514	515	41	12.6*	393	0.76	not calculated

On the basis of these findings, some conclusions can be drawn, bearing in mind, the computer calculated the internal rates of return with a 0.25 percent interval only.

---

* This is the cost of a cubic metre of water at the dam. Depending on the quantity used in the region the cost per m^3 varies.

Conclusions Limassol region :

1. The rapid rate of development, gives an better internal rate of return (about 1%).

2. From the Li 3 alternatives it might be concluded, it is more economical to construct a desalination plant in the year 2000, i.e. to sell the water at 35 mils /CM is better than to use it for agriculture in the Limassol region.

3. The selling price of 15 mils /CM for water diverted for agricultural gives a 1% increase compared to selling at 10 mils/CM. It should be noted, the direct cost of the water at the dam is 12.6 mils/CM on the average. (see section 2.7)

4. Bearing in mind that the exported water is sold at 10 mils/CM the influence of a decrease in agricultural use in the Limassol area is not significant. In other words it may very well be that it would be possible to make better use of the water in the Larnaca and/or Famagusta regions.

5. Comparison between Li 1b and Li 4a shows no reasonable increase of benefits by cultivating the Salt Lake (area 6). This is particularly so because in this area all benefits are due entirely to the project, while in other areas only the increase of benefits is charged.
Furthermore, reclamation of the Salt Lake necessitates the construction of a desalination plant in 1985, while conclusion 2 shows this is not economical. It is advisable to abandon the idea of reclaiming the Salt Lake.

The tables for expenditure and benefits for the Li sub-alternatives are used here after, in the calculation of internal rates of return of the complete Limassol-Larnaca-Famagusta schemes.

5.2 The Famagusta region

In S.B. Mesaoria the ground water extraction exceeds replenishment by about 100%. Of the total volume of water extracted about 99% is supplied by the "sand aquifer", which has been divided by the Groundwater and Mineral Resources Project into 4 hydrological basins : (see map).

Basin 1 : Stretches along the east coast, from Famagusta to Cape Greco. The northern section (1 N) is heavity exploited, and this has created a deep depression and has caused pollution of the aquifer by sea intrusion. Section 1S, to the south of Paramali, is a shallow coastal aquifer, with a steep hydraulic gradient which is unsuitable for groundwater management.

Basin 2 : Includes chiefly the villages of Phrenaros, Liopetri and Xylotymbou.

Basin 3 : Lies to the north of basin 2 and includes the villages of Avgorou, Akhna and Makrasika.

Basin 4 : Stretches along the south coast between Dhekelia and Ayia Napa.

This last basin has similar characteristics to those of 1 S and for this reason the hydrologists do not recommend any additional recharge works. Also from an economical point of view the supply of water to area 4 is not recommanded as mainly potatoes are grown, with relatively low benefits. The latter can be seen in table 41 which follows.

However, the basins 2 and 3 have favourable possibilities for recharging. The recharging of basin 1 N, would make it possible to arrest sea intrusion and save this potentially rich citrus area.

The following table summarizes for each basin :

a. The annual extraction in, MCM

b. The annual overdraft in, MCM

c. The year when it is expected the aquifer will be exhausted from a practical point of view. These figures have been provided by the hydrogeologist of the Water Development Department.

d. Percentage of the area, that can be irrigated with the dependable yield of the aquifer :

Table 40 - Famagusta hydrological basins

Basin	Annual extraction	Annual overdraft	year of exhaustion	Safe area
1 N	7.4	- 3.6	1980	48.6
1 S	5.9	- 3.05	1972	51.7
2	13.0	- 9.3	1985	28.5
3	12.0	- 7.5	1977	62.5
4	7.5	- 2.5	1980	33.3

In order to prevent damages in the areas, which are irrigated from the aquifer, it will be necessary to supply water from the neighbouring regions of Larnaca and Limassol.

A study will be made of the economical effects of the conveyance of water to these basins with respect of the basins net benefits due to the project.

A special report has been prepared on the cost of the distribution system, serving the various basins, or a combination of basins. In this study seven alternatives have been used, providing the water requirement to replace the deficits in the present basins or combination of basins.

The benefits due to the project depend on the relation between the annual overdraft and extraction of the basin. This gives the percentage of the area, which can be irrigated at present with the dependable yield of the aq and the percentage of irrigated land that has to be abandoned and used later for dry farming.

This reduction of irrigated lands and introduction of dry farming gives a loss of benefit. However, when water is imported in order to maintain the present situation, this loss will not occur and the "saving" of this loss is introduced as a future benefit due to the project.

In this study seven different quantities of water are supplied to the Famagusta region. For each case a different combination of basins can be supplied with water. Capital investments in the region and the maximum agricultural benefits are summarized below.

Table 41 - Distinction Between the "Fa" Alternatives

Alternative	Deficit to be replaced M.C.M	Basins served	Area in ha	Main pipe line	Distrib. system	Pumping Stations	Farm equipment	Total Capital investment £x1000	Maximum benefits due to Project £x1000
Fa 1	3.5	1 N	1859	414	256	100	149	919	831
Fa 2	9.6	2+4	7362	1258	1013	307	589	3167	2271
Fa 3	10.7	1N+2	8072	1294	1201	332	646	3373	2937
Fa 4	13.1	1N+2+4	9221	1536	1269	379	738	3915	3102
Fa 5	14.4	2+3	8615	1310	1185	351	689	3535	2884
Fa 6	16.8	2+3+4	9764	1604	1344	399	781	4118	3049
Fa 7	20.4	1N+2+3+4	11623	1882	1599	454	930	4865	3880

Construction of the distribution system and main conveyor will start in the year 1976 (year 2), in order to start the utilization of water in 1977. It has been assumed, capital investment will not exceed £500,000 per year.

On the basis of these assumptions and table 41, seven tables have been prepared giving the annual total capital investment, operation plus maintenance and energy costs over a 50 year period. These tables have been filed with the Project.

Based on the assumed maximum annual investment of £500.000 in the Famagusta region, schedules of construction have been prepared for the main conveyor, distribution system etc.

Due to the overdraft of each basin, the aquifer will reach exhaustion in a certain period. During this period, the cropping pattern has to be adopted to the new conditions; of reduction of irrigated land and the introduction of dry farming. It has been assumed the agricultural benefits of each basin will decrease Lineairly to a minumum in the years listed in table 40.

This decrease in benefits will cease as soon as water is supplied to the basin. It is assumed this will be one year after construction is started on the main conveyor to the basin concerned. Furthermore, it is assumed agricultural benefits will return to their present value two years after completion of the entire irrigation system for the basin. This assumption is correct only if the different citrus plantations will be preserved during the interim period.

The increase of benefits after water is supplied to each basin can be calculated onthe base of the schedule of construction for each alternative. (see figure 14).

Benefits for each alternative have been calculated on an annual basis for a 50 year period. Tables have been prepared showing these benefits, and have been filed with the Project.

The two sets of tables for the Famagusta alternatives (expenditure and benefits) have been used in the calculation of the internal rate of return, cost/benefit ratio etc. for the complete Limassol-Larnaca-Famagusta Schemes.

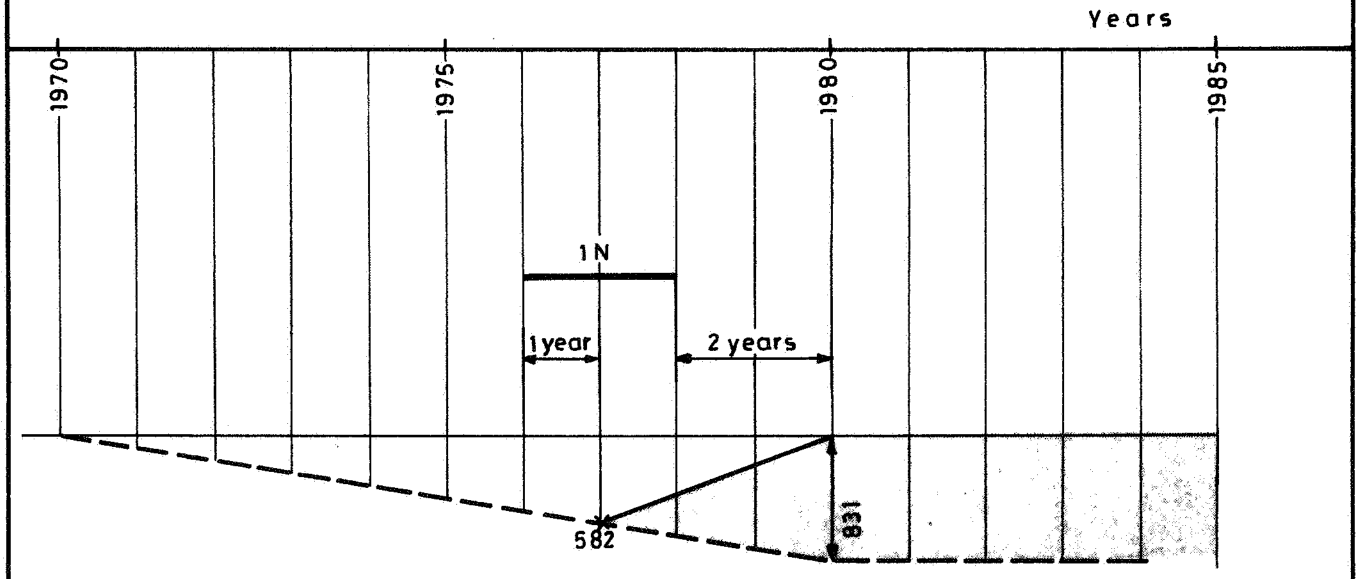
Fig. 14

SOUTH EASTERN MESAORIA

Alternative Fa 1

(Basin 1N)

Construction schedules and benefits derived from the project per alternative



Reduction of agricultural benefits due to the overdraft of basin

Recovering of benefits starting 1 year after begin of construction

Benefits due to project, reaching a maximum two years after completion of the project

Benefits in thousands of pounds

Fig. 14 (Continued)

SOUTH EASTERN MESAORIA

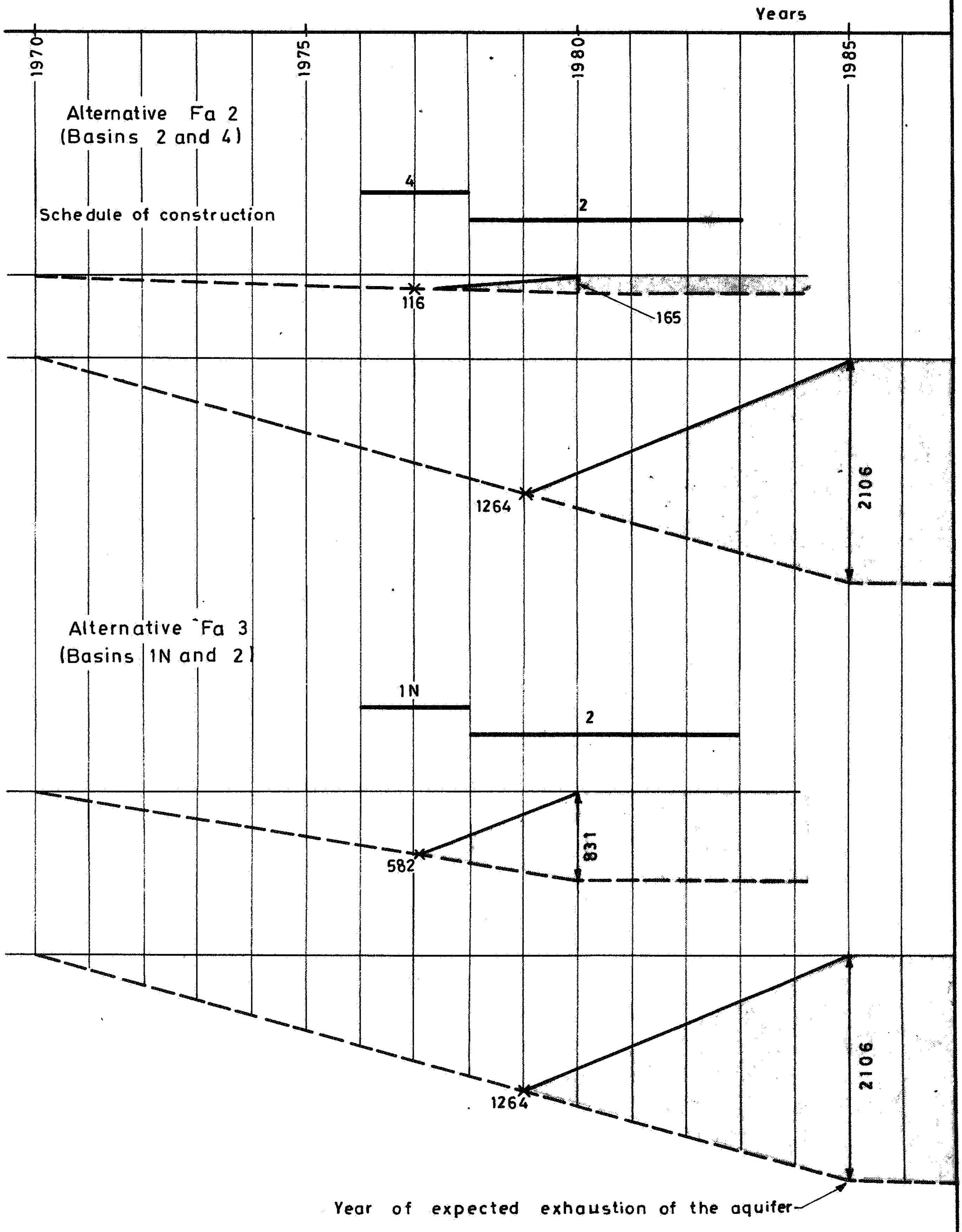
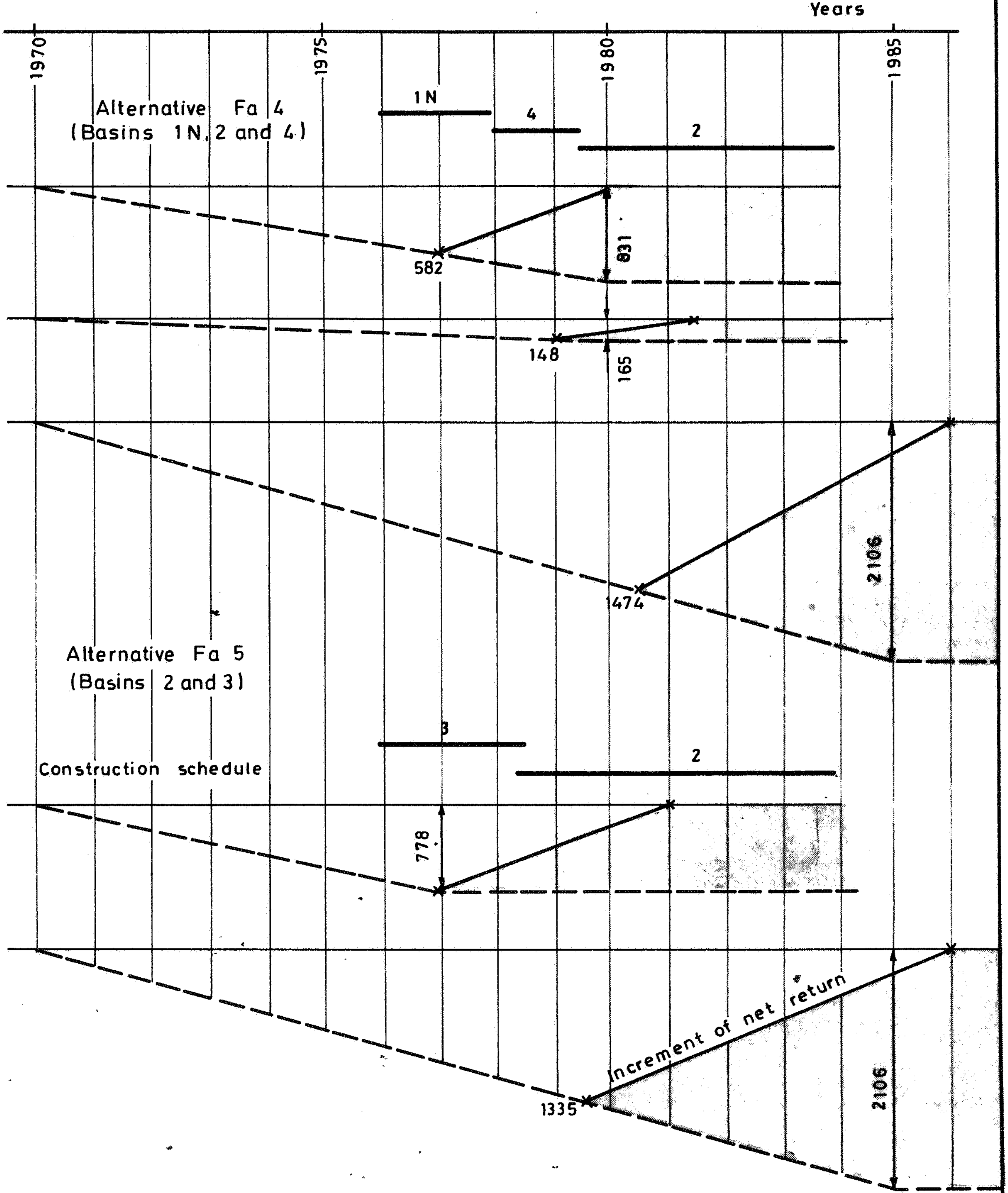


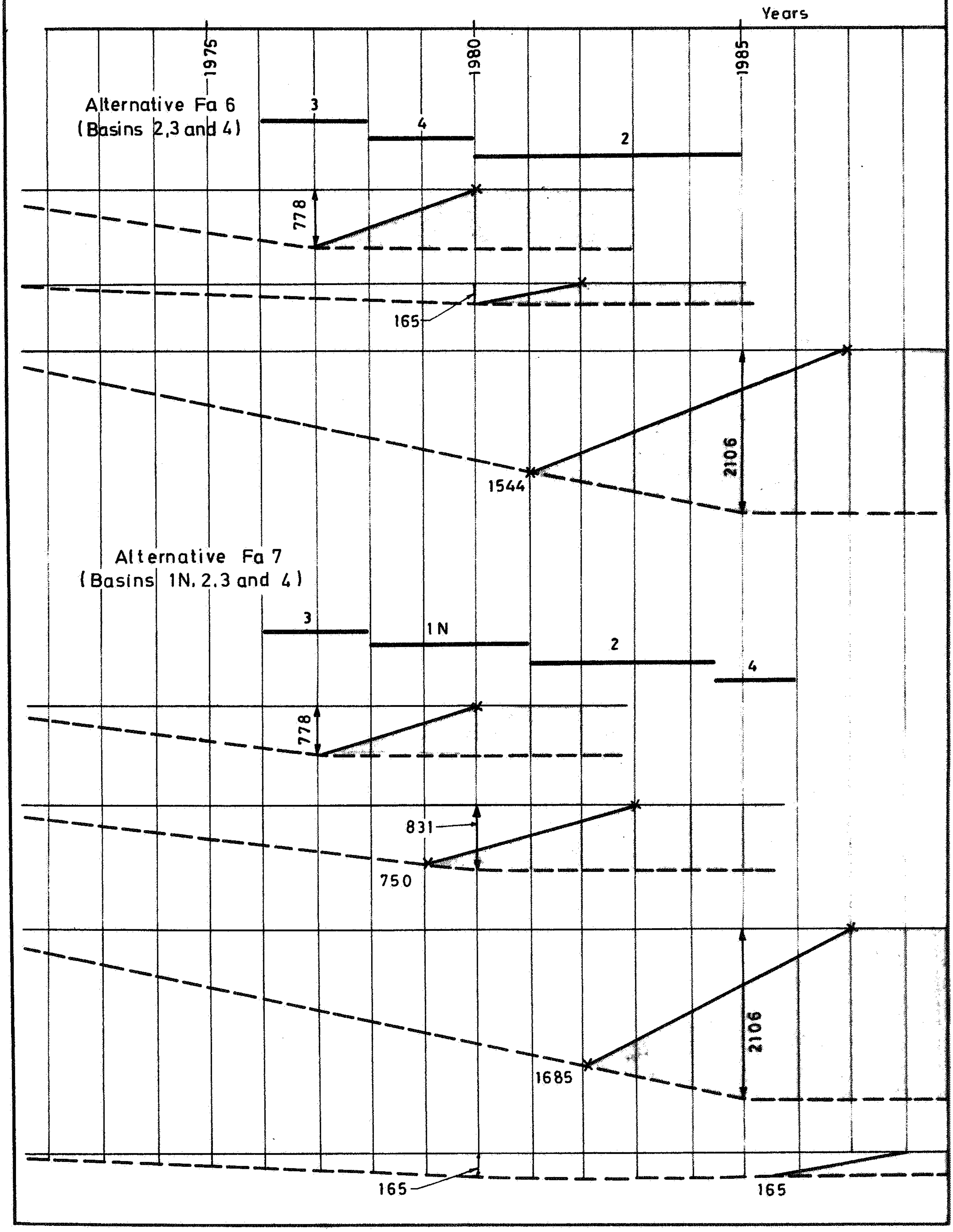
Fig. 14
(Continued)

SOUTH EASTERN MESAORIA



SOUTH EASTERN MESAORIA

Fig. 14 (Continued)



5.3 Description of the Larnaca alternatives, and their relationship to the Limassol and Famagusta sub-alternatives.

In the Larnaca region,two agricultural area's exist with very good soil conditions, but little surface water available for irrigation.

In both large area's of relatively flat lands have been selected, as being very suitable for irrigation.

Of these area's the Vasilikos - Pendaskinos area is located nearest to the main rivers, so the conveyance of water to this area is relatively cheap compared to the conveyance cost of the Kiti - Perivolia area. The benefits on the other hand are expected to be the same. In this study the water supply to the Vasilikos - Pendaskinos area is kept more or less constant, while the main variations have been made in the water supply to the Kiti - Perivolia area.

A short description of each area is given below :

Vasilikos - Pendaskinos area :

By selecting exclusively lands of categories I and II, a net irrigable area of 1820 ha is available. All this lands are situated in the coastal plain below the main transport canal. Based on the established cropping pattern, the annual demand is 10.8×10^6 m^3, with its peak demand in August (20.3%).

Kiti - Perivolia area :

Also by selecting exclusively lands of categories I and II, a net irrigable area of 5340 ha is available This lands have a relatively flat slope and are mainly situated below the 60.00 m contour line. The annual demand for the entire area is established at 32.0×10^6 m^3, of which 5.0×10^6 m^3 can be met by local resources (mainly ground water).

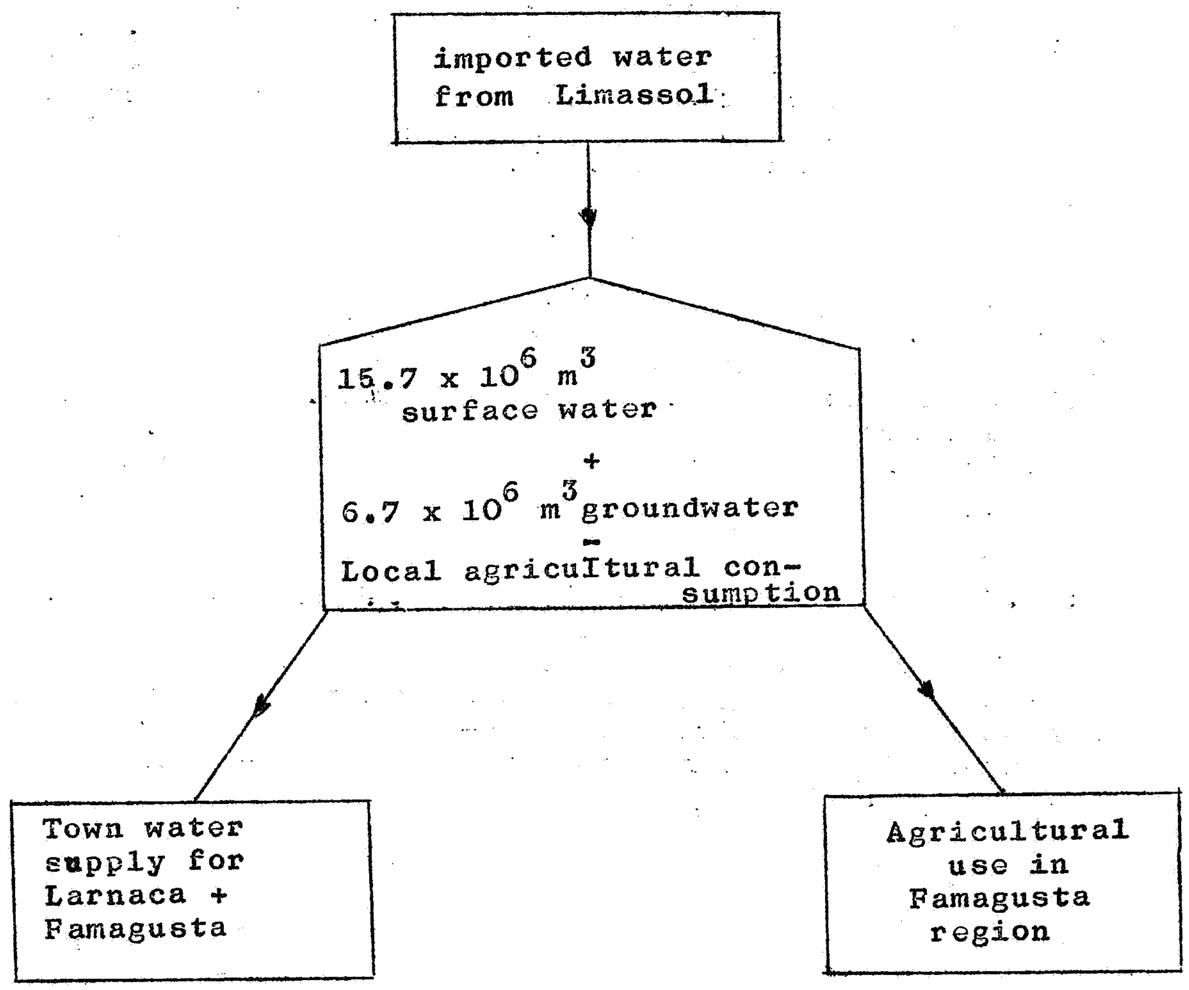
The location of each area is indicated on the 1:50.000 scale map, which is attached to this report.

The Larnaca alternatives are related to the Limassol sub-alternatives by the volume of water imported from this region and to the Famagusta sub-alternatives by the volume of diverted water for agricultural and non-agricultural consumption.

Under the assumption that the dams recommanded will be constructed, the available surface water resourses will total 15.7 MCM/A. Further local resourses are : 1.7 MCM/A groundwater from the Vasilikos-Pendaskinos area and 5.0 from the Kiti - Perivolia aquifer including the Kiti reservoir.

These annual yields plus the imported water (Li sub-alternatives) give one group of alternatives, for the Larnaca region.

On the other hand variations can be made in the supply of water to the combined Vasilikos - Pendaskinos and Kiti - Perivolia areas, the diversion of water to Famagusta region for agricultural use (Fa sub-alternatives) and the water consumption by Larnaca and Famagusta towns, as shown on the diagrammatic plan figure 15.



By variation of the three blocks around this circle 22 alternatives for the Larnaca region have been selected as noted in tables 1 to 3.

For the "A" alternatives, there is no town water supply demand, because a desalination plant will be constructed. Local agricultural water consumption in the Vasilikos - Pendaskinos region is about constant (9.1 to 10.8 MCM), while for each Li sub-alternative, different "Fa" sub-alternatives are used at the expence of the agricultural development in the Kiti - Perivolia area.

Three of the alternatives (AI, AV and AVIII) do not depend or include the raising of the Yermasoyia dam.

In group "B" the following two of the alternatives have been deleted for further study.

BI Area 3 in the Limassol region receives part of the required annual water supply, which complicates the calculations of agricultural benefits.

BIII The areas 1 and 2 have traditionally the same water rights. It is not realistic to supply area 1 with more water while depriving area 2 of its water resourses.

This group of alternatives has been studied to see the effect of the construction of desalination plants.

The same can be said about the "C" alternatives. Furthermore the effect of the utilization of water in the Larnaca or Famagusta region can be studied as this is the only variation over the alternatives CII through CV.

5.4 Water demand and water availability

Demand :

The water consumption for non-agricultural purposes, by the Larnaca and Famagusta towns has been estimated up to the year 2000 by the project staff. This anticipated consumption is shown in figure 16. The agronomy project staff has provided some development rates for the Vasilikos - Pendaskinos and Kiti - Perivolia areas. Using this data, curves can be drawn for the water demand of each alternative. (Figure 16 to 23).

WATER DEMAND AND AVAILABILITY

Alternatives A I to A IV

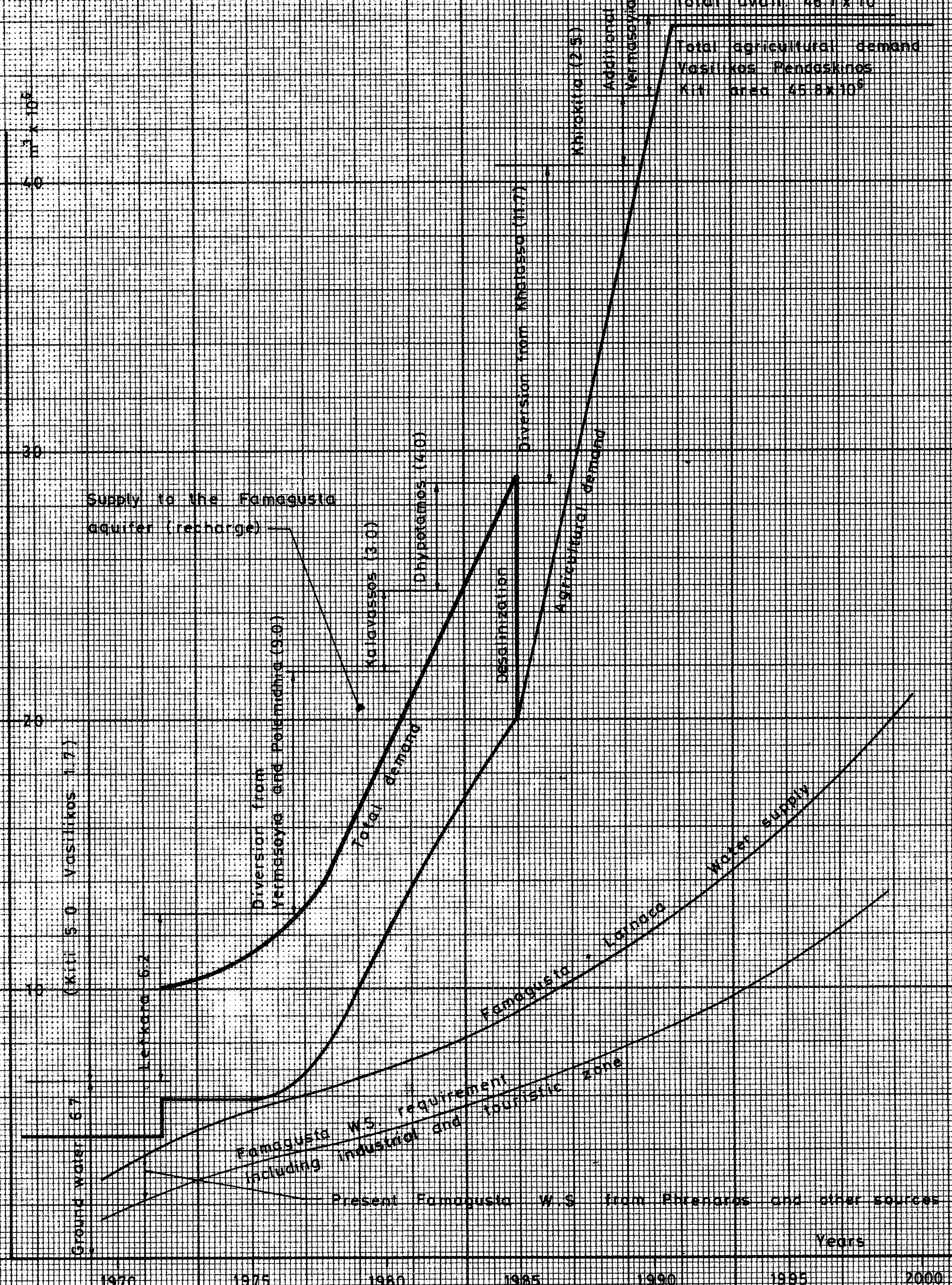


Fig. 17

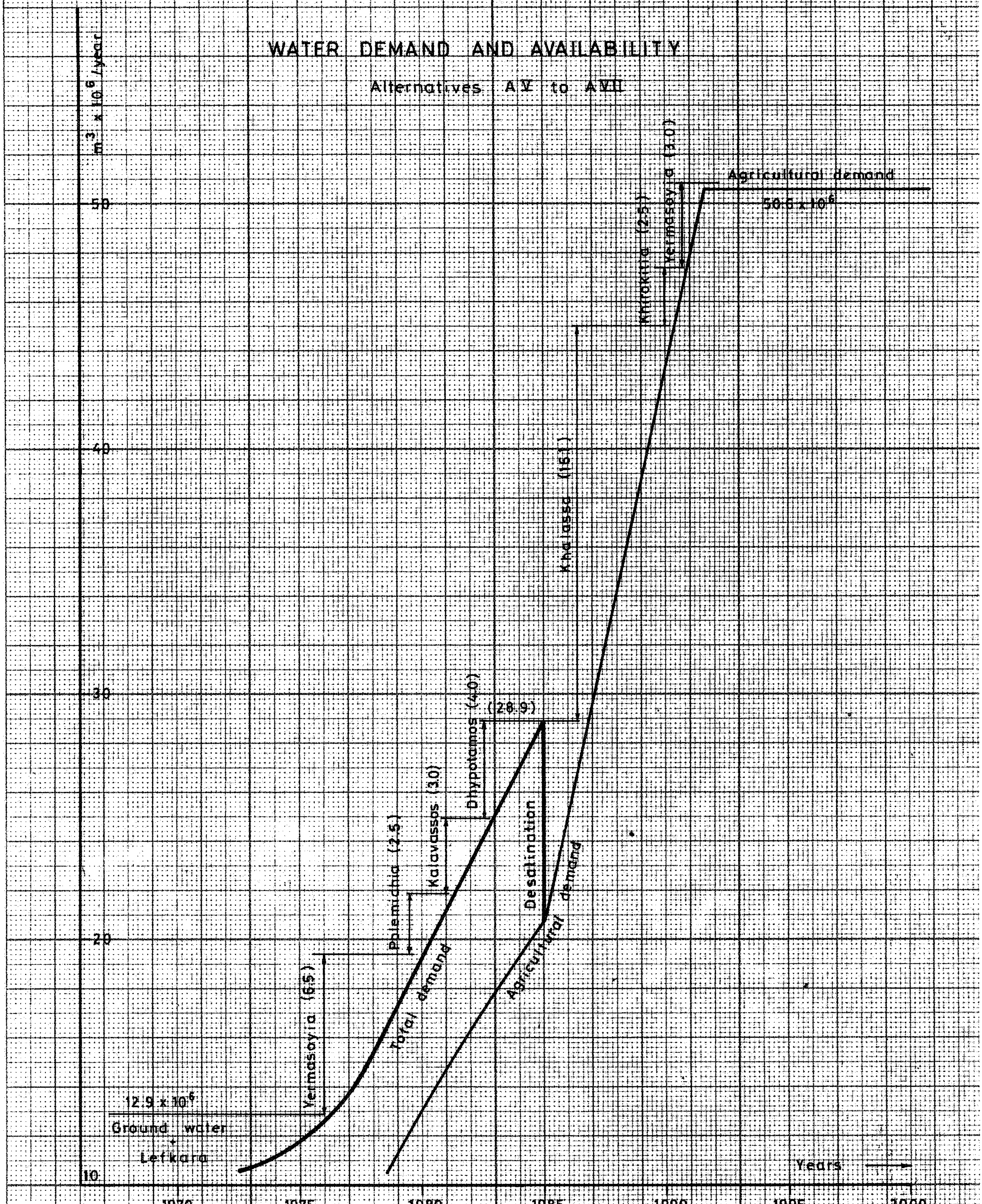
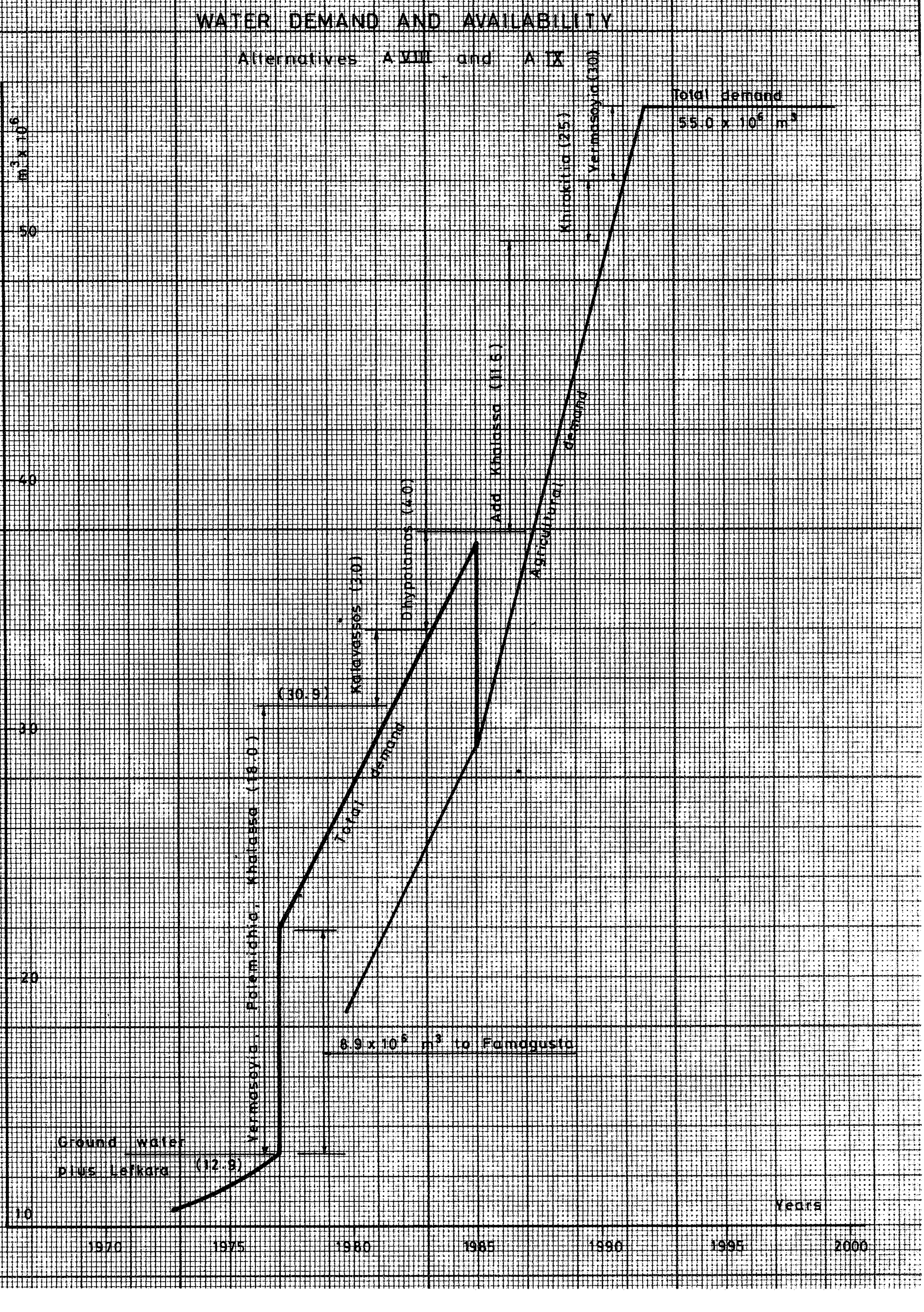

WATER DEMAND AND AVAILABILITY
Alternatives A V to A VII
m³ x 10⁶ /year
Agricultural demand
50.6 x 10⁶
Yermasoyia (3.0)
Khirokitia (2.5)
Khalassa (15.1)
(28.9)
Dhypotamos (4.0)
Kalavassos (3.0)
Polemidhia (2.5)
Desalination
Agricultural demand
Total demand
Yermasoyia (6.5)
12.9 x 10⁶
Ground water + Lefkara
Years
10
20
30
40
50
1970
1975
1980
1985
1990
1995
2000

Fig. 18



WATER DEMAND AND AVAILABILITY
Alternatives A VIII and A IX
m3 x 10^6
50
40
30
20
10
1970
1975
1980
1985
1990
1995
2000
Years
Total demand
55.0 x 10^6 m^3
Vermasoyia (30)
Khirokitia (25)
Add. Khalassa (11.6)
Dhypotamos (4.0)
Kalavassos (2.0)
(30.9)
Vermasoyia, Polemidhia, Khalassa (18.0)
Total demand
Agricultural demand
8.9 x 10^6 m^3 to Famagusta
Ground water
plus Lefkara
(12.9)

WATER DEMAND AND AVAILABILITY

Alternatives A X to A XII

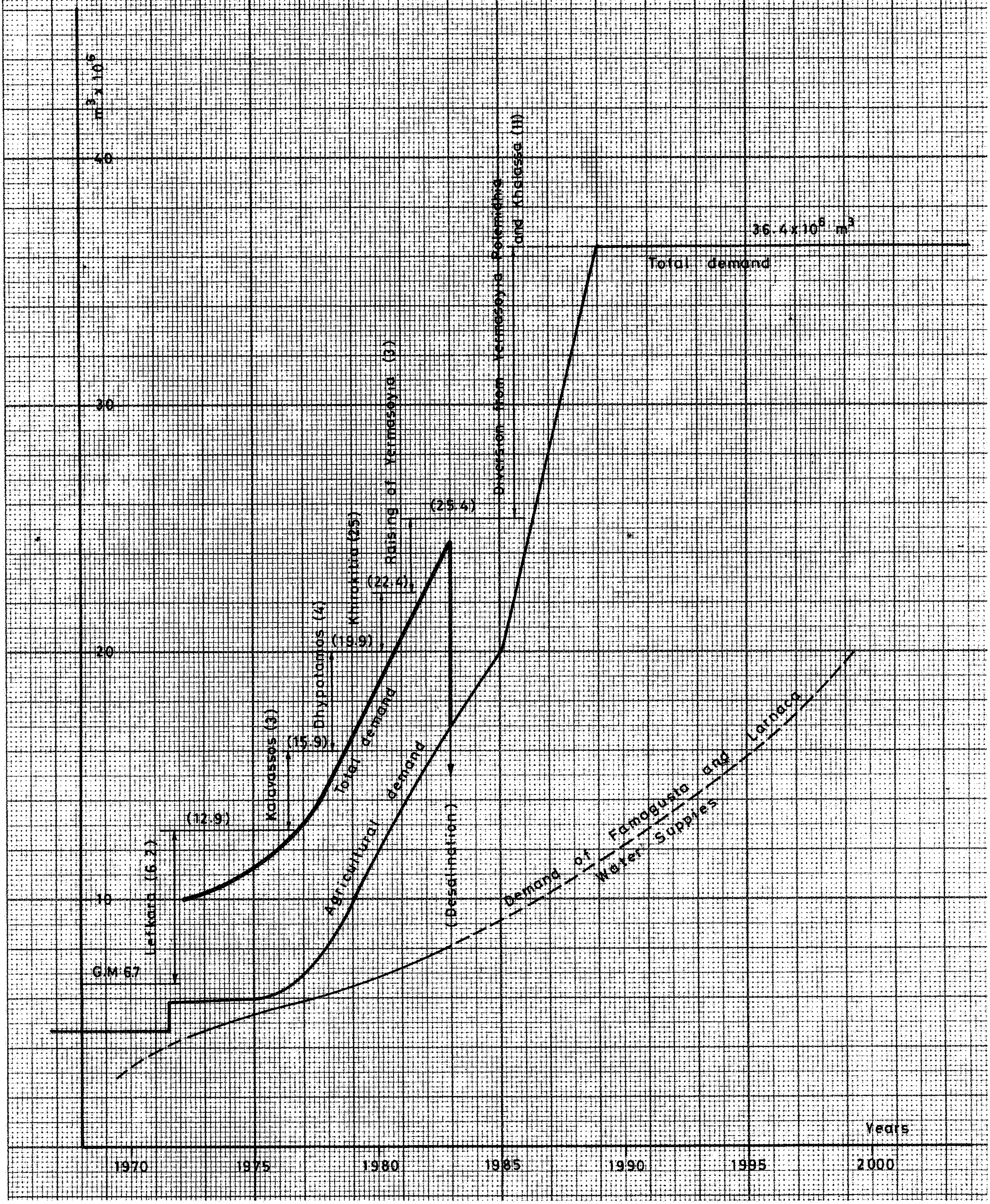


Fig. 20

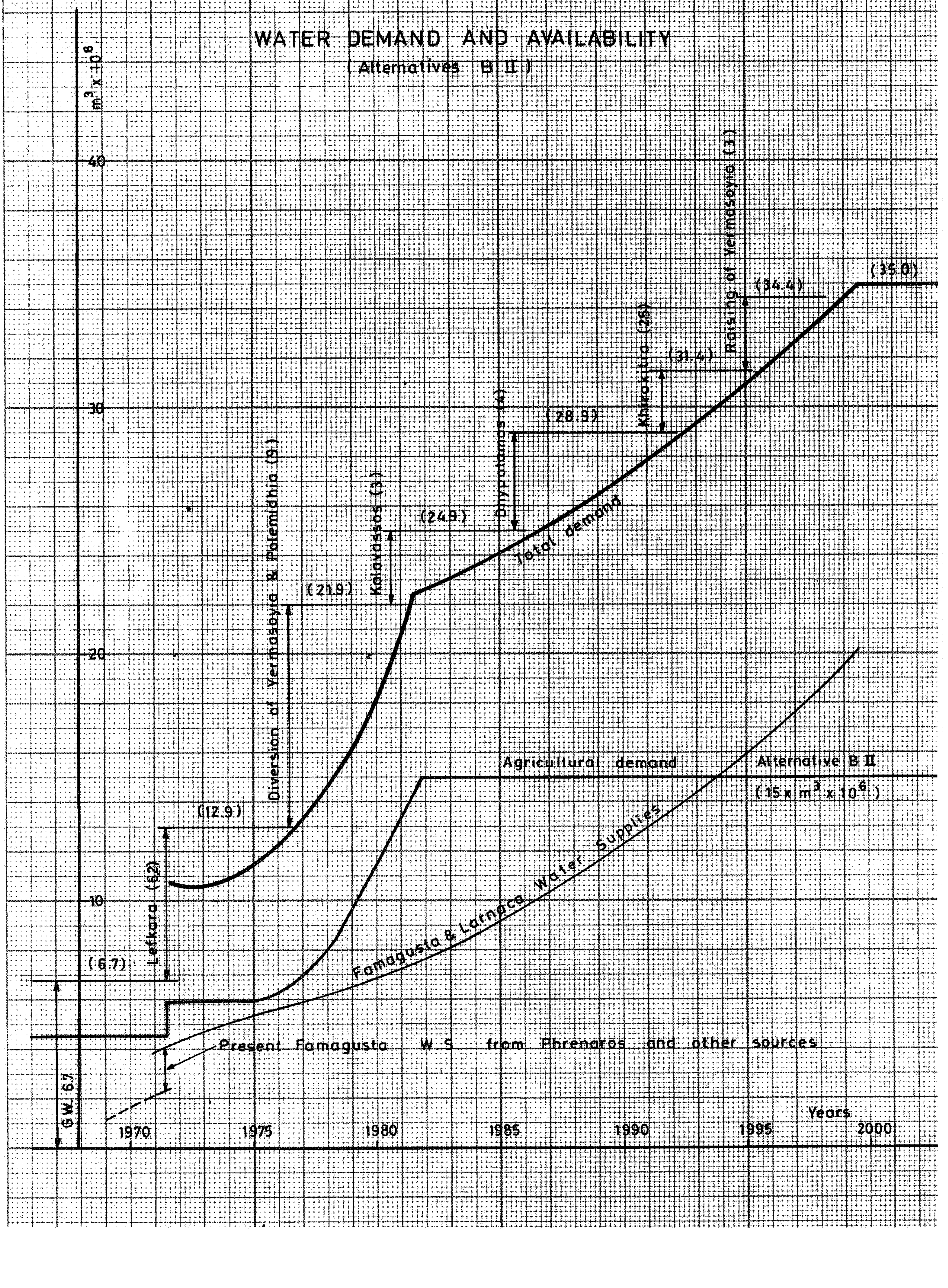
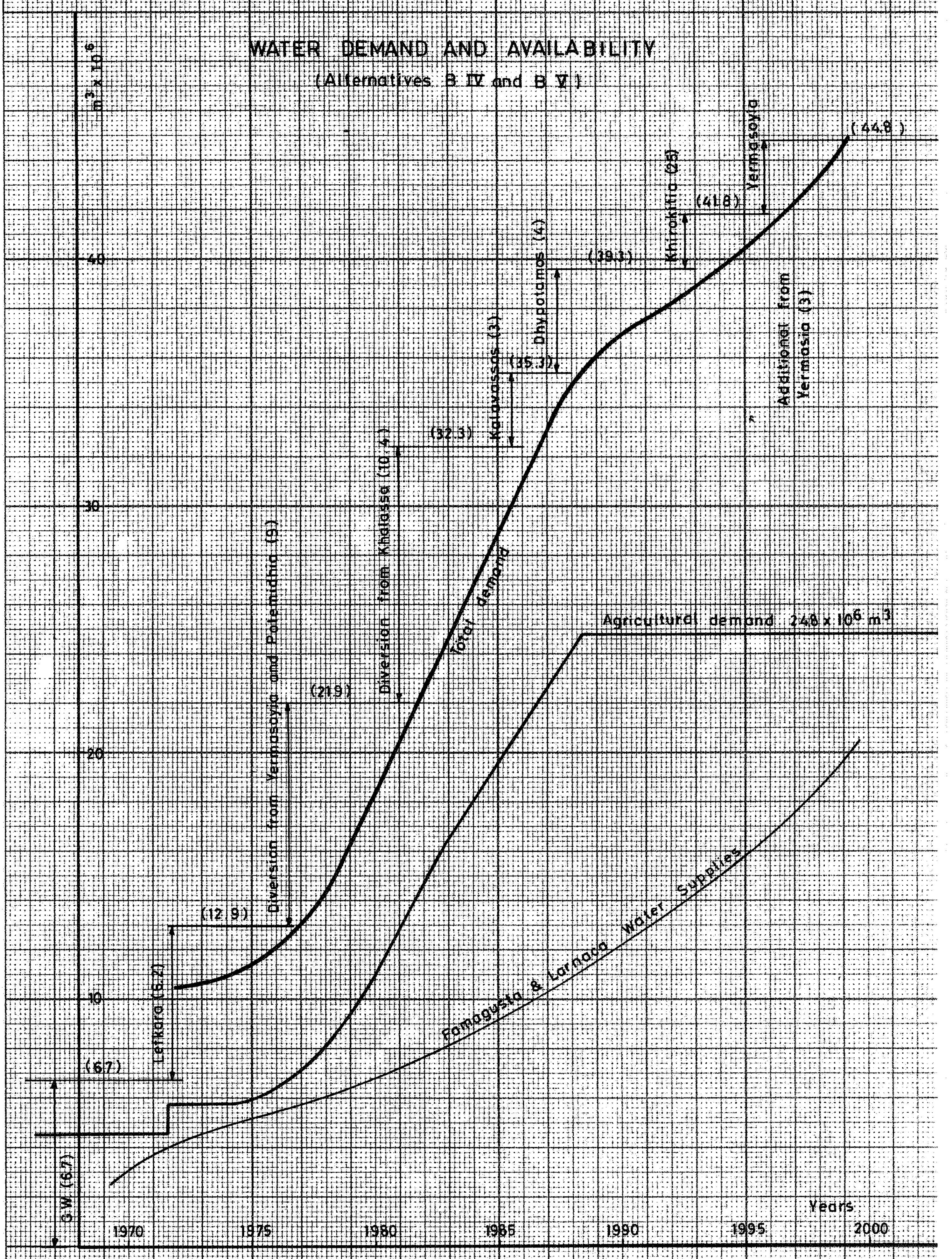
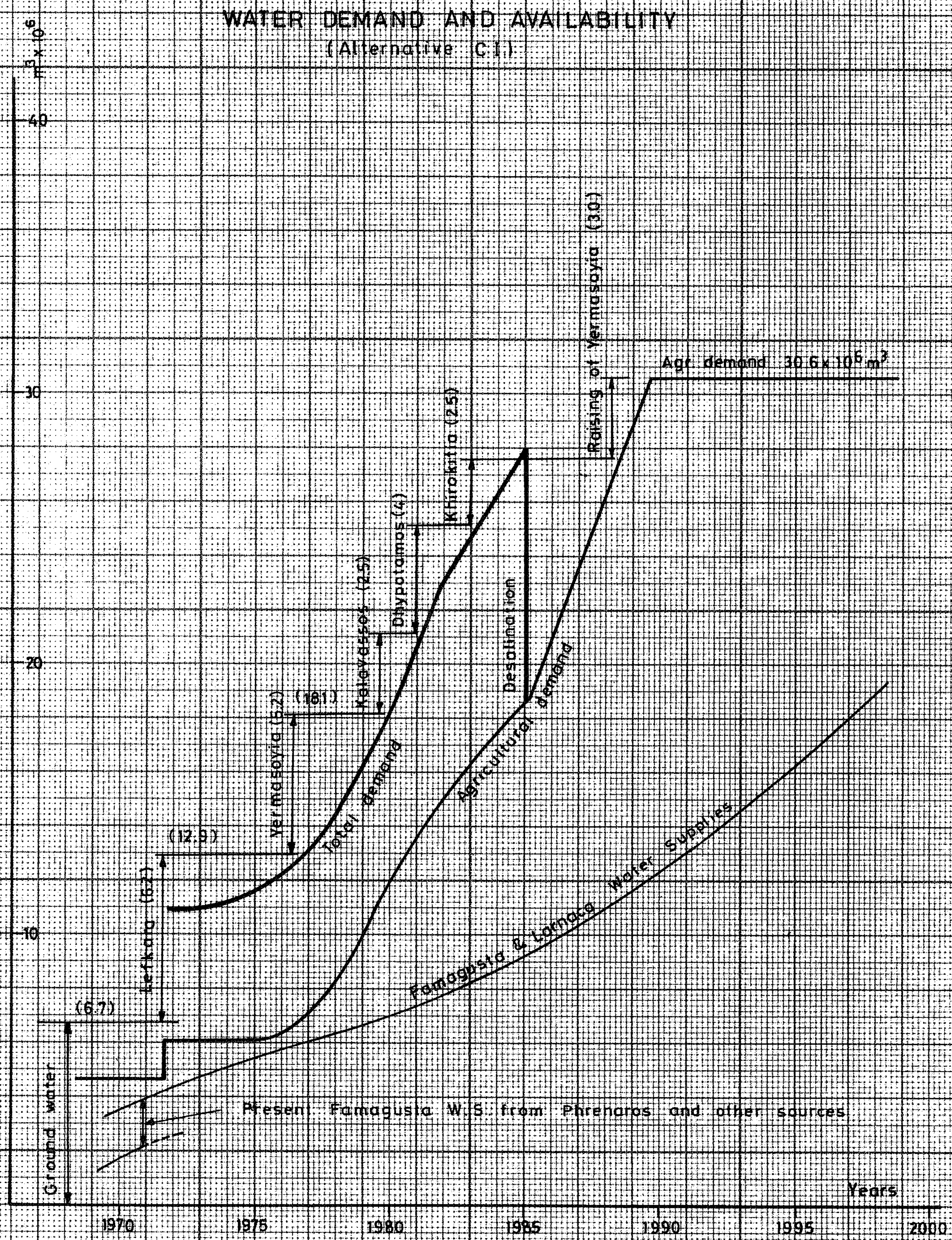
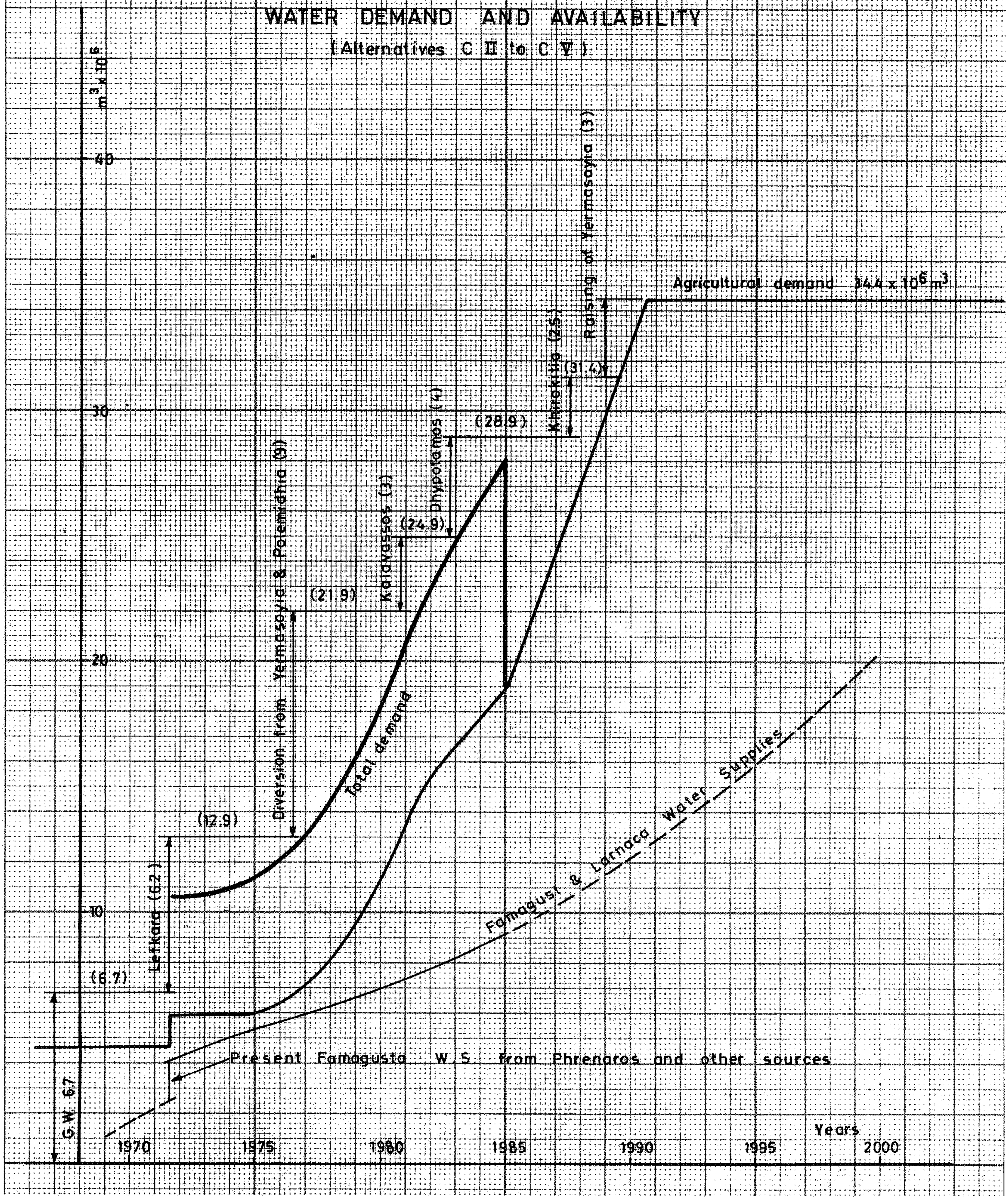

WATER DEMAND AND AVAILABILITY
(Alternatives B II)
$m^3 \times 10^6$
40
30
20
10
(35.0)
(34.4)
Raising of Yermasoyia (3)
(31.4)
Khirokitia (2.5)
(28.9)
Dhypotamos (4)
(24.9)
Kalavassos (3)
Total demand
(21.9)
Diversion of Yermasoyia & Polemidhia (9)
(12.9)
Lefkara (6.2)
(6.7)
Agricultural demand
Alternative B II
(15 x $m^3 \times 10^6$)
Famagusta & Larnaca Water Supplies
Present Famagusta W.S. from Phrenaros and other sources
G.W. 6.7
Years
1970
1975
1980
1985
1990
1995
2000

Fig. 21


WATER DEMAND AND AVAILABILITY
(Alternatives B IV and B V)
m³ x 10⁶
40
30
20
10
(44.8)
Yermasoyia
Khirokitia (2.5)
(41.8)
Dhypotamos (4)
(39.3)
Additional from Yermasoyia (3)
Kalavassos (3)
(35.3)
(32.3)
Diversion from Khalassa (10.4)
Diversion from Yermasoyia and Polemidhia (9)
Total demand
Agricultural demand 24.8 x 10⁶ m³
(21.9)
Famagusta & Larnaca Water Supplies
(12.9)
Lefkara (6.2)
(6.7)
G.W. (6.7)
Years
1970
1975
1980
1985
1990
1995
2000


WATER DEMAND AND AVAILABILITY
(Alternative C.I)
$m^3 \times 10^6$
40
30
20
10
Agr. demand 30.6 x 10^6 m^3
Raising of Yermasoyia (3.0)
Khirokitia (2.5)
Dhypotamos (4)
Kalavassos (2.5)
Desalination
(18.1)
Yermasoyia (5.2)
Total demand
Agricultural demand
(12.9)
Lefkara (6.2)
Famagusta & Larnaca Water Supplies
(6.7)
Ground water
Present Famagusta W.S. from Phrenaros and other sources
Years
1970
1975
1980
1985
1990
1995
2000


WATER DEMAND AND AVAILABILITY
(Alternatives C II to C V)
m³ x 10⁶
40
30
20
10
Agricultural demand 34.4 x 10⁶ m³
Raising of Yermasoyia (3)
Khirokitia (2.5)
(31.4)
(28.9)
Dhypotamos (4)
(24.9)
Kalavassos (3)
(21.9)
Diversion from Yermasoyia & Polemidhia (9)
Total demand
(12.9)
Lefkara (6.2)
(6.7)
G.W. 6.7
Famagust & Larnaca Water Supplies
Present Famagusta W.S. from Phrenaros and other sources
Years
1970
1975
1980
1985
1990
1995
2000

Availability :

Local groundwater resourses, which can be mined, give a safe yield of 6.7 MCM per year.

The Lefkara dam project is in a final design stage, and it is expected construction will be completed by the end of 1972.

The Polemidhia and Yermasoyia dams exist and can supply water as soon as the diversion canals are completed. Water from the Khalassa reservoir usually cannot by use for diverted purpose before it has been shown, it is not needed in the Limassol region. In this respect, it is assumed a desalination plant to serve Limassol town will be completed in 1985, which mades more water available for agricultural purposes in the "A" alternatives. Agricultural and town water demands, as shown on figures 16 to 23, have to be covered by the dependable yields of the reservoirs to be constructed and completed in the years shown on the same figures.

On the basis of these schedules of construction of dams, a construction schedule for all canal sections can be made. Furthermore, the annual conveyance capacities can be fixed by the use of tables 1 to 3 and the yields from each dam as given in table 10.

The length of each section is known (table 25) while the capital investments in an open canal or pipe line have been shown in figure 9 and 10 or table 6 respectively.

For each of the 22 alternatives, schedules of construction and investment have been prepared and are represented in a diagram which will appear later in this report.

In these diagrams groups of 3, 4 or 5 figures are written next to each canal section. They represent the following units, depending on their position with regard to the year when the section has to be completed:

4.5 — Annual volume of regulated flow through the section in million cubic metres.

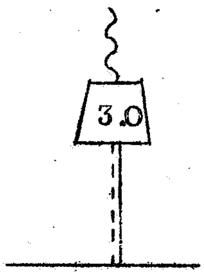
0.50 — Capacity of the conduit in CM/sec. as required.

1986 — Year when the section has to be completed.

206 — Estimated capital investment in thousands of pounds :

7 A — Annual energy consumption of pumping stations in £ x 10^3.

Symbols used are :

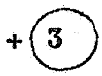


unregulated river

storage reservoir with its dependable yield MCM/year

AC - pipe line

Open canal

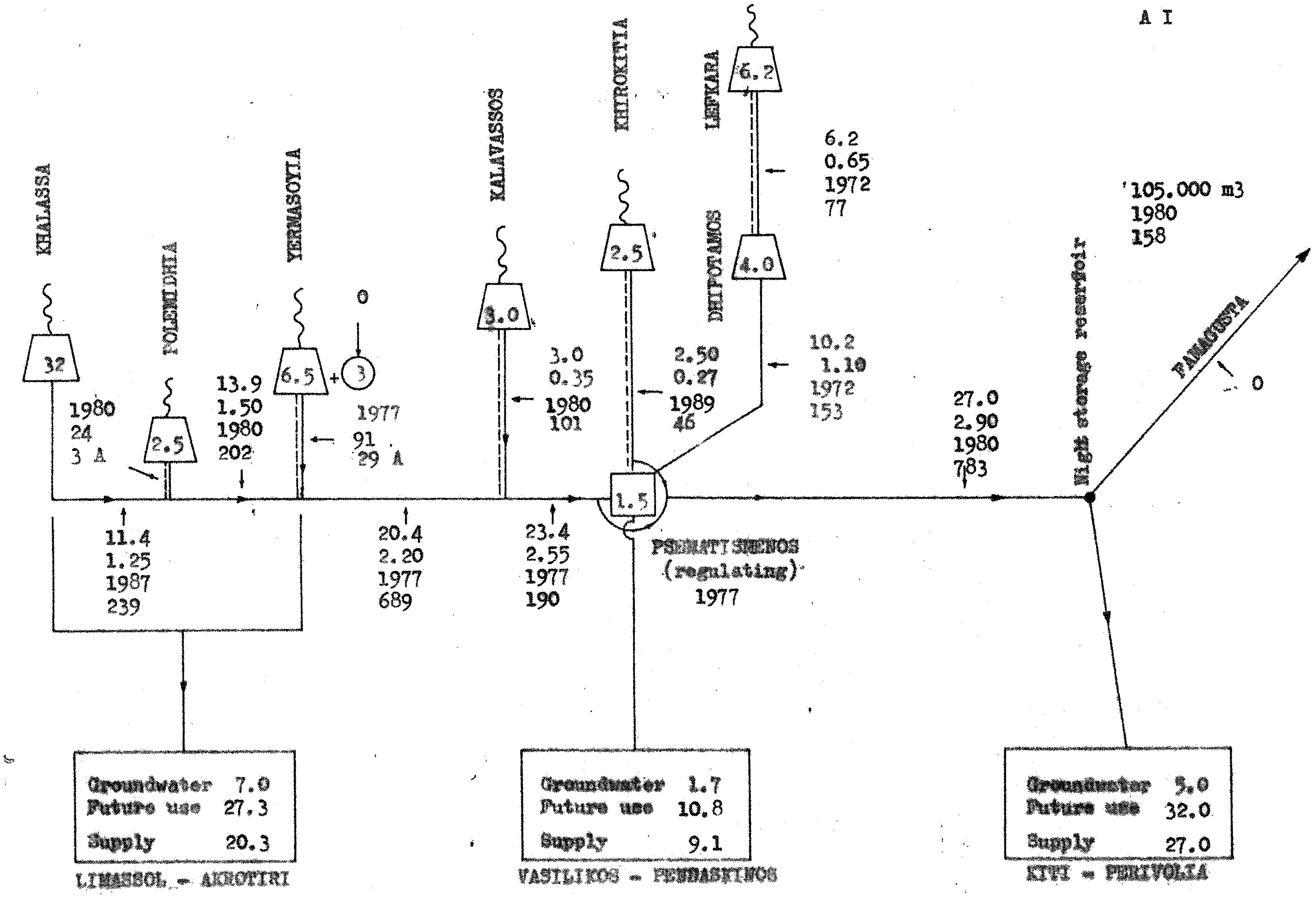


Extra dependable yield available after raising of the Yermasoyia dam.

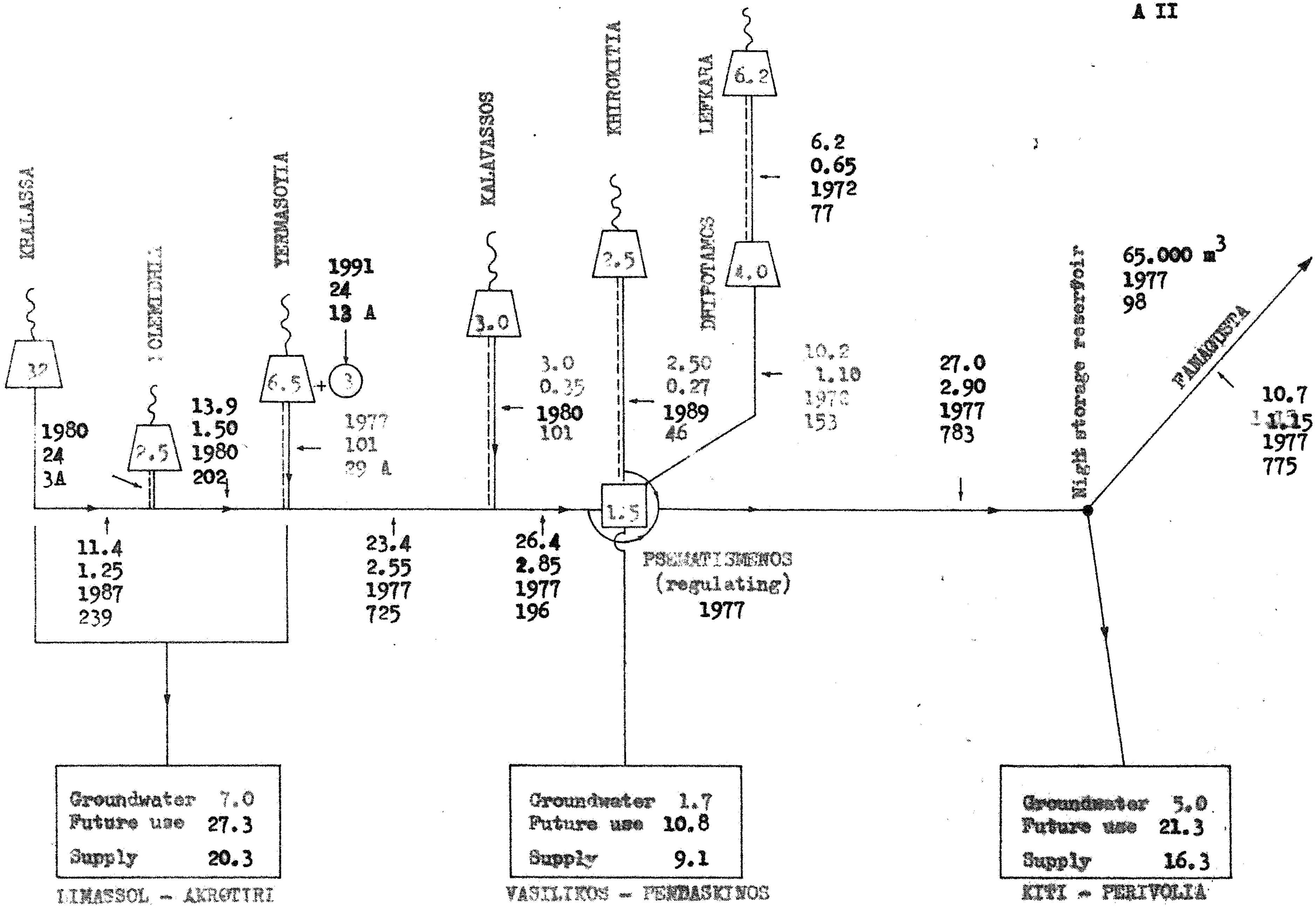
The figures in the three squares representing the supply areas, are given in million cubic metre per year.

ALTERNATIVE

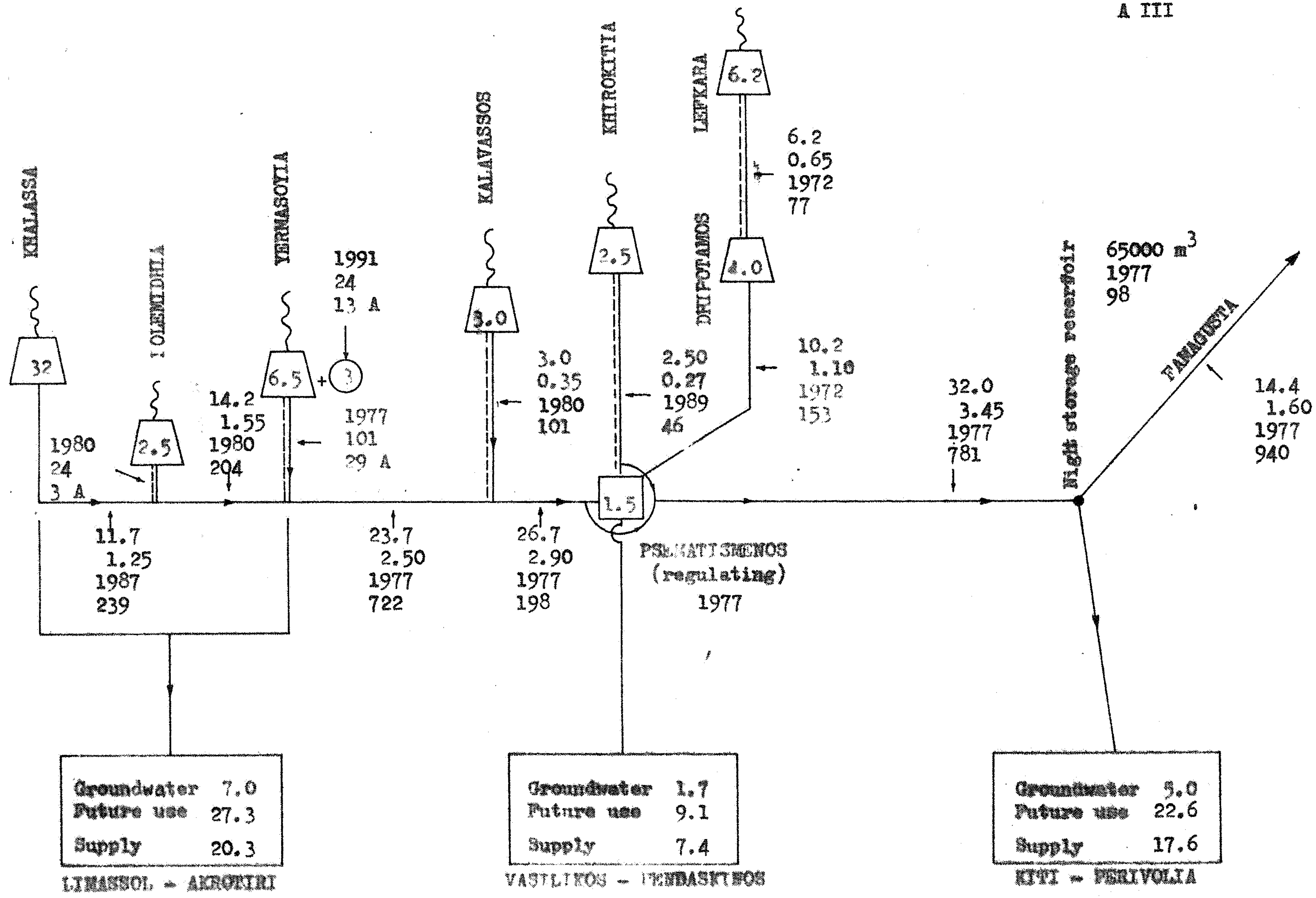
A I

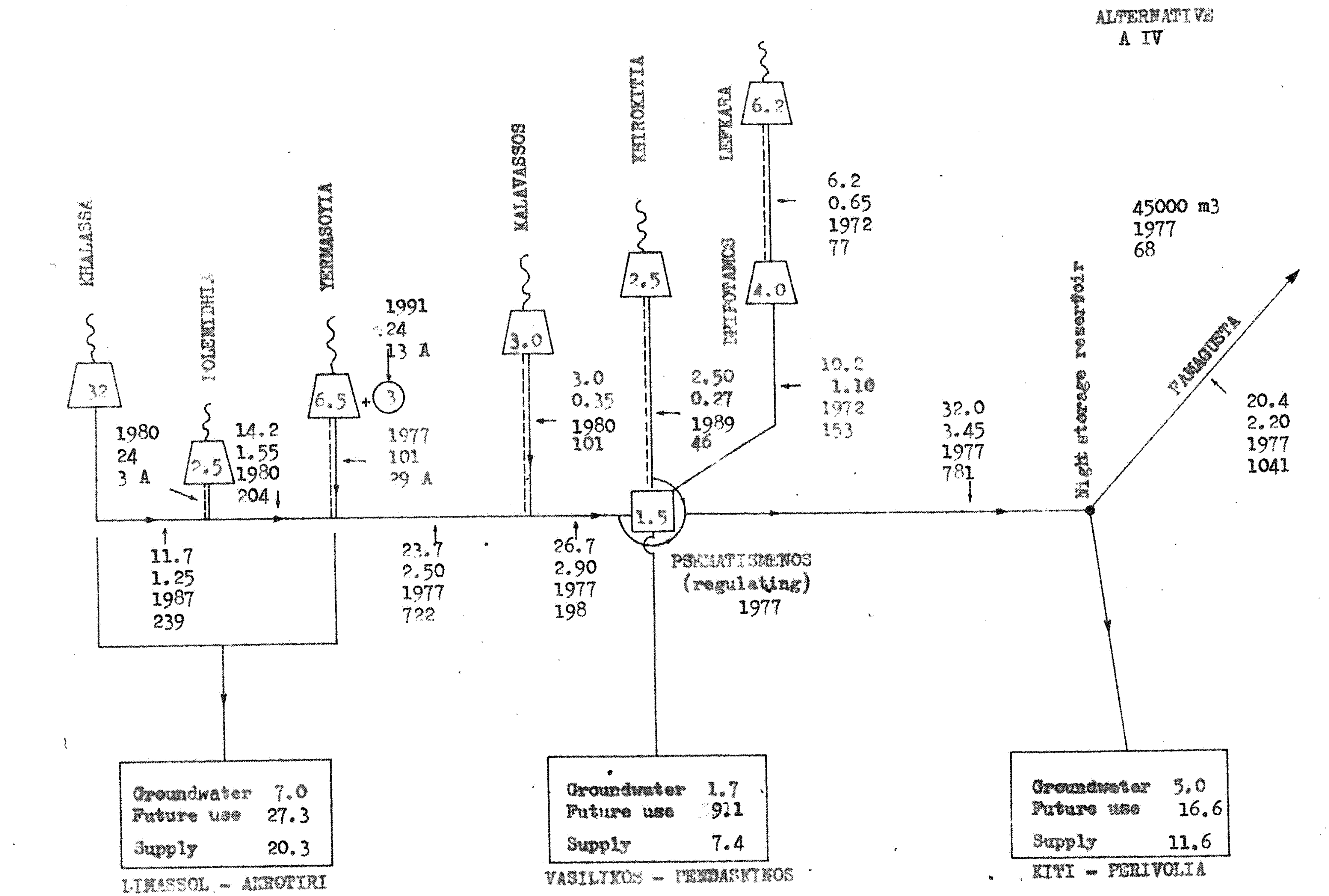


ALTERNATIVE
A II

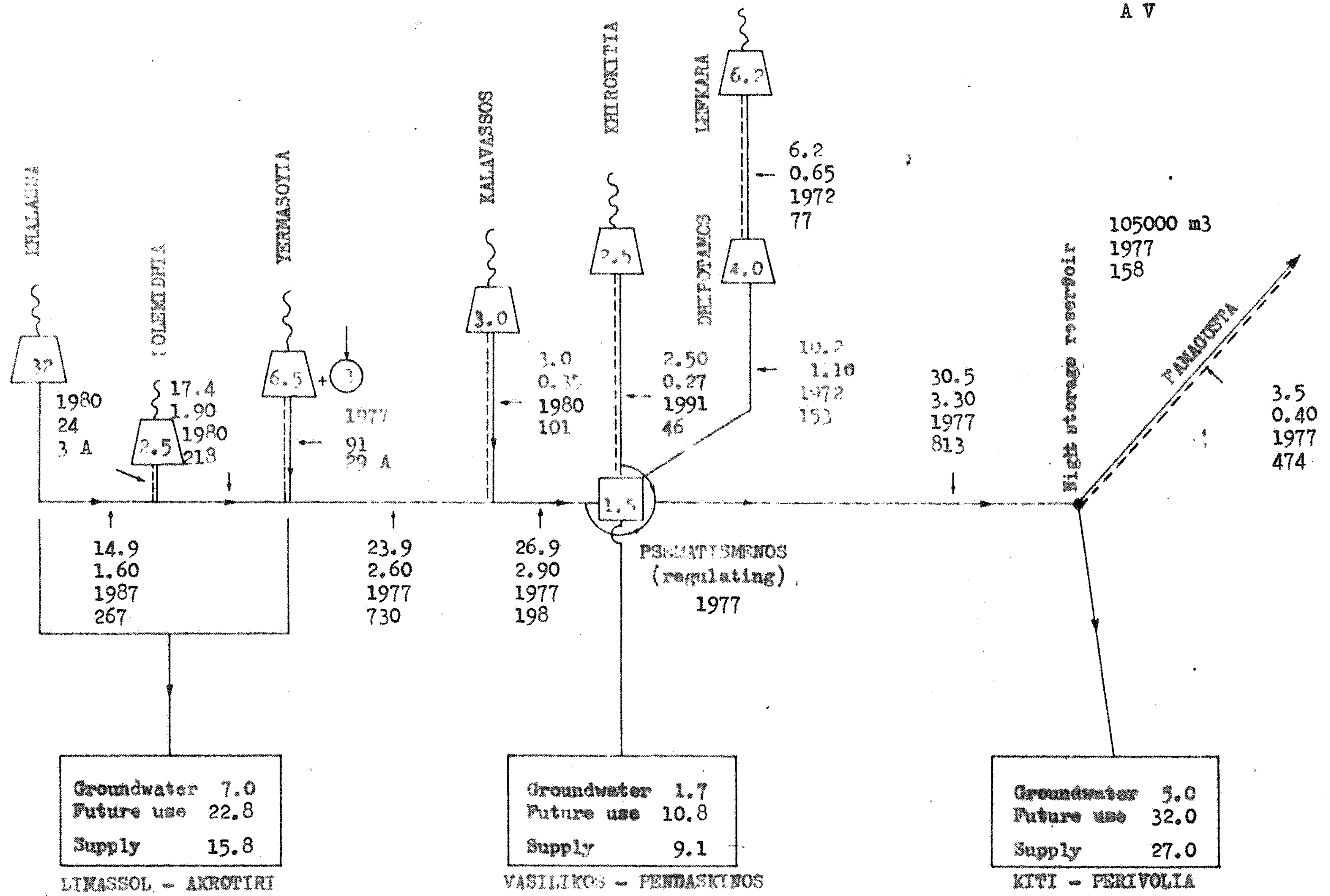


ALTERNATIVE
A III

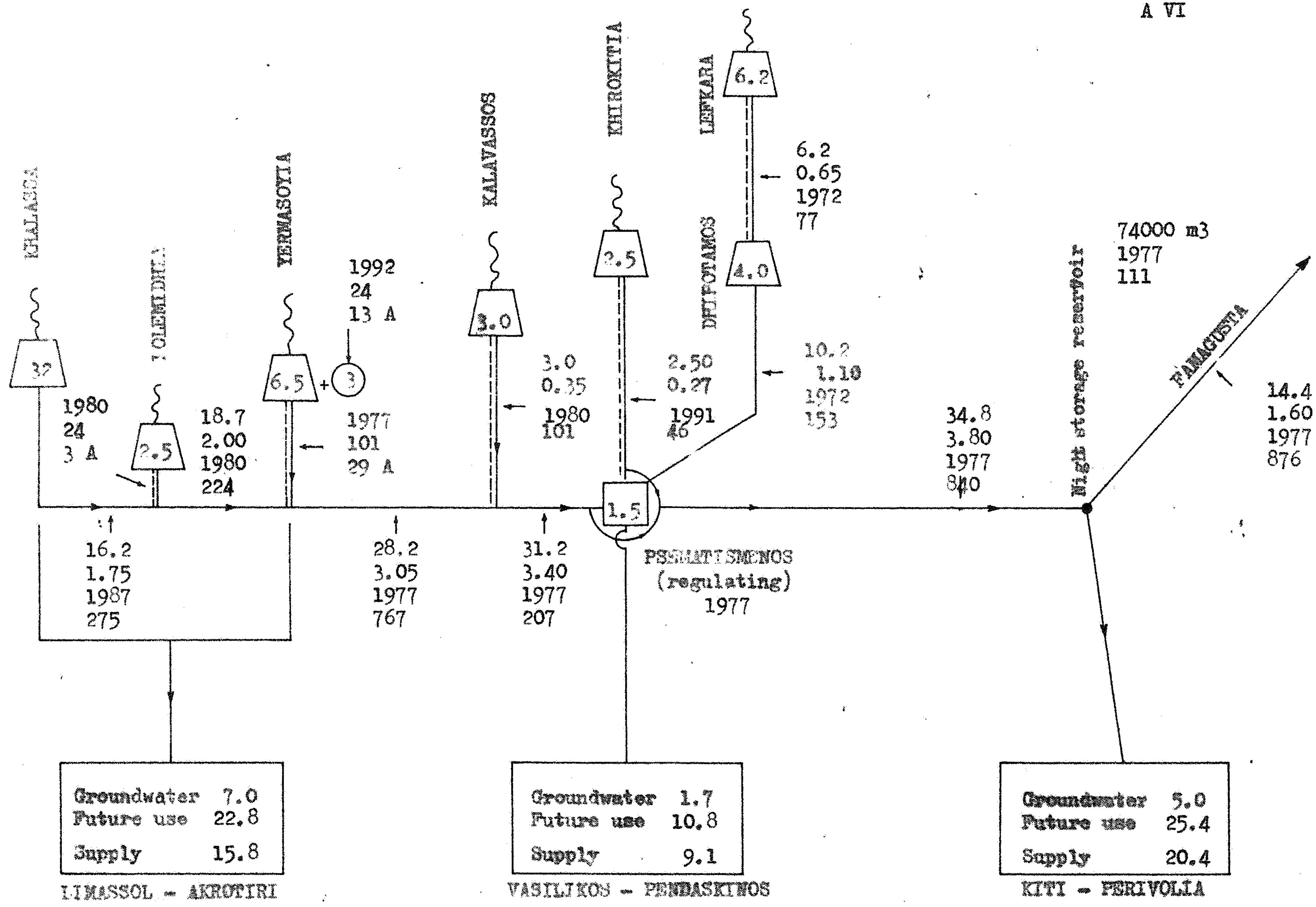



ALTERNATIVE
A IV
KHALASSA
32
1980
24
3 A
POLEMIDHIA
2.5
14.2
1.55
1980
204
11.7
1.25
1987
239
YERMASOYIA
6.5
3
1991
24
13 A
1977
101
29 A
23.7
2.50
1977
722
KALAVASSOS
3.0
3.0
0.35
1980
101
26.7
2.90
1977
198
KHIROKITIA
2.5
2.50
0.27
1989
46
LEFKARA
6.2
6.2
0.65
1972
77
DIPOTAMOS
4.0
10.2
1.10
1972
153
1.5
PSEMATISMENOS
(regulating)
1977
32.0
3.45
1977
781
Night storage reservoir
45000 m3
1977
68
FAMAGUSTA
20.4
2.20
1977
1041
Groundwater 7.0
Future use 27.3
Supply 20.3
LIMASSOL - AKROTIRI
Groundwater 1.7
Future use 9.1
Supply 7.4
VASILIKOS - PENDASKINOS
Groundwater 5.0
Future use 16.6
Supply 11.6
KITI - PERIVOLIA

ALTERNATIVE
A V

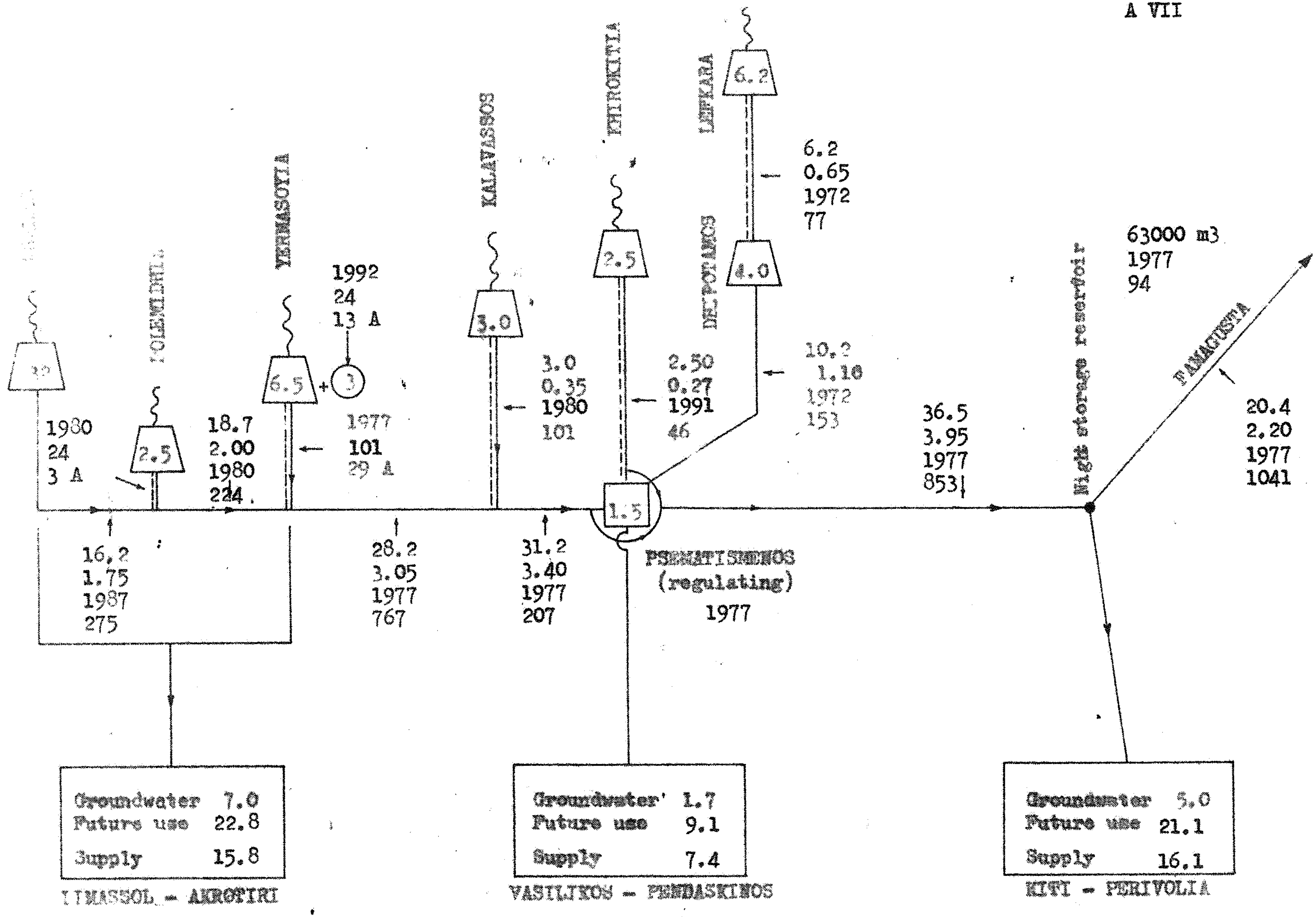


ALTERNATIVE
A VI



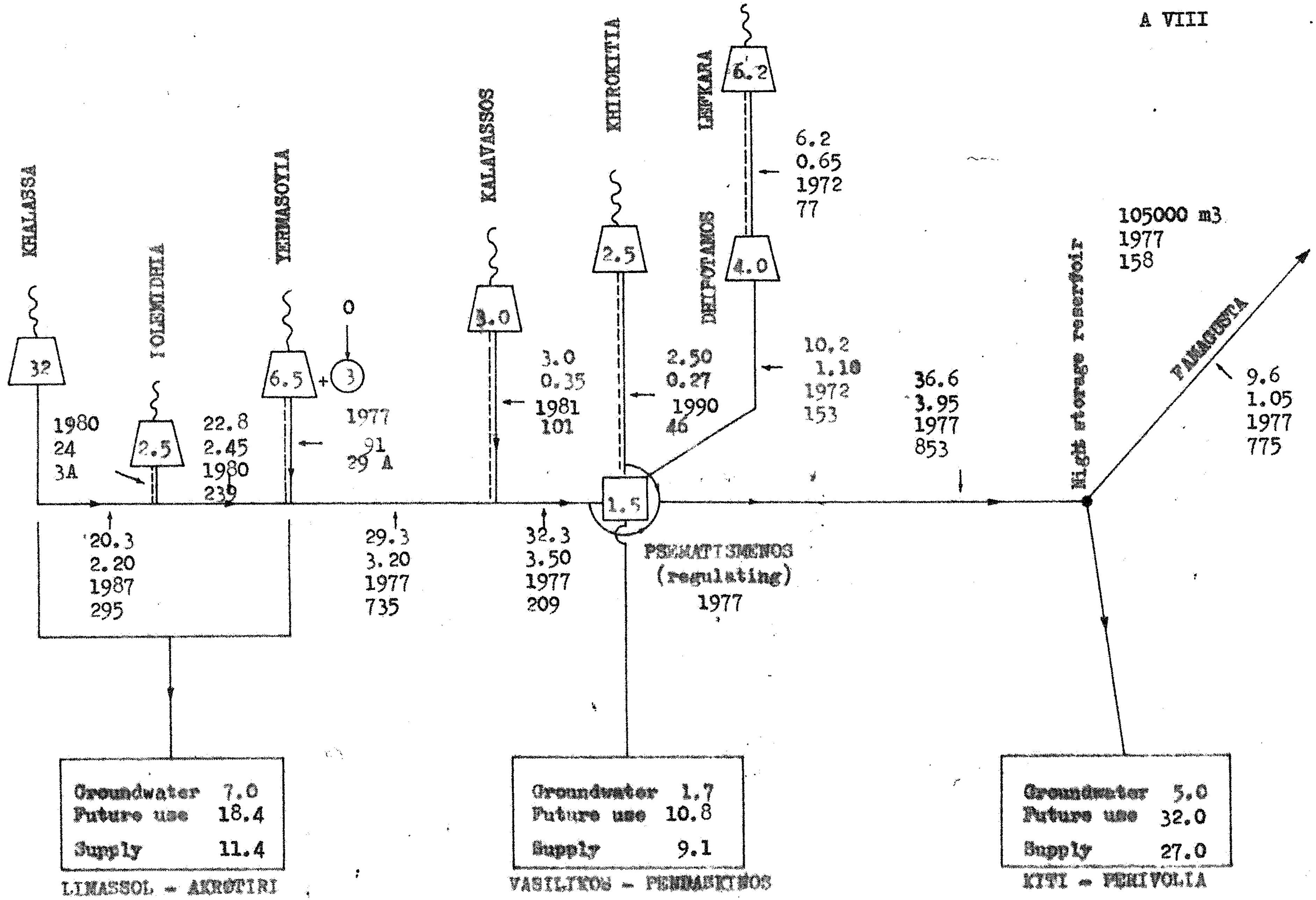
ALTERNATIVE

A VII



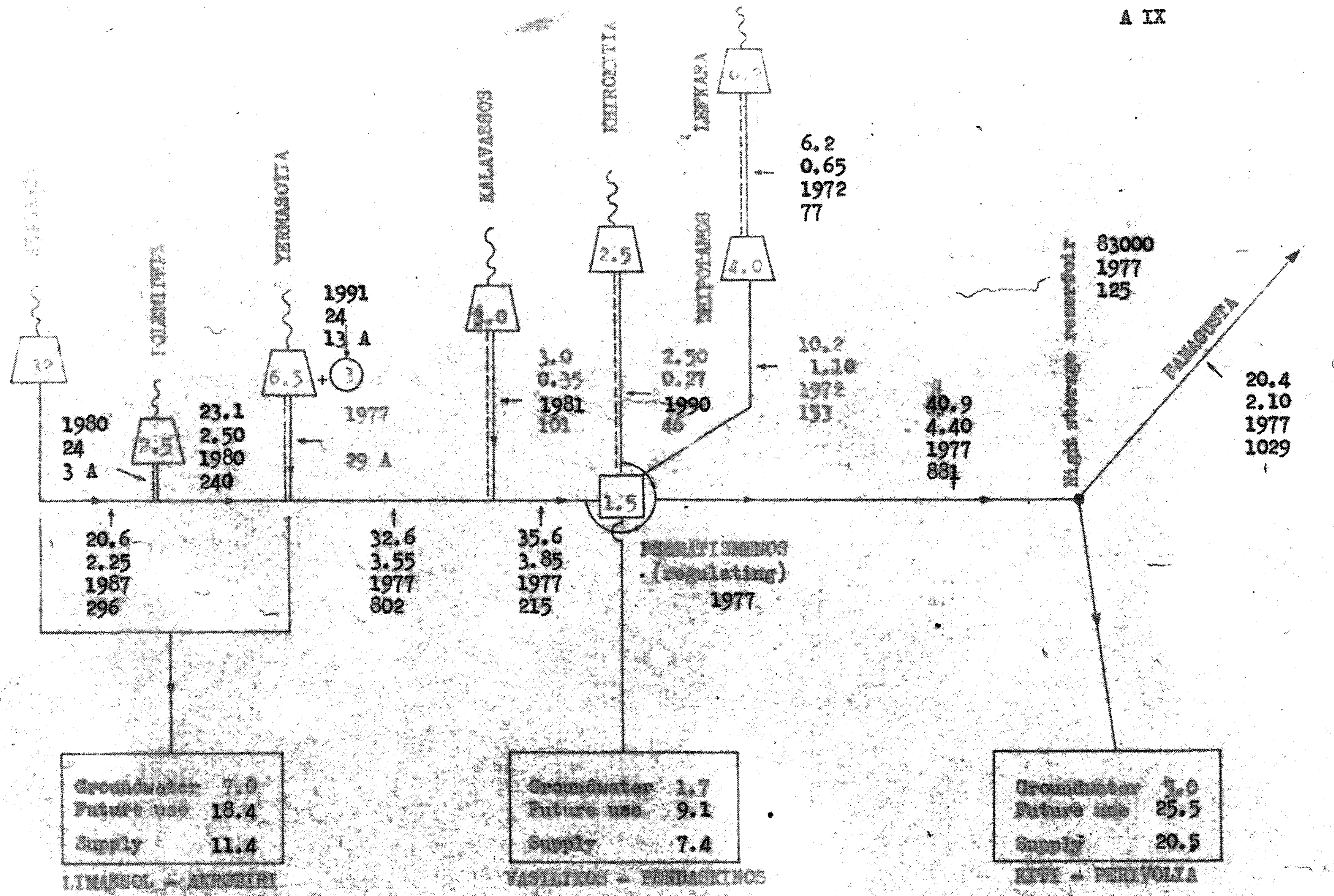
ALTERNATIVE

A VIII



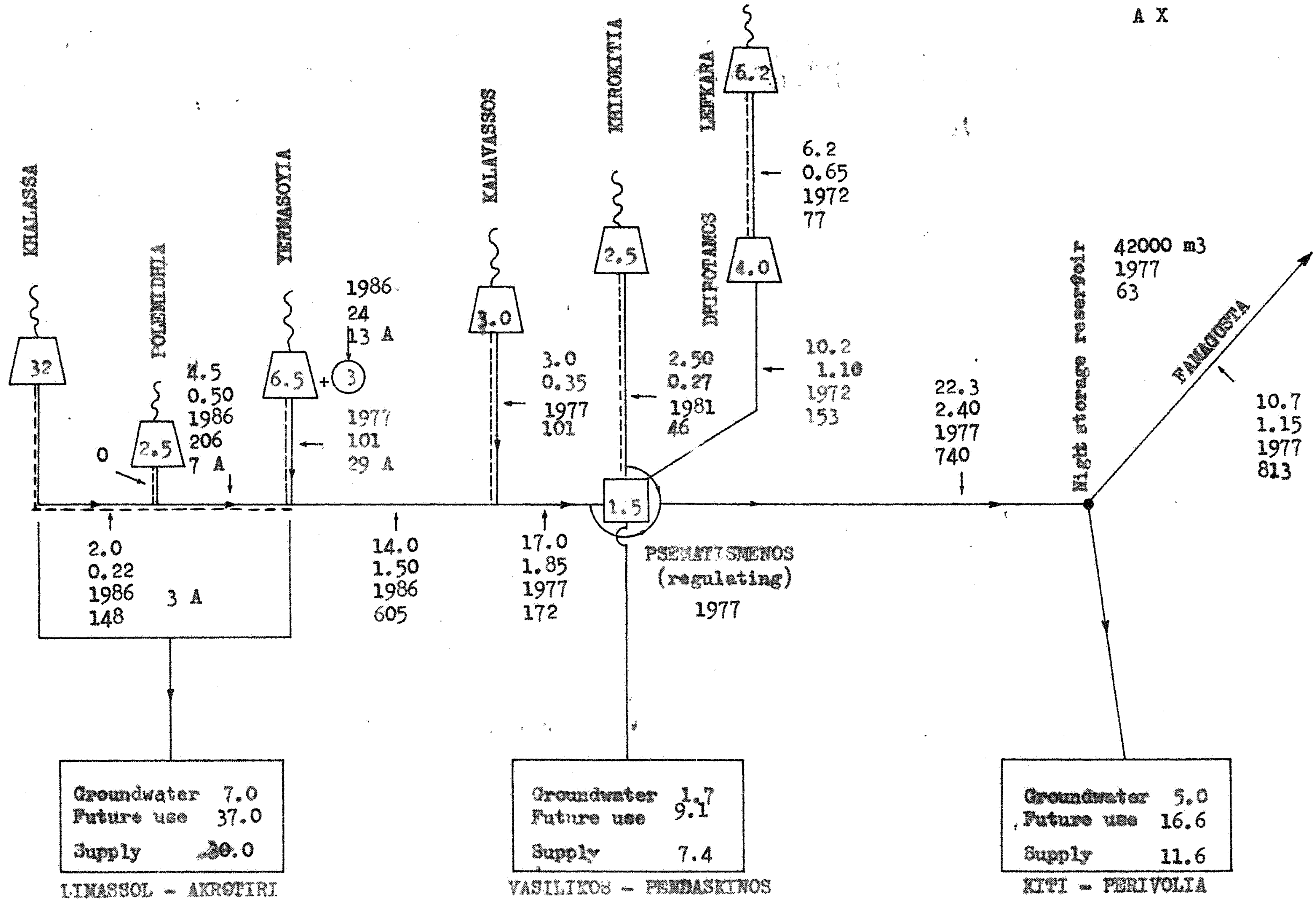
ALTERNATIVE

A IX



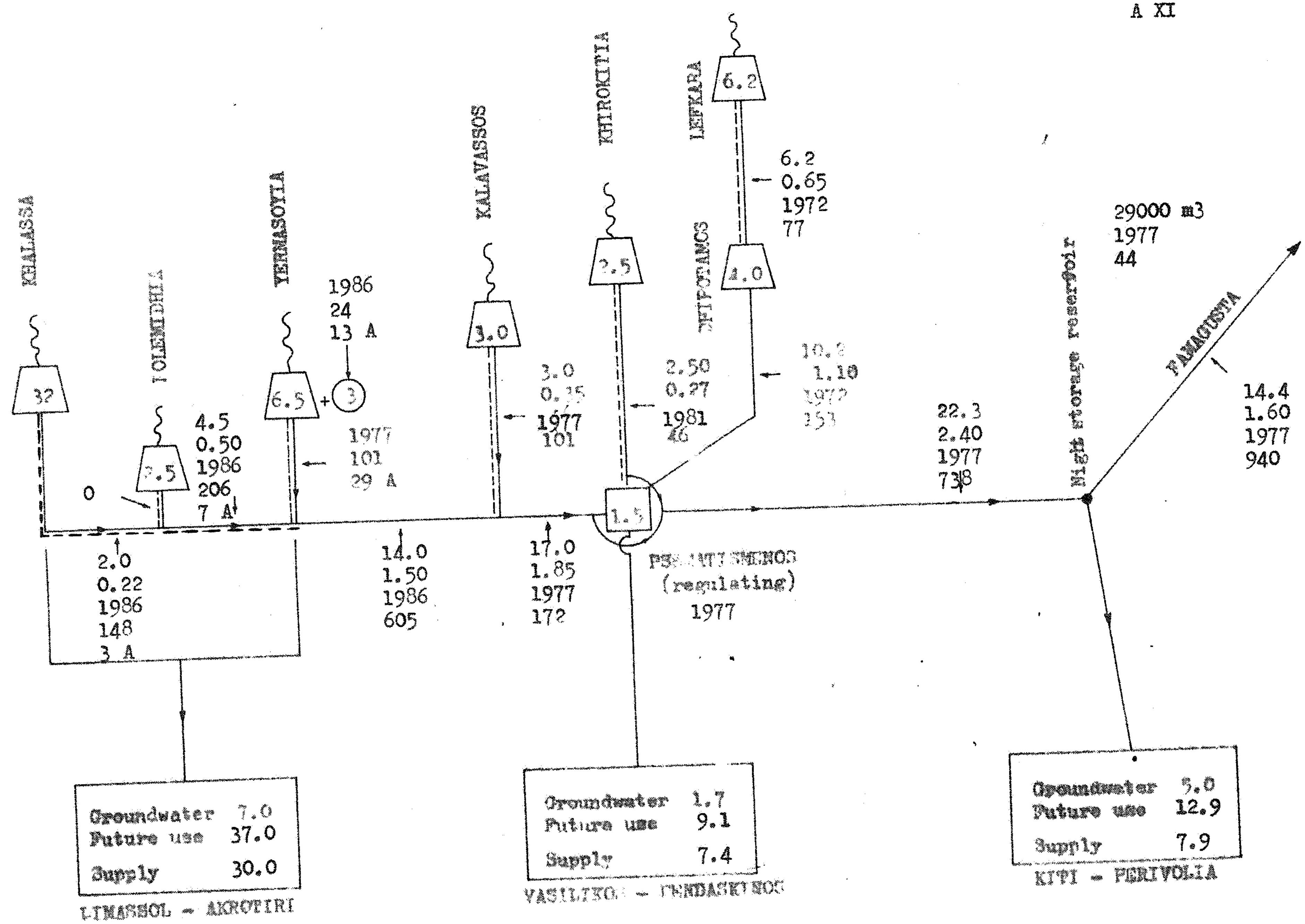
ALTERNATIVE

A X



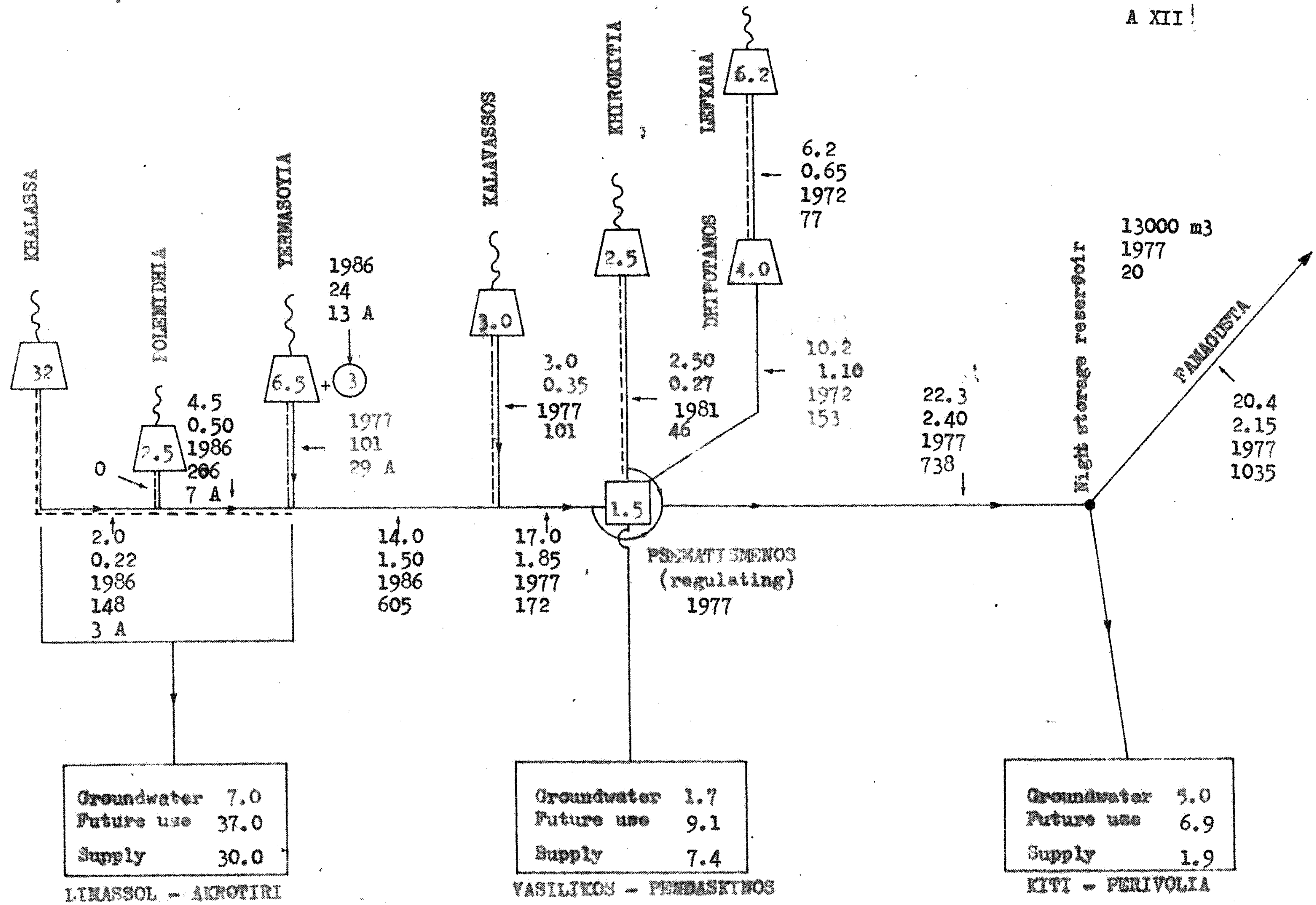
ALTERNATIVE

A XI



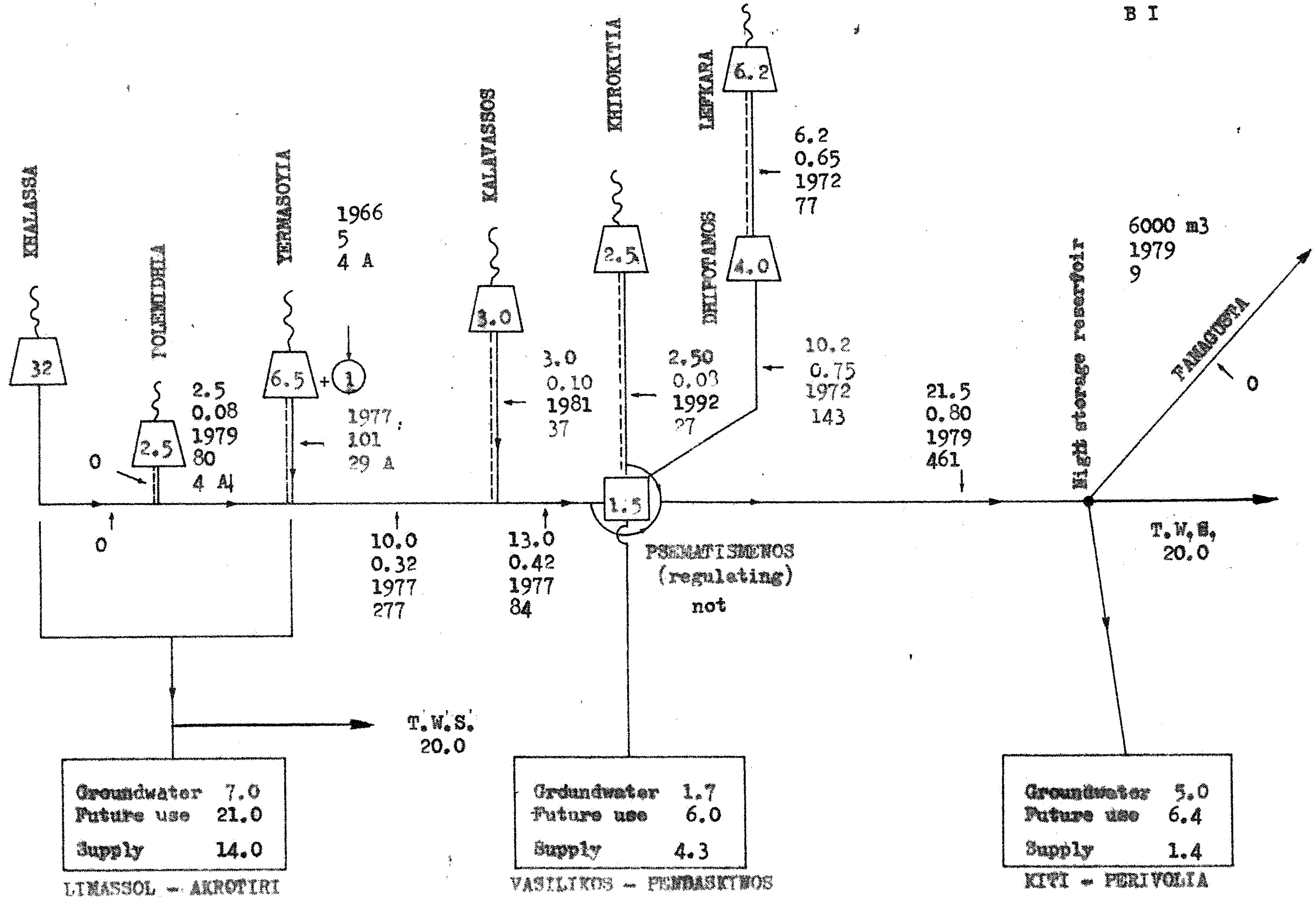
ALTERNATIVE

A XII

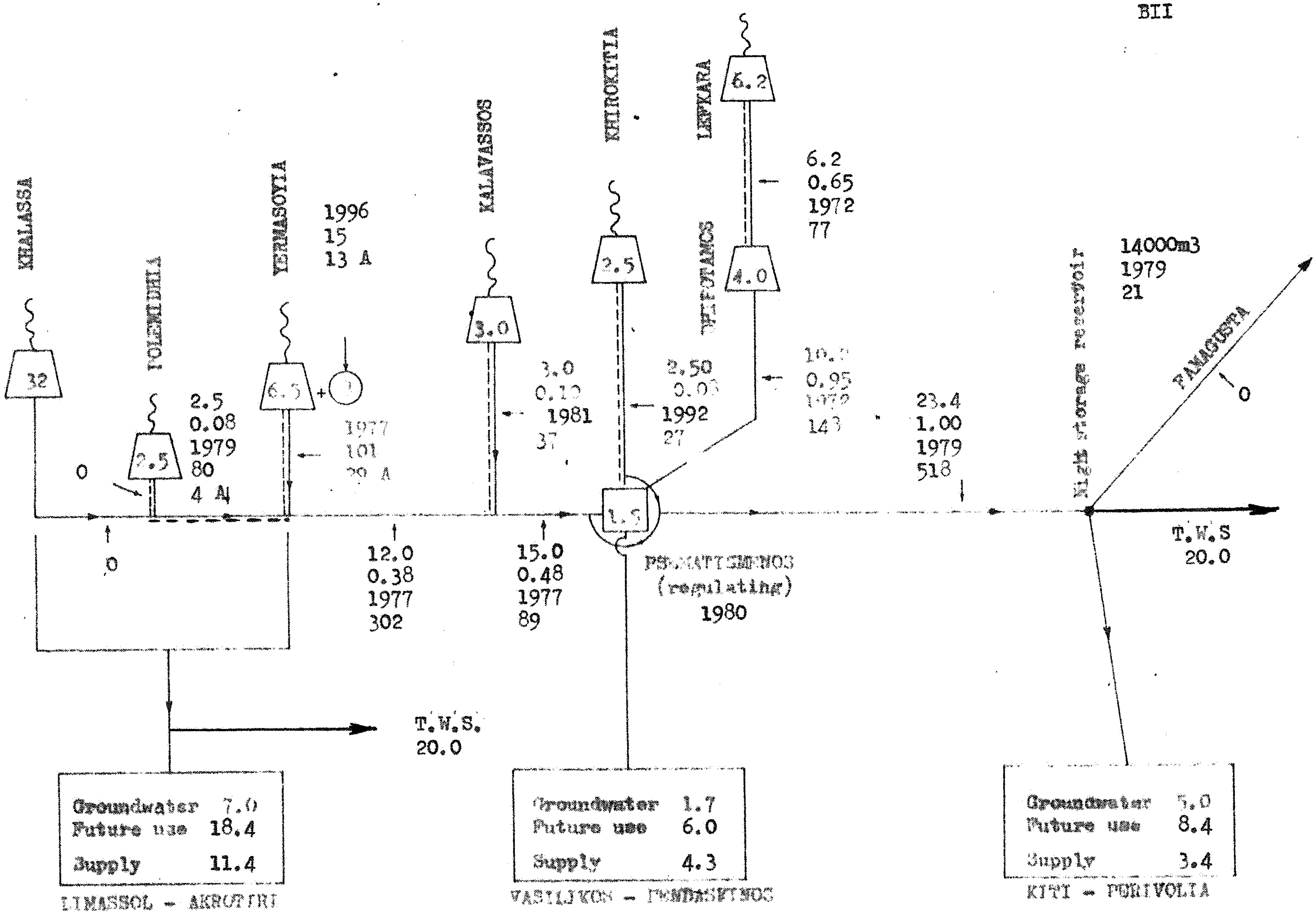


ALTERNATIVE

B I

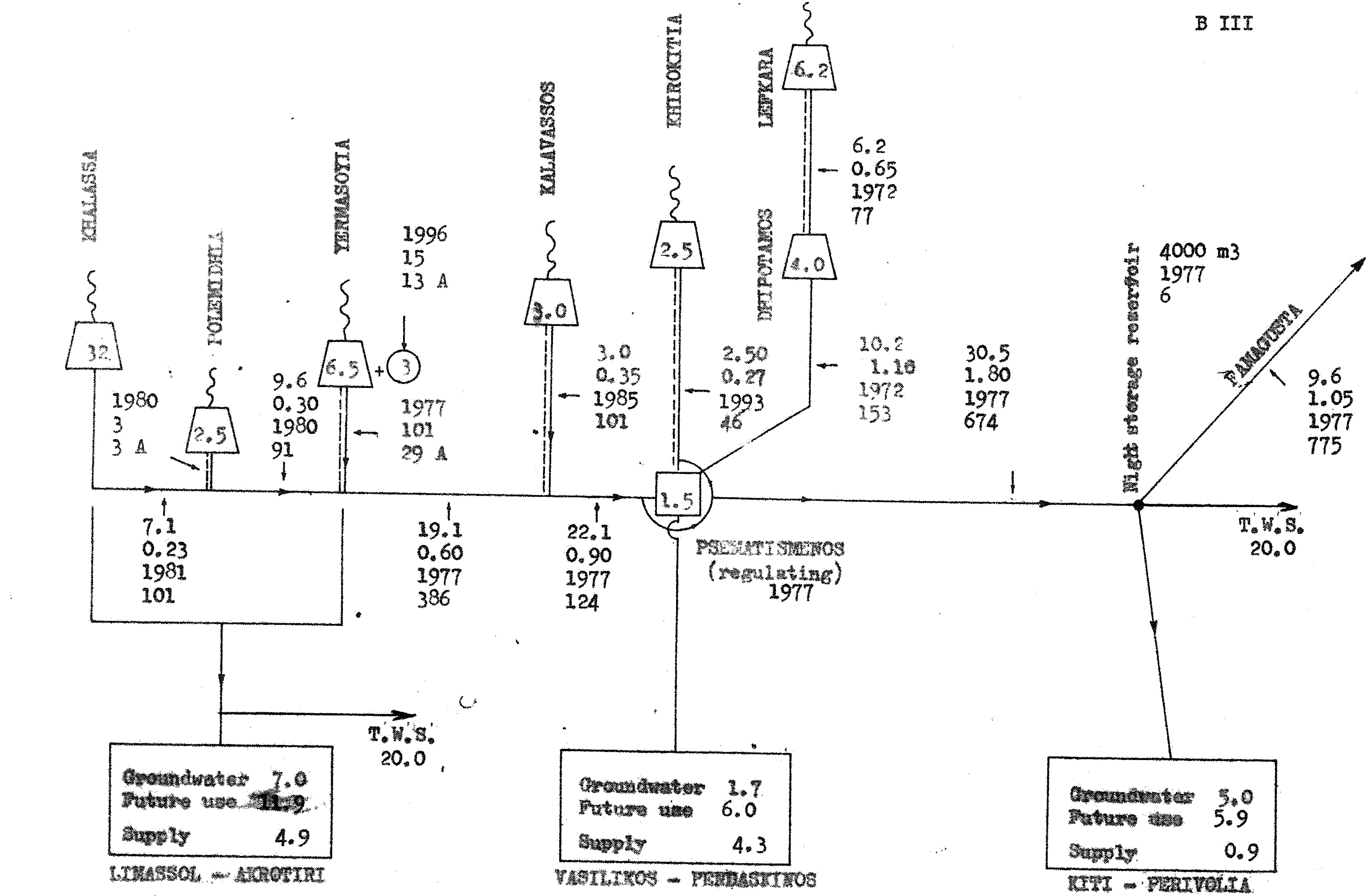


ALTERNATIVE
BII



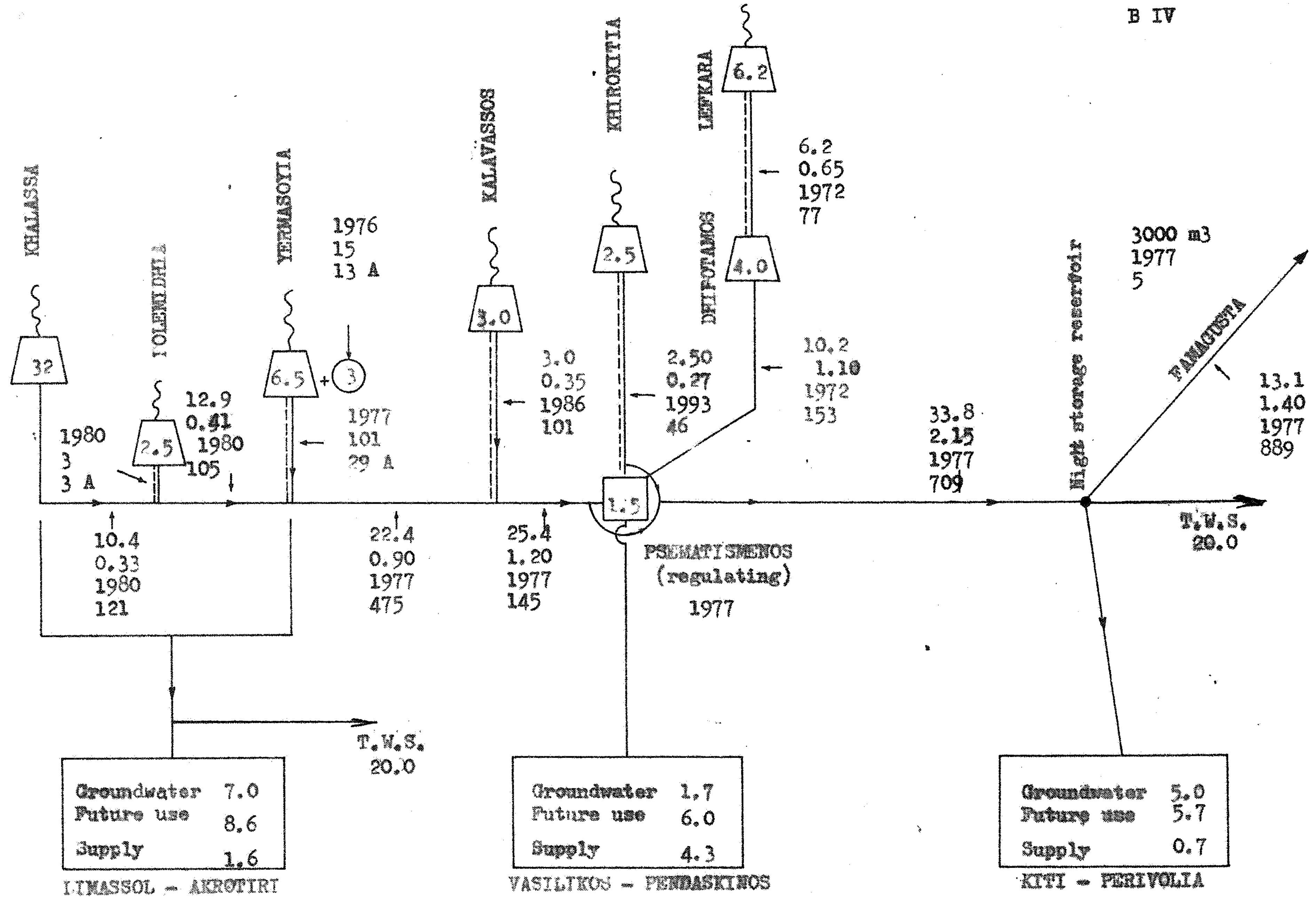
ALTERNATIVE

B III



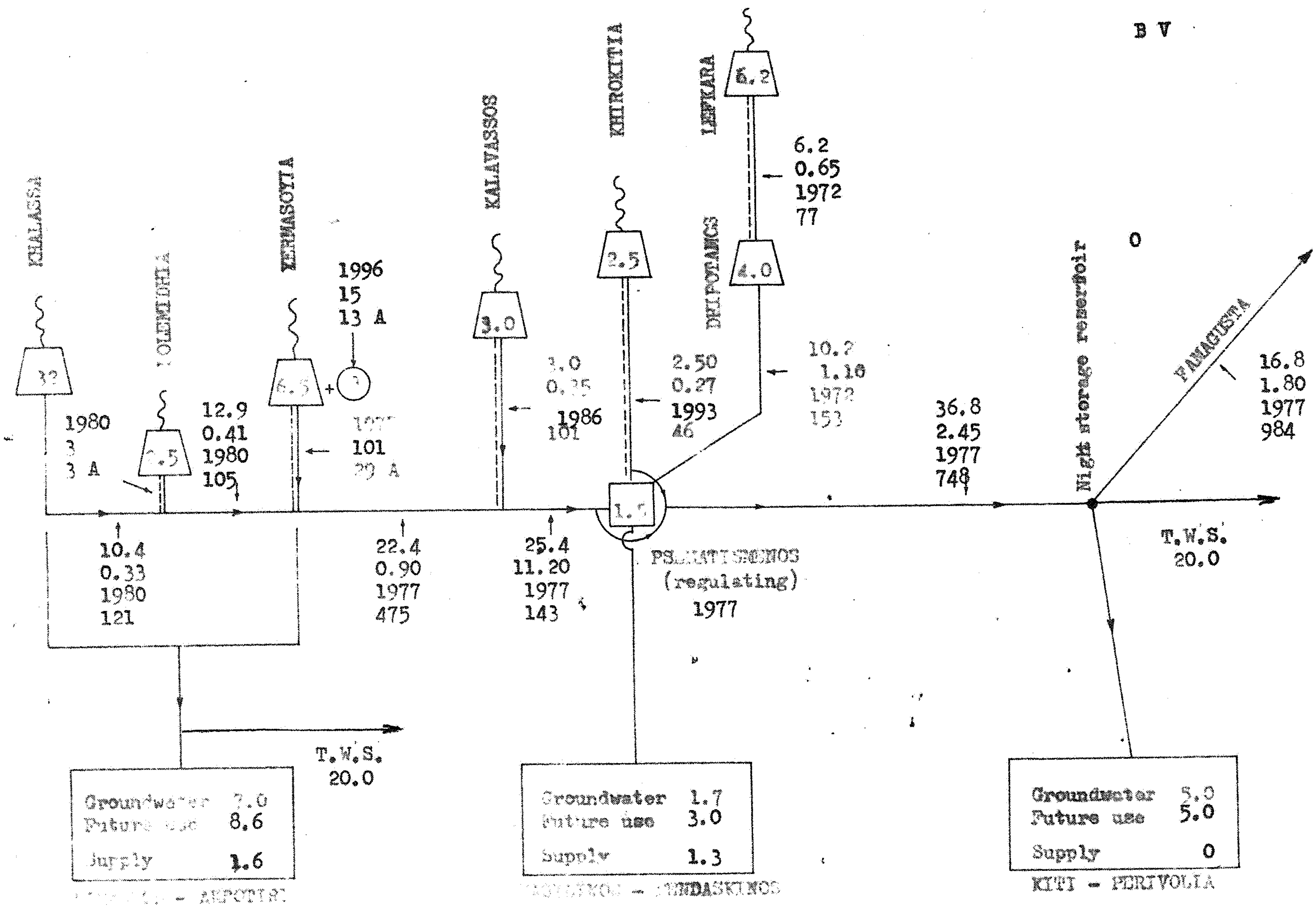
ALTERNATIVE

B IV



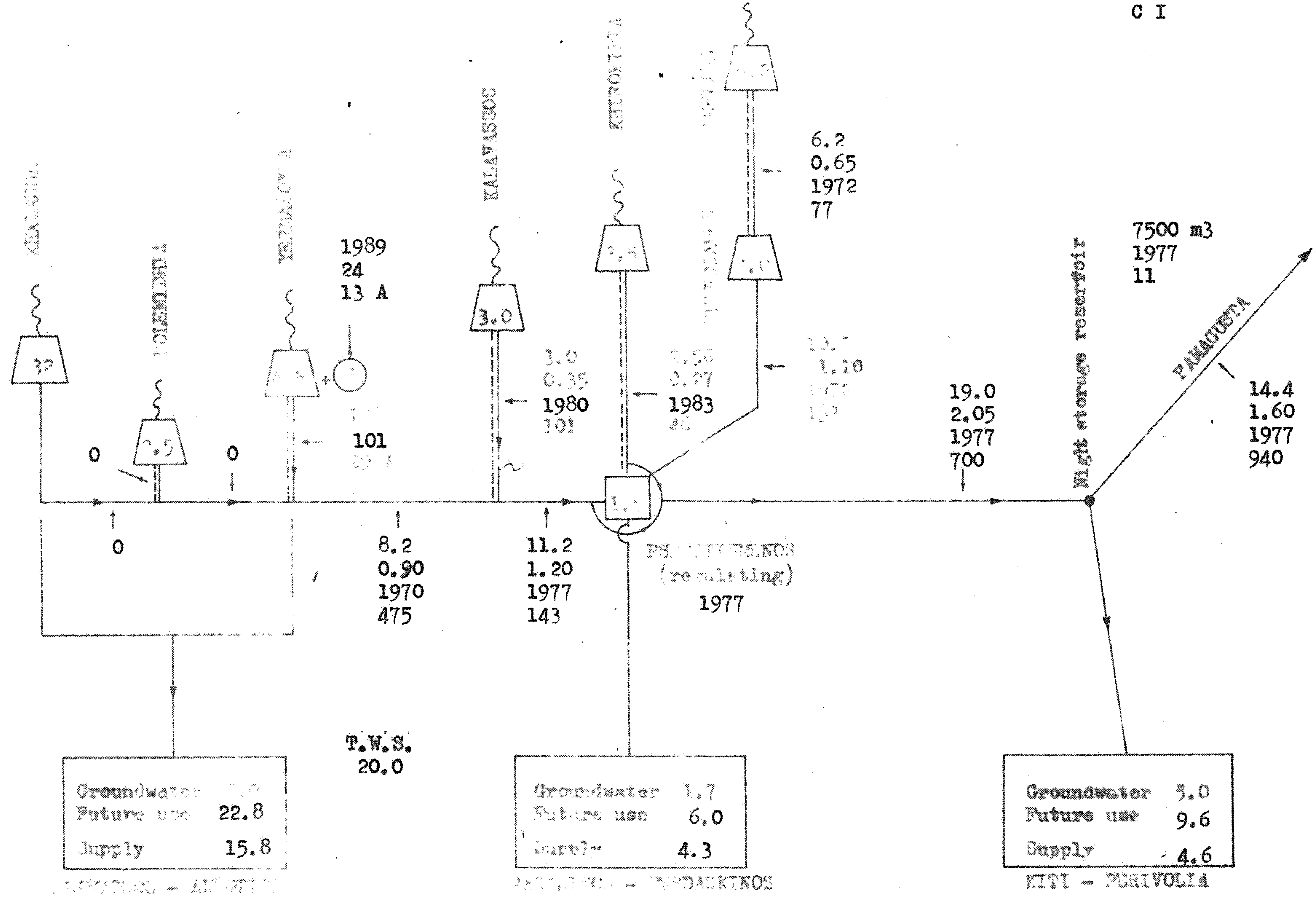
ALTERNATIVE

B V



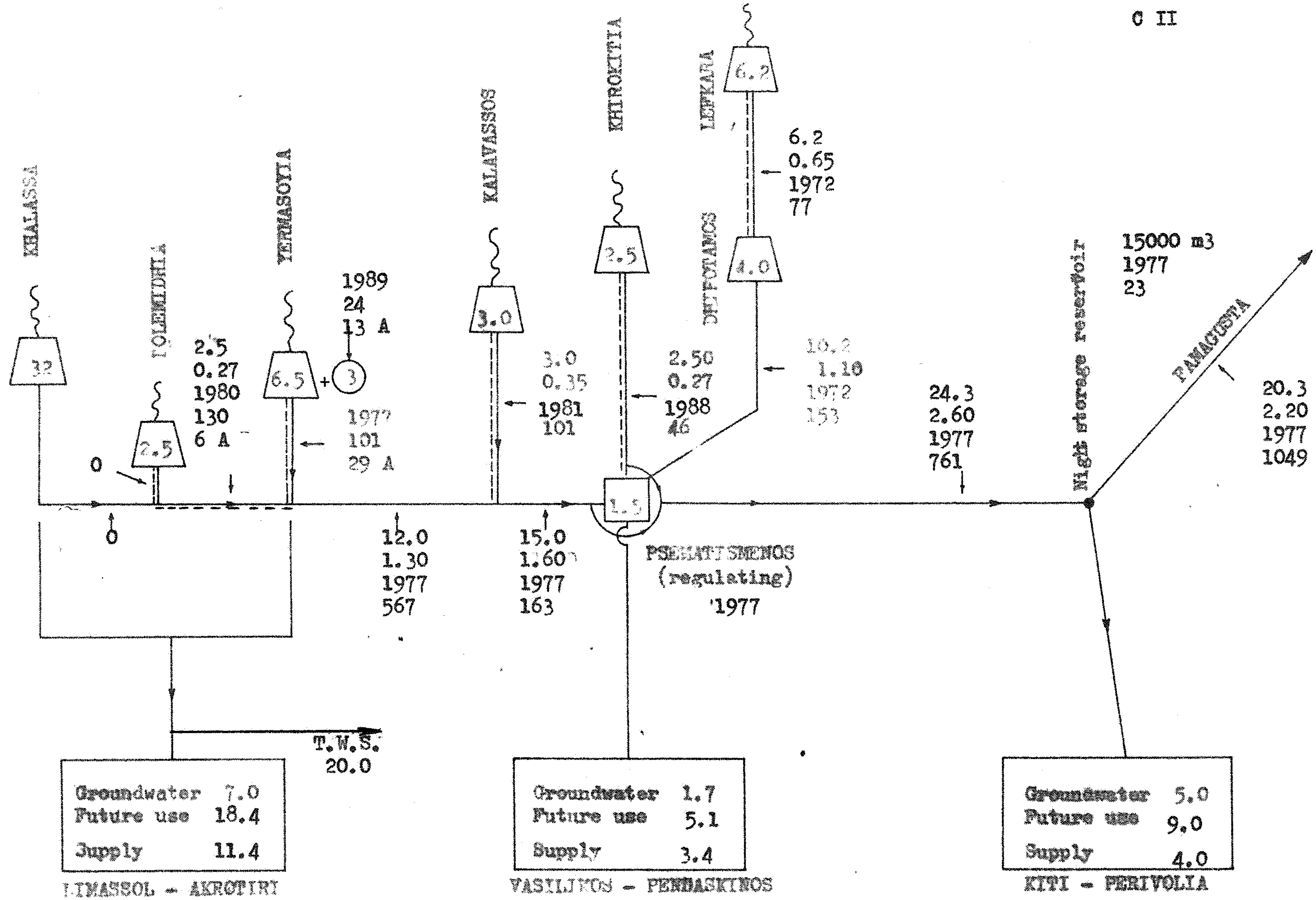
ALTERNATIVE

C I



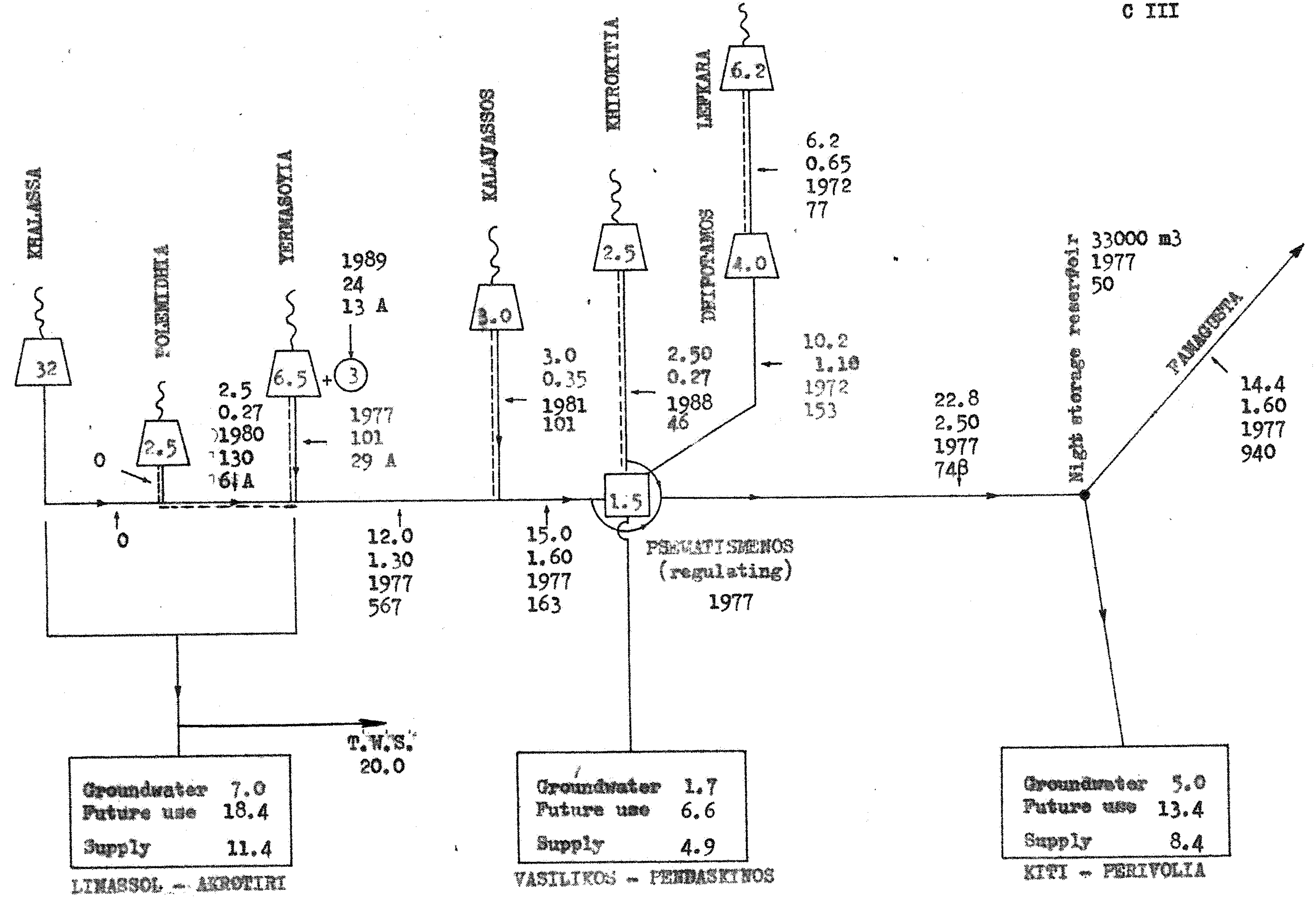
ALTERNATIVE

C II



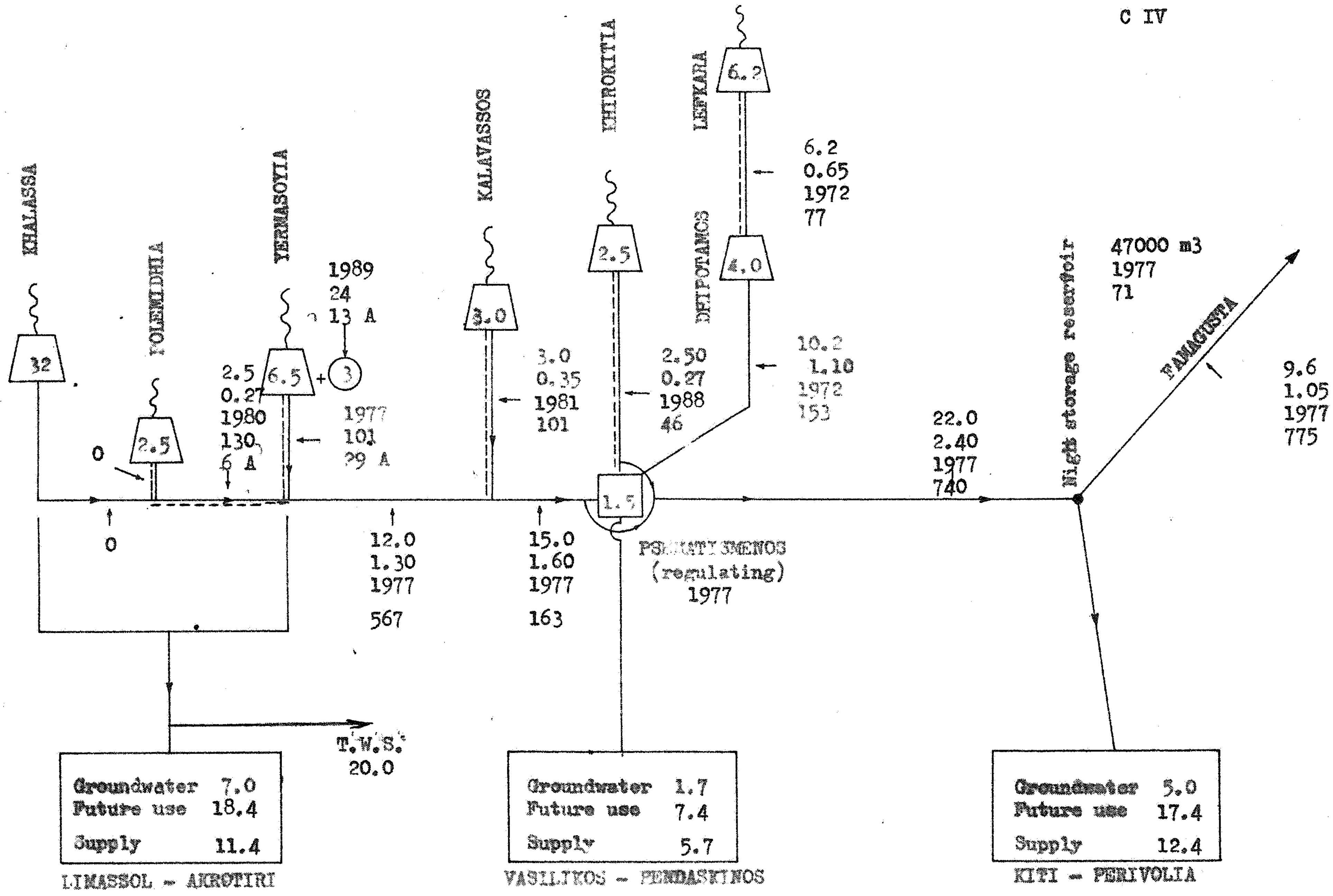
ALTERNATIVE

C III



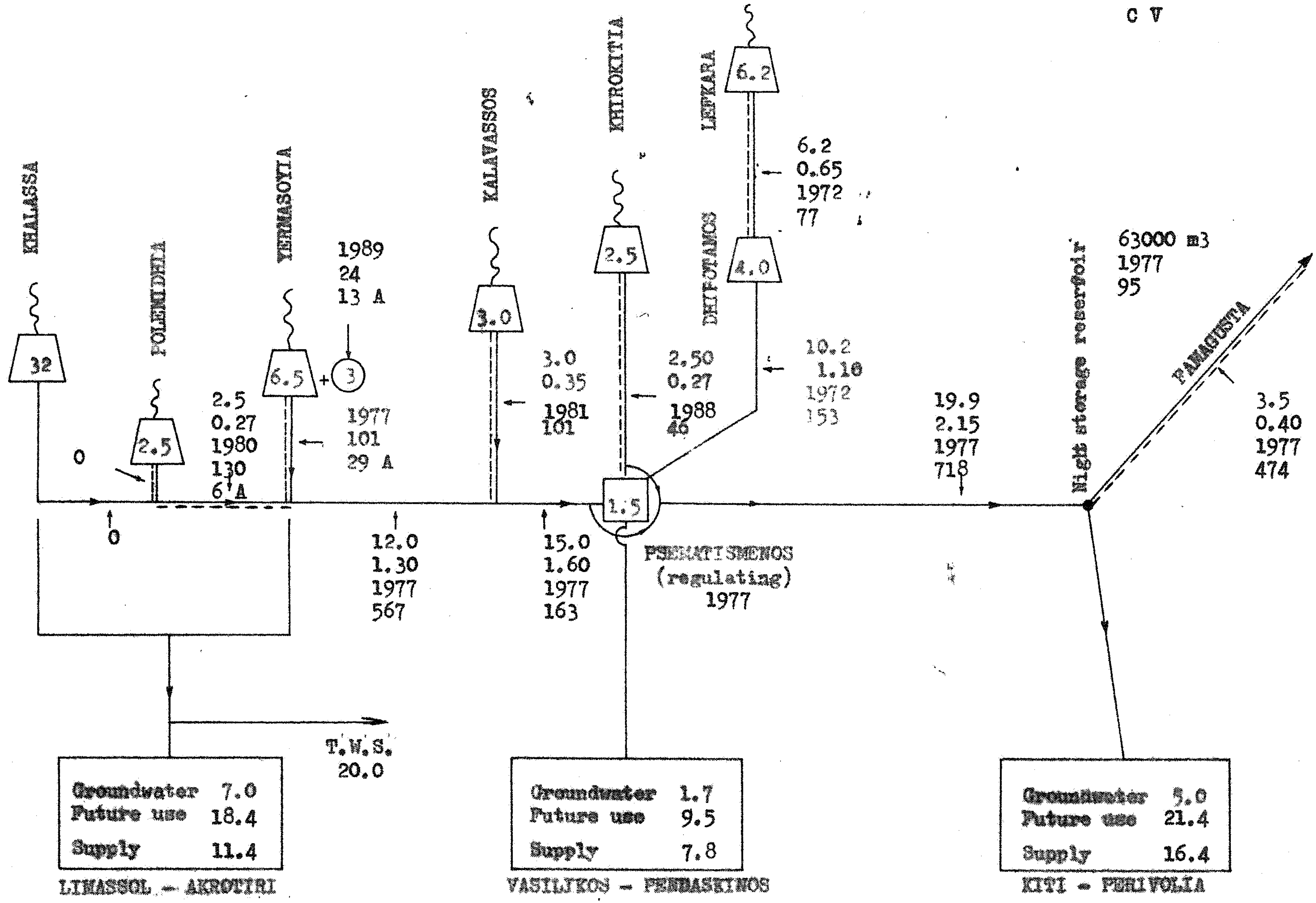
ALTERNATIVE

C IV



ALTERNATIVE

C V



Based on the assumptions made and explained in chapter 2 and the diagrams for each alternative tables have been prepared showing the capital investment, operation and maintenance, and energy cost per year over a 50 year period.

As an example the sheet for alternative AIII is represented as table 42. Similar tables for each of the other alternatives have been filed with the Project.

In the group "B", water will be conveyed to Famagusta town for domestic water supply purpose through the entire project period. This water is supposed to be conveyed through the existing gravity flow pipe line. It has been assumed town water supply water will be conveyed from the most distant dams, since the reduction in cost of the conveyor system will be most important. In other words; the khalassa, Polemidhia and Yermasoyia reservoirs will be utilized for town water supply in preference to the Lefkara and Dhipotamos reservoirs. In the calculations of expenditure, the installation cost

Region : Larnaca
Project : Limassol-Larnaca-Famagusta Schemes
Alternative : A III
Main assumptions : See figure 16

Table 42

Years of Project	Investments							Operation Maintenance, and Annual Costs							
	Dams	Canals	Pipes	Pumping stations	Distribution stations	Farm Equipment	Total Investment irrigation system	Dams	Canals	Pipes	Pumping stations	Distribution stations	Farm Equipment	Total O + M	Annual energy
0	1508	1063	92		57	25	1,237	3.5	21	0.5		1.4	1.0	27	
1 75	143	881			13	8	902	3.8	38	0.5		1.8	1.3	45	
2	281	880	51	50	13	8	1,002	4.4	56	0.7	1.6	2.1	1.6	66	
3	12	98			13	8	119	4.4	58	0.7	1.6	2.4	1.9	69	9
4	346				13	8	21	5.3	58	0.7	1.6	2.7	2.2	71	20
5	755	204	106	19	13	8	350	7.0	62	1.2	2.2	3.0	2.6	78	29
6 80	255				13	8	21	7.6	62	1.2	2.2	3.3	2.9	79	30
7	407				13	8	21	8.5	62	1.2	2.2	3.6	3.2	81	31
8	14				13	8	21	8.6	62	1.2	2.2	4.0	3.5	81	32
9					13	8	21	8.6	62	1.2	2.2	4.4	3.9	82	32
10					137	8	145	8.6	62	1.2	2.2	7.8	4.2	86	32
11 85					137	92	229	8.6	62	1.2	2.2	11.2	7.9	93	32
12		239			137	92	468	8.6	67	1.2	2.2	14.6	11.6	100	32
13	261				137	100	237	9.2	67	1.2	2.2	18.0	15.3	108	32
14	833		45		137	100	282	11.1	"	1.5	2.2	21.4	19.0	117	32
15	255				137	100	237	11.7	"	1.5	2.2	24.7	22.7	124	32
16 90	300			24	137	100	261	12.4	"	"	3.0	28.0	26.4	133	32
17	69			50		100	150	12.5	"	"	3.0	28	29	137	36
18						8	3	12.5	"	"	"	"	29	137	40
19						8	8	"	"	"	"	"	"	"	45
20				19		8	27	"	"	"	"	"	"	"	45
21 95						8	8	"	"	"	"	"	"	"	"
22						3	8	"	"	"	"	"	"	"	"
23						8	3	"	"	"	"	"	"	"	"
24						8	8	"	"	"	"	"	"	"	"
25						8	8	"	"	"	"	"	"	"	"
26 2000						92	92	"	"	"	"	"	"	"	"
27						92	92	"	"	"	"	"	"	"	"
28						100	100	"	"	"	"	"	"	"	"
29						100	100	"	"	"	"	"	"	"	"
30						100	100	"	"	"	"	"	"	"	"
31 5				24		100	124	"	"	"	"	"	"	"	"
32				50		100	150	"	"	"	"	"	"	"	"
33						8	8	"	"	"	"	"	"	"	"
34						8	8	"	"	"	"	"	"	"	"
35				19		8	27	"	"	"	"	"	"	"	"
36 10						8	8	"	"	"	"	"	"	"	"
37			92		13	8	113	"	"	"	"	"	"	"	"
38					13	8	21	"	"	"	"	"	"	"	"
39					13	8	21	"	"	"	"	"	"	"	"
40					13	8	221	"	"	"	"	"	"	"	"
41 15					13	92	105	"	"	"	"	"	"	"	"
42			50		13	92	155	"	"	"	"	"	"	"	"
43					13	100	113	"	"	"	"	"	"	"	"
44					13	100	113	"	"	"	"	"	"	"	"
45			106		13	100	219	"	"	"	"	"	"	"	"
46 20				24	13	100	137	"	"	"	"	"	"	"	"
47				50	13	100	163	"	"	"	"	"	"	"	"
48					13	8	21	"	"	"	"	"	"	"	"
49					13	8	21	"	"	"	"	"	"	"	"

of the Lefkara - Famagusta pipe line has been charged against the B alternatives which will have an adverse effect on the internal rate of return. This is, because a conduit with a larger capacity has to be constructed in any event.

Agricutlural benefits from the extension of cultivated areas have been calculated by the agronomy counterparts of the project and are listed on the benefit tables of each alternative. Non - agricultural benefits consist of the sale of water to Famagusta and Larnaca towns at delivery point at the established rate of 45 mils/m^3. The non - agricultural benefits for each alternative have been listed on the tables mentioned previously.

Three sets of tables are available now, giving the expenditure and benefits for the Limassol and Famagusta sub-regions and for the Larnaca region. To find the total expenditure and benefits of each main-alternative, the two sub-regions have to be combined with the Larnaca region on the basis of a closed water balance for the entire Limassol - Larnaca - Famagusta project. The following combinations have to be made :

Table 43 - Combination of regional alternatives

LARNACA	LIMASSOL	FAMAGUSTA
A I	Li 1a	O
A II	Li 1a	Fa 3
A III	Li 1a	Fa 5
A IV	Li 1a	Fa 7
A V	Li 2a	Fa 1
A VI	Li 2a	Fa 5
A VII	Li 2a	Fa 7
A VIII	Li 3a	Fa 2
A IX	Li 3a	Fa 7
A X	Li 4a	Fa 3
A XI	Li 4a	Fa 5
A XII	Li 4a	Fa 7
B I	deleted	O
B II	Li 3c	O
B III	deleted	Fa 2
B IV	Li 5a*	Fa 4
B V	Li 5a*	Fa 6

* Benfits from Limassol town water supply only.

Table 43 - continued

LARNACA	LIMASSOL	FAMAGUSTA
C I	Li 2a/CI	Fa 5
C II	Li 3c	Fa 7
C III	Li 3c	Fa 5
C IV	Li 3c	Fa 2
C V	Li 3c	Fa 1

For each of the 20 combined alternatives a table has been prepared showing for each of the 50 project years :

1. Capital investments in thousands of pounds
2. Operation and Maintenance cost
3. Cost of the annual consumption of energy
4. Total expenditure per year.
5. Agricultural benefits due to the project.
6. Benefits from water sold for the town water supplies of Limassol, Larnaca and Famagusta.
7. Total benefits.
8. Difference between expenditure and benefits.

The colums 4, 7 and 8 have been calculated by computer. A computer program is available to calculate the internal rate of return. The results are shown in table 44.

These cash-flow tables have been filed with the Project.

Table 44 - The internal rates of return

Main alternative	Internal rate of return %
A I	14.1
A II	17.1
A III	16.1
A IV	16.9
A V	14.4
A VI	15.9
A VII	16.1
A VIII	14.9
A IX	16.4
A X	14.9
A XI	14.1
A XII	14.9
B II	12.6
B IV	14.9
B V	14.1
C I	15.1
C II	16.1
C III	15.6
C IV	14.4
C V	14.4

In addition, a table has been prepared showing the following items :

1. Total capital investment for the entire Limassol - Larnaca - Famagusta region, depends on the region where most water is consumed and will vary from £18.340.000 to £5.500.000.

2. Total annual cost of operation, maintenance and energy after completion of the project.

3. Agricultural annual benefits for each region when full benefits are reached due to the project, and the year when these benefits are reached.

4. Benefits from town water supply after the year 2000.

5. Total annual benefits due to the project in its final stage.

These figures are given in table 45.

From this table the agricultural annual benefits per m^3 of water supplied to the various regions can be calculated. This has been done by summarizing the annual benefits and annual water supply per region. By division of the net benefits by the used the average benefits of 1 CM of water can be found. (Table 47)

Table 45 - Total Expenditures and benefits for the alternative schemes

Alternative	Total capital investment	Total Annual cost	Maximum benefits (Year and region): 1998 Limassol	2007 Larnaca	1987 Famagusta	2000 Town water supply	Total maximum benefits	Internal rate of return
AI	18343	236	3012	5860	-	-	8872	14.1
AII	23100	346	3012	4660	2937	-	10609	17.1
AIII	23113	351	3012	4139	2884	-	10015	16.1
AIV	23420	382	3012	3225	3880	-	10117	16.9
AV	20347	363	2376	5844	831	-	9051	14.4
AVI	23140	350	2376	4825	2884	-	10085	15.9
AVII	25518	383	2376	3911	3880	-	10167	16.1
AVIII	22129	330	1619	5863	2271	-	9753	14.9
AIX	24235	389	1619	4585	3880	-	10084	16.4
AX	24247	381	3876	3231	2937	-	10044	14.9
AXI	24307	387	3876	2662	2884	-	9422	14.1
AXII	24621	413	3876	1742	3880	-	9498	14.9
BII	17220	175	1619	1498	-	1600	4717	12.6
BIV	20578	275	-	1077	3102	1600	5779	14.9
BV	21220	268	-	511	3049	1600	5160	14.1
CI	20506	290	2376	1777	2884	710	7747	15.9
CII	21744	330	1619	1428	3880	710	7637	16.1
CIII	20640	302	1619	2340	2884	710	7553	15.6
CIV	20679	289	1619	3079	2271	710	7679	14.4
CV	18235	232	1619	4020	831	710	7180	14.4

The annual costs were computed assuming an interest rate of 7%, the total cost to be amortized over 40 years (average).

The operations maintenance and energy costs have been calculated for each alternative.

A lump sum of £30.000 per year has been added for administration costs, extension services and miscellanous, works.With the above the annual costs can be calculated for each alternative.

On the other hand we know the annual amount of surface water developed and the following items have been calculated for each alternative for pruposes of an economic comparison.

1. Total annual cost

2. Annual volume of surface water developed and consumed.

3. Cost of water in mils per cm.

4. Annual benefits due to the project when full production is reached.

5. Benefit / cost ratio.

6. Internal rate of return.

Please see table 46.

Table 46 - Economical features for each of the alternative schemes.

alter- native	Total annual cost	Surface water development m3x106/year	Cost of water mils/m^3	Annual benefits due to project	cost/ benefit ratio	Internal rate of return
AI	1650	56.4	29.4	8872	5.4	14.1
AII	2110	59.4	35.5	10609	5.0	17.1
AIII	2120	59.3	35.5	10015	4.7	16.1
AIV	2170	59.7	36.4	10117	4.7	16.9
AV	1820	55.4	32.8	9051	5.0	14.4
AVI	2120	59.4	35.7	10085	4.8	15.9
AVII	2330	59.4	39.2	10167	4.4	16.1
AVIII	2020	57.1	35.4	9753	4.8	14.9
AIX	2240	59.4	37.5	10084	4.5	16.4
AX	2230	59.4	37.5	10044	4.5	14.9
AXI	2240	59.4	37.6	9422	4.2	14.1
AXII	2290	59.4	38.6	9498	4.1	14.9
BII	1500	59.4	25.2	4717	3.1	12.6
BIV	1850	59.4	31.2	5779	3.1	14.9
BV	1890	59.4	31.8	5160	2.7	14.1
CI	1860	58.8	31.6	7747	4.2	15.9
CII	2000	58.8	34.0	7637	3.8	16.1
CIII	1880	58.8	32.0	7553	4.0	15.6
CIV	1870	58.8	31.9	7679	4.1	14.4
CV	1630	58.8	37.7	7180	4.4	14.4

LIMASSOL – LARNACA – FAMAGUSTA SCHEMES

Alternative schemes

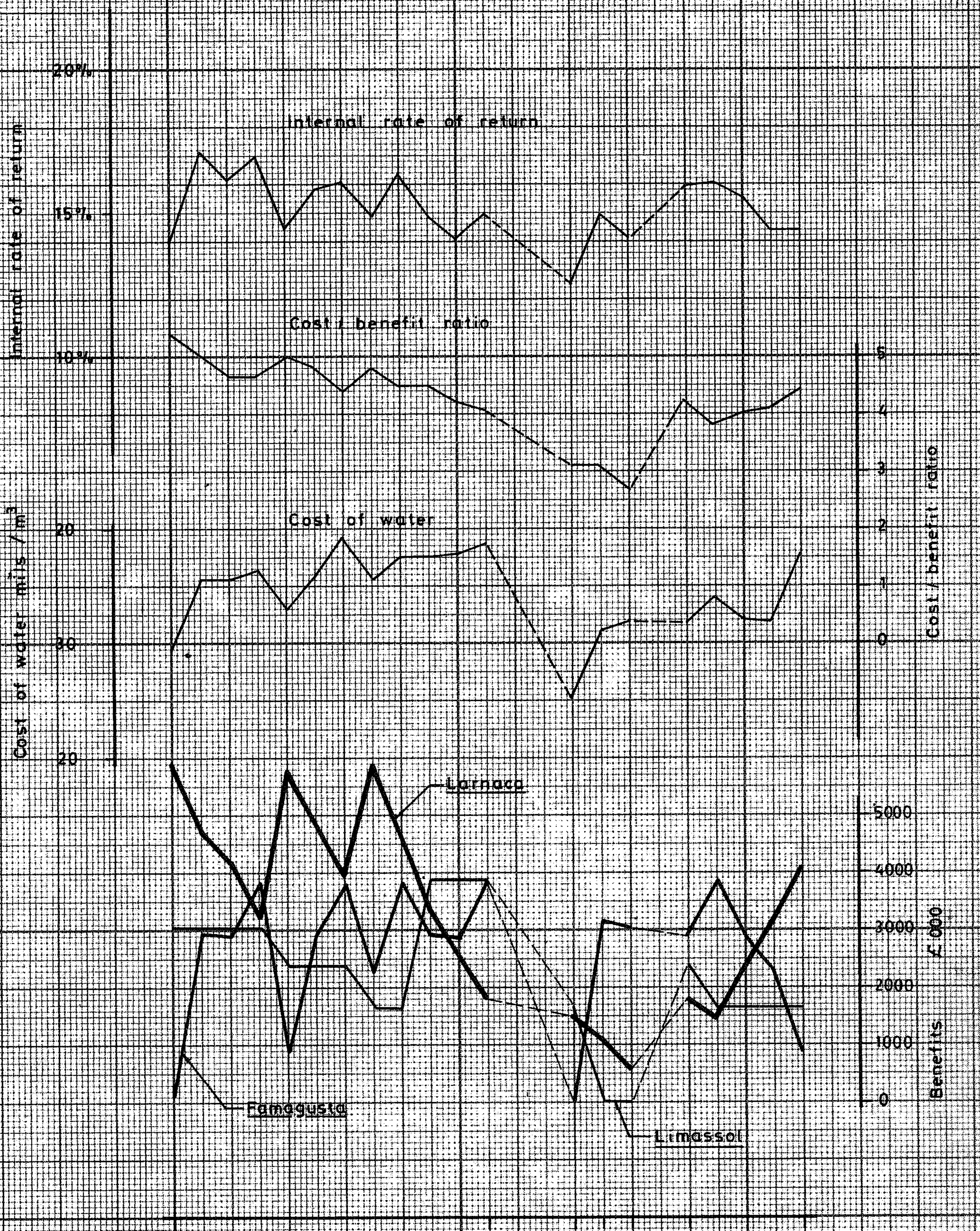


Table 47 - Average Benefits per m^3 water per region.

Region	Average benefits mils/ m3	Year when full benefits are reached
Limassol	140	1998
Larnaca	166	2005-2010
Famagusta	219	1987

The relatively high benefits in the Famagusta region are mainly due to the high percentage of cytrus plantations on the total irrigated area. These high benefits and the year when full benfits are reached have a favourable influence on the internal rate of return.

5.5 Conclusions and Recommandations

The economical features of each alternative, as shown in table 45 and 46, have been represented in figure 24. Based on these findings certain conclusions can be drawn.

However, in practice conclusions will not be drawn on these local economical features only. Also social political, traditional as well as national economical considerations will have their influence, for example :

a. The feeling of the people in the Limassol region about export of water from this region.

b. The relatively poor agricultural development in the Larnaca region.

c. The eventual decrease of agricultural exports, when no desalination plants are constructed.

d. The tourist development around Famagusta town.

e. The influence people in the Famagusta region have on the eventual import of water in order to save their agricultural benefits.

Apart from this important considerations some conclusions can be drawn on the economical considerations, which can serve as a guide line for decisions which have to be taken in the near future. This conclusions are listed below :

1. From figure 24 or table 46 it is clear there is a strong corelation between;

   a. The internal rate of return and the agricultural benefits in the Famagusta region.

   b. The cost / benefit ratio and the agricultural benefits in the Larnaca region.

2. After comparison of the alternatives AX to AXII with AII to AIV it can be seen, the cultivation of area 6 (salt lake Limassol) gives a 2.1% decrease of the internal rate of return, a decrease of the cost / benefit ratio with 0.5 and an increase of the cost of water of 2.1 mils per cubic metre.

   Therefore, it is advisable to abandon the reclanation of the salt lake.

3. Due to the difference in net return per cubic metre of water from agricultural and town water supplies of 124 and 22 mils respectively, and after comparing the CI, CII, CIV and AVI, AIX, AVIII alternatives it is found that the internal rate of return decreases with 0.26% and the cost/benefit ratio with 0.66 points.

   On the other hand the cost of water per m^3 increases by 3.6 mils for the A alternatives.

   The difference in internal rate of return and cost/ benefit ratio is not very big and depends mainly on the arbitrarily selected selling rate of water to Limassol town, being, 35 mils per cubic metre at the dam. A raising of this price to 45 mils/m^3, very well might give better figures for the C than for the A alternatives. Therefore, it is not recommanded to construct a desalination plant, serving Limassol town, before the year 2000. However, it should be noted, in the C alternatives, the agricultural benefits are about 3.000.000 £ per year lower than in the A alternatives. This agricultural products can be exported abroad and give an important revenue of foreign curvency. If this is prefered, a desalination plant should be constructed before or in the year 1985.

4. The internal rates of return and cost benefit ratio's are relatively low for the "B" alternatives, due to the cost of the existing pipe line to serve Famagusta town water supply, which is relatively expensive and has a low flow capacity only.

With regard to the construction of a desalination plant to serve Famagusta and Larnaca, the same can be said as under 3. However, for the "B" alternatives the agricultural benefits are about £6.300.000 annually, less than for the "A" alternatives.

5. From a comparison of the annual volume of water conveyed to Famagusta and the agricultural benefits in this region it can be shown, the supply of water to area 4, has mainly a negative influence on the internal rate of return and cost/benefit ratio. Therefor, it is not advisable to convey water to area 4 (Famagusta) but to use the water in the Larnaca region.

6. A comparison of table 39 and 46 shows a significant increase in the internal rate of return and cost/benefit ratio whenever the Larnaca and Famagusta regions are included in the project. Thus, the diversion of water to these regions is favourable from an economical point of view.