DEPARTMENT OF WATER DEVELOPMENT

CYPRUS WATER DEVELOPMENT

1959

BY

I. L. WARD, C.B.E., B.E., M.I.C.E., M.I.W.E.,
Director of Water Development.

APRIL 1959

NICOSIA
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"By water all things find life".
—Koran.

The history of this island, like the history of many another semi-arid land, reflects the story of its water supplies. Periods of prosperity and progress bring with them the need for water both for irrigating crops and for the amenities of civilisation, and as the population grows so does the demand for water. The population of Cyprus and its living standards are now growing faster than ever before and with them is the need for more and more water. Cyprus has no River Nile, no Euphrates, and no Jordan to bring it regular supplies of fresh water from afar and it must therefore do its best to manage with what is brought by the rain that falls upon its small surface and perhaps, in future, by purifying the salt sea that surrounds it. One of the great challenges that faces the new republic is the problem of controlling, conserving and utilising its water.

2. This report is intended to show in outline how progress in water development can be continued in the coming years and the appendices include a tentative five year programme of works and investigations. A firm programme of works will have to take into consideration many non-technical factors which are not considered here such as the availability of money, the number and quality of the available trained staff, the willingness of Government to change old-established water rights and systems of water distribution, and the capacity of the cultivators to adjust themselves to and benefit from new ideas. These matters will no doubt receive attention in due course.

3. Very large sums of money will be required for a full programme of water development but the investment will be sound both as regards domestic water and irrigation. The domestic water supply schemes are necessary to maintain and improve standards of living and they should generally pay for themselves by the sale of water. Most irrigation schemes will be highly profitable to the island as a whole as well as to those who own the irrigated land, provided of course that they are chosen with due regard to local conditions. In a few cases expensive works may be required even though there is no prospect of direct financial benefit to Government. Among these will be some of the groundwater recharge schemes which are necessarily somewhat experimental and which are needed to improve conditions and to prevent further deterioration in places where the water level is falling. In the Morphou area, where there is much private investment in agriculture dependent on groundwater, the question of recharge is of particular importance, but should be examined carefully before large sums of money are spent.

4. The overall investigation needed to determine a well planned programme of construction is itself a considerable undertaking which should be suitably phased so that it will proceed concurrently with construction but always a stage ahead. The larger schemes may take several years to investigate and plan in detail and it is therefore advisable to press on with the planning of many works even though only relatively few can be undertaken at a time.

5. If the Department of Water Development is suitably staffed it will itself be capable of carrying out most of the works envisaged in this report. In the case of the larger or more specialised schemes, however, it will be advisable to call in consultants to design the works and to supervise construction.

6. Where costs are indicated, unless otherwise stated, they cover construction only and are exclusive of any compensation for water or land acquisition. They are approximate only and intended as a rough guide to show the general magnitude of the proposed works and are not suitable for inclusion in detailed financial estimates.

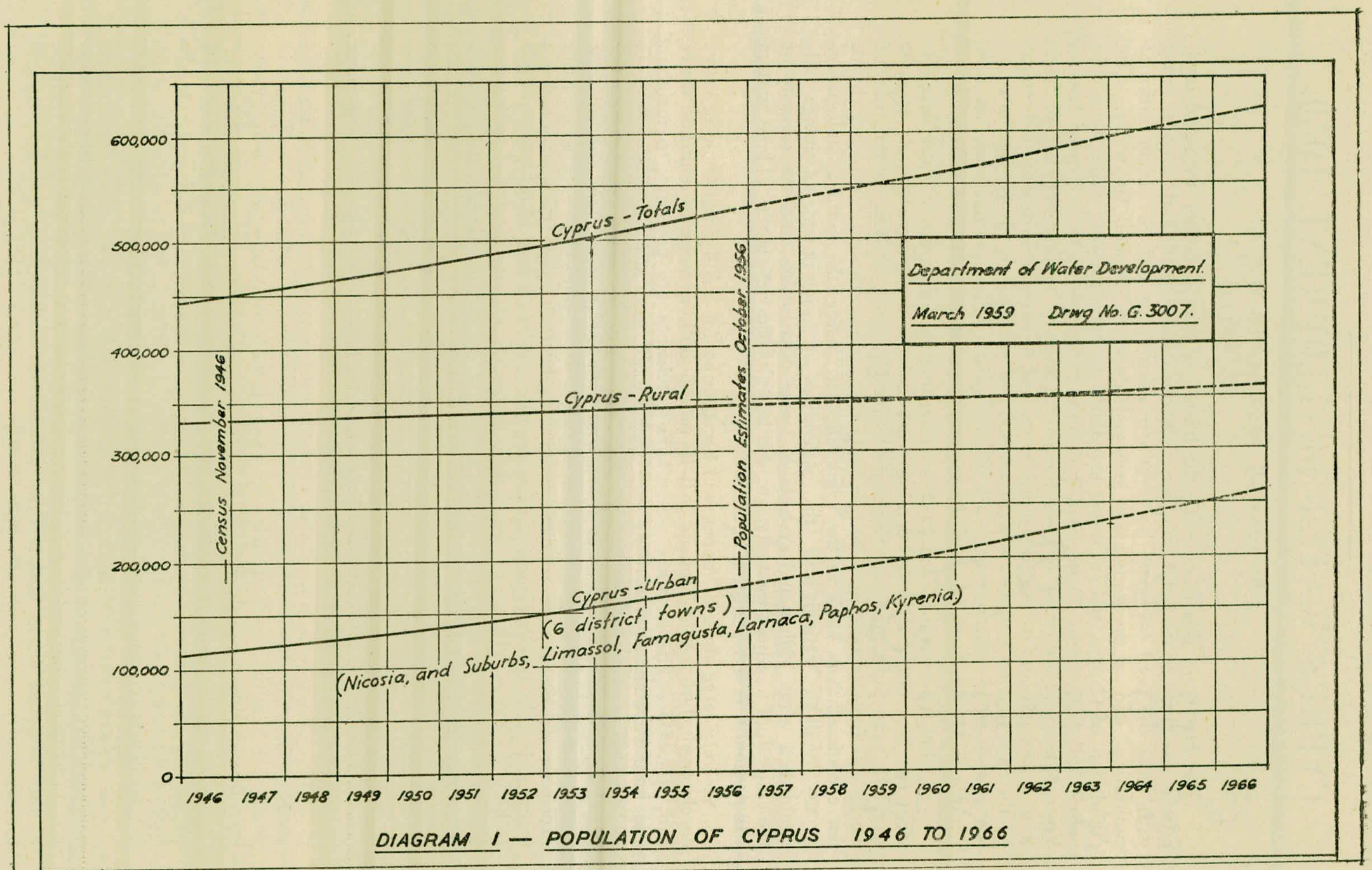

DIAGRAM 1 — POPULATION OF CYPRUS 1946 TO 1966

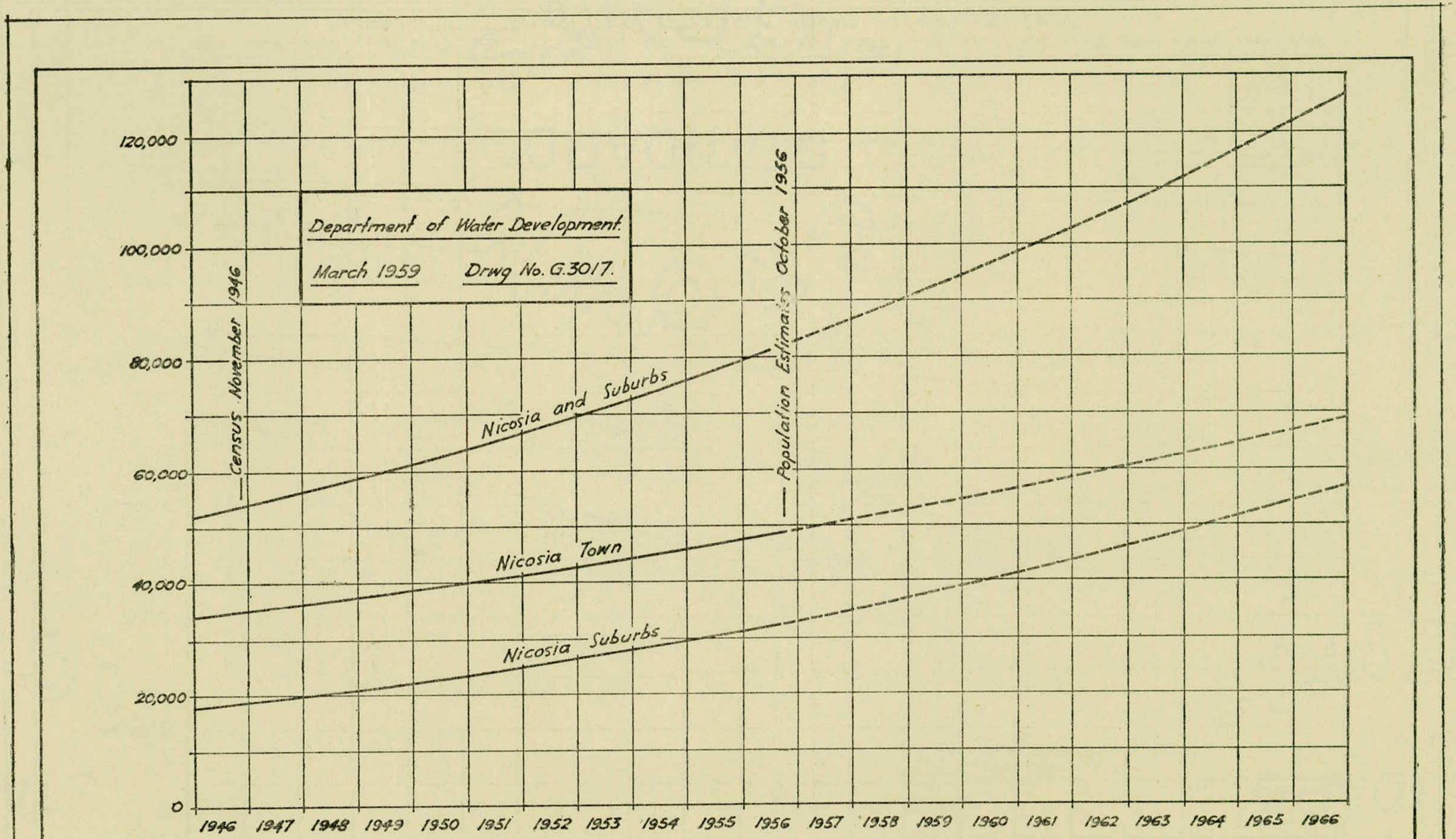

DIAGRAM 2— POPULATION OF NICOSIA 1946 TO 1966

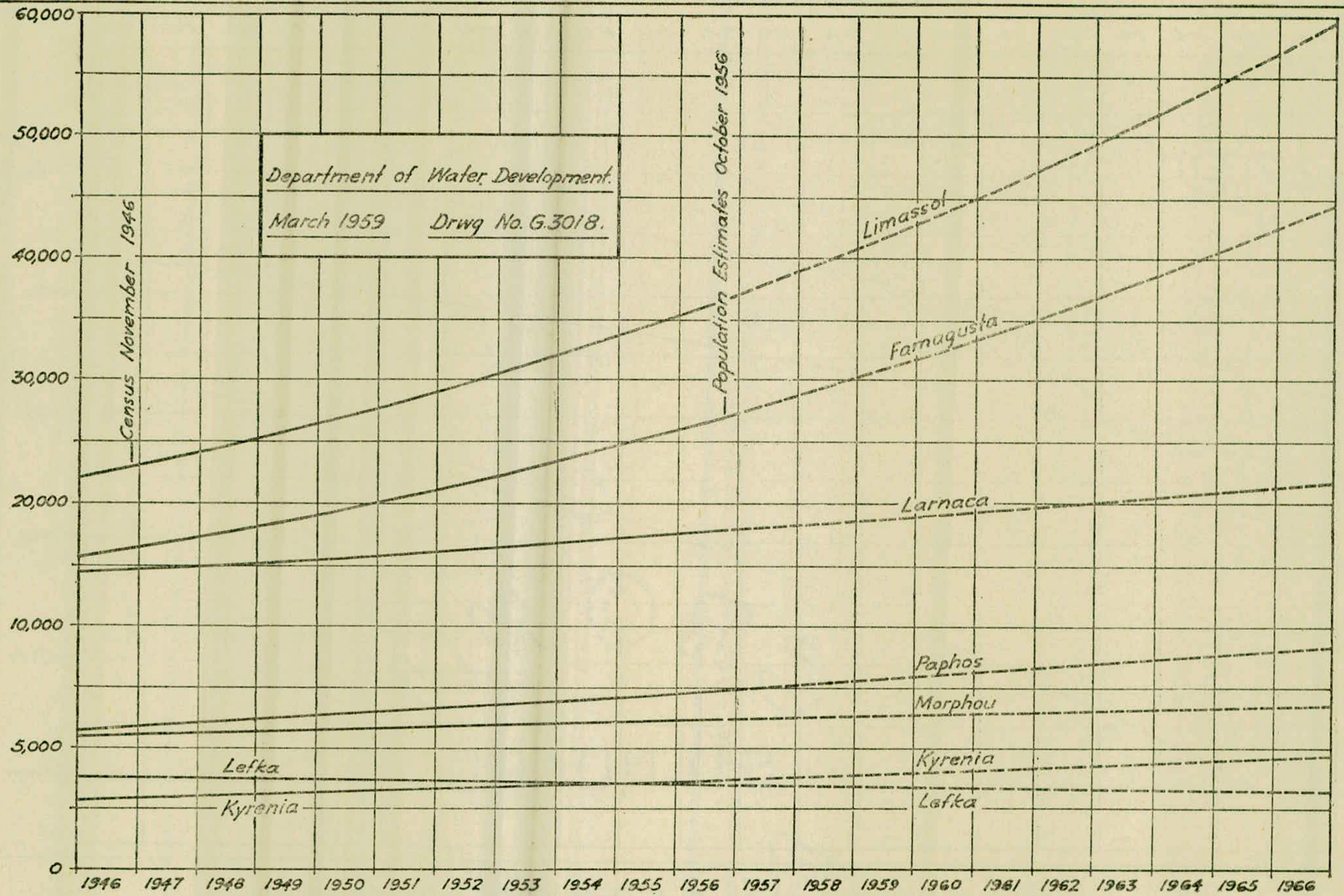

DIAGRAM 3 — POPULATION OF LARGE TOWNS 1946 TO 1966

TABLE I.—CHIEF TOWNS—POPULATION AND WATER REQUIREMENTS, 1946–1966.

Town	Population			1966—Estimate			Water available in 1959 (approx.)	Additional water required 1959–1966
	1946 Census	1956 Published Estimate	Increase 1946–56 %	Population (Round Figures)	Consumption per head per day gallons	Total water requirements mgd†	mgd†	mgd†
Greater Nicosia	53,300	81,700	53·3	125,000	50	6.25	3.00*	4.25*
Famagusta	16,200	26,800	65.4	45,000	50	2.25	1.00*	1.75*
Limassol	22,800	36,500	60.1	60,000	50	3.00	1.50	1.50
Larnaca	14,800	17,900	20.9	22,000	50	1.10	0.90	0.20
Paphos	5,800	7,300	25.9	9,000	40	0.36	0.15*	0.25*
Kyrenia	2,900	3,700	27.6	5,000	40	0.20	0.09	0.11
Morphou	5,500	6,100	10.9	7,000	40	0.28	0.25	0.03
Lefka	3,800	3,500	(—)7.9	3,500	40	0.14	0.12	0.02

† mgd = million gallons per day. * Some of present sources are failing and allowance is made accordingly in the last column.

DOMESTIC WATER SUPPLIES.

7. Much additional water is needed urgently in the chief towns and the cost of providing it will be high, particularly in Nicosia and Famagusta. The need for additional water arises from a number of causes among which are the increase in population, the rising standard of living and the establishment of water-consuming industry. The average increase in urban population was 50% in the ten years 1946-56 as compared with 6% in the villages, indicating a general drift towards the towns. The quantity of water that is required is much more than indicated by the rise in population because there is also a growing per capita consumption caused by higher standards of living. A further reason why more water is needed is that many of the wells in urban areas that formerly gave, in the aggregate, large quantities of water are now partly drying up or becoming contaminated and have to be replaced.

8. In 1946 the average summer consumption per person in Nicosia was probably of the order of 15 to 20 gallons per person per day whereas in the summer of 1958, in the Water Board area where there were no restrictions, the consumption rose to about 60 gallons per person per day. An average over the whole of Greater Nicosia, if there were no restrictions, would now probably amount to about 45 or 50 gallons per person per day in summer. Limassol and Famagusta, in the summers of 1957 and 1958, were each taking water at the rate of about 38 gallons per head per day without appreciable restriction. Having regard to the above considerations, a suitable figure to use for the design of water supplies in the larger towns over the next ten years will be say 50 gallons per head per day.

9. Fortunately planning for extensions or improvements to the water supplies is well advanced and in most cases new schemes can be started as soon as money and staff are available. Generally speaking the new sources are either boreholes or springs. These have advantages over open impounding reservoirs in that there is no interference with irrigation rights on rivers, the water needs no treatment other than precautional chlorination, there are no losses by evaporation, and the supply is not so sensitive to seasonal variations in rainfall. Only in one case, Larnaca, is an open impounding reservoir considered for a future extension.

10. Proposed improvements for the various towns are described in the following paragraphs and Table I shows the rise in population during the ten years 1946-56 and the probable requirement in 1966 assuming an average summer consumption of 50 gallons per person per day in the larger towns and 40 in the smaller. The actual population over the period 1946-56 and a forecast for 1956-66 are shown in Diagrams 1 to 3.

11. The village domestic water problem is generally not so difficult to solve as the town problem but there are nevertheless many villages that are remote from suitable sources and on the whole the cost of village works will be more expensive in the future than it has been in the past. Many additions and improvements will be required to old works and there will be a frequent demand for house connections instead of street fountains.

Nicosia.

12. The water supply of Nicosia outside the walls was formerly in the hands of some 12 or more private companies and within the walls it was administered chiefly by the Nicosia Water Commission. The sources were all wells or chains-of-wells around the town. The present Water Board was formed in 1951 with a duty to provide water within an area of supply which included the whole of the municipal area and a small part of the suburban villages. It took over most of the private companies in 1953 but not the Nicosia Water Commission. The suburban villages of Nicosia are at present supplied by the Government Department of Water Development.

13. Two large schemes were carried out by the Department of Water Development in the period 1952-59, the first for the Water Board and the second directly for Government. The 1952-55 scheme provided additional water chiefly from Kokkini Trimithia, Upper Arab Ahmed, Laxia and Makedhonitissa and it included the Strovolos reservoir and the distribution system outside the walls within the Water Board's area of supply. The 1956-59 scheme brought in more sources, including those at Sykhari, Dhikomo and Dhali, and added the Engomi, Mandres and Lakatamia reservoirs and a distribution system in the suburban villages.

14. To add still more water it is now proposed to pump from new boreholes in the Morphou Bay area through a 24 mile pipe line against a total head of nearly 800 feet, and orders were placed in 1958 for pipes, pumping plant and other equipment for the first stage of the scheme. The plans for the main pumping station and rising main were prepared by the Westminster consulting engineers, Messrs. Howard Humphreys and Sons. Outline plans are also ready for providing pressure water within the walls, which is urgently needed for a uniform distribution of the available water as well as for fire-fighting.

15. In the summer of 1958 the total quantity of water supplied to Nicosia by Government, the Water Board and the Water Commission amounted to about 3 million gallons per day, of which about 1 million gallons was from privately owned sources supplied through the works of the new schemes. This amounts to about 34 gallons per person per day for a population of 88,000. The demand was not satisfied within the walls where there are no pressure mains or in the suburbs where houses were not all connected to the new scheme. In the Water Board's area of supply outside the walls the consumption was about 60 gallons per person per day.

16. The first stage of the Morphou Bay scheme will bring in a further two million gallons per day and the second stage yet another two millions. By the time both stages are finished it is probable that some of the existing public and private sources will have diminished, particularly in the Kokkini Trimithia area. If the diminution of present sources amounts to 1.00 m.g.d., and if 4.00 m.g.d. are added then the 3.00 m.g.d. of 1958 will be increased to about 6.00 m.g.d. At 50 gallons per person per day this will be sufficient for a population of 120,000 which at the present trend will be reached in 1965 or thereabouts.

17. The cost of the completed and proposed works for Nicosia is as shown : —

	Construction Costs £	*Acquisition Costs* £	*Total* £
Scheme of 1952–55	504,000 Ac	200,000 Ap	704,000 Ap
Greater Nicosia Scheme (1957–58) ..	750,000 Ap	100,000 E	850,000 Ap
Pressure within walls (proposed) ..	125,000 E	Small	125,000 E
Morphou Bay, Stage I (Proposed)— (Pipes purchased 1958)	900,000 E	Small	900,000 E
Morphou Bay, Stage II— (Proposed)	600,000 E	Small	600,000 E
	2,879,000 E	300,000 E	3,179,000 E
or say ..	2,900,000 E	300,000 E	3,200,000 E

Ac = Actual Cost Ap = Approximate actual cost E = Estimated cost.

18. Before Stage I of the Morphou Bay scheme is completed, if the present population trend continues, it will be necessary to find more water and to plan additional works. It is perhaps possible that more water will be available from the Morphou Plain. The possibility of obtaining other water from the Kyrenia hills should also be fully explored even if it involves some expensive prospecting drilling and a large number of initial failures. Two areas that should be examined are (*a*) the southern slopes to the west of Krini and (*b*) the stretch between Dhikomo and Sykhari. If water is found in these areas it will come from natural underground storage reservoirs such as these now developed at Sykhari and Dhikomo and if not used in winter it will have the great advantage of remaining available for the summer, the period of peak demand.

19. If no suitable source of underground or surface water can be found to satisfy the requirements of Nicosia after the completion of the Morphou Bay scheme consideration may have to be given to the expensive process of distilling sea water. The processes by which sweet water can be obtained from the sea are changing and improving year by year. Insofar as one can see in 1959 the best method of de-salting sea water for Nicosia will be by combining a new electric power station near Karavostasi with a distillation plant and by pumping the water to Nicosia, probably in conjunction with the Morphou Bay scheme mentioned above. The cost of distillation under these conditions would in 1959 probably amount to between 6/- to 8/- per thousand gallons and is clearly very high compared with the cost of pumping from boreholes, which is less than 1/6. These prices are of course exclusive of the cost of pumping from Morphou Bay to Nicosia and of distribution within Nicosia.

20. The present administration of the Nicosia water supply by three separate authorities (Government, the Water Board and the Water Commission) requires revision. It will be advisable, in the writer's opinion, to form a single large metropolitan water board to include the Nicosia Municipal Area and both suburban and extra-urban villages within an 8-10 mile radius as well as the airport so that the Greater Nicosia scheme, the present Water Board's works, and the Morphou Bay scheme can all operate together as an integrated waterworks. The works of this enlarged board, including those in existence and those planned will be worth over £3,000,000 and the population to be supplied will be over 100,000 by 1960. A well qualified staff experienced in modern practice will therefore be required to operate the works and to plan for future requirements.

Famagusta.

21. Before the summer of 1952, Famagusta received its water chiefly from wells and boreholes in the Stavros quarter of the town and on the Ramparts, while an additional small quantity came from the Panayia spring by means of an ancient aqueduct. Excessive pumping had then caused the wells and boreholes to become brackish through the infiltration of sea water. The present Water Board was formed in 1951 when it took over the responsibility for water supplies from the Municipality. In 1952 the first stage of a new scheme brought in 380,000 gallons per day of good quality water from near Phrenaros and included a new storage tank at Stavros. This was followed in 1953-1955 by the second stage which added a further 500,000 g.p.d. from a new pumping area at Phrenaros North, two more main storage tanks, and a completely new distribution system. These works were carried out by the Department of Water Development for the Famagusta Water Board at a cost of £290,000. The total quantity of water available now in 1959, after the completion of the above works and other minor improvements, amounts to about one million gallons per day. This is not quite sufficient to meet the present demand in summer, when restrictions are imposed by turning off the water at night.

22. The water table at Phrenaros is falling rapidly, at the average rate of about 2.5 feet per year, and it is most unlikely that the present sources of supply will survive for many years at the present rate of pumping. A new scheme is therefore required to satisfy the increasing demand and also to compensate for the inevitable reduction in pumping at Phrenaros that will occur as the water level continues to fall. It will be seen from Table I that the percentage increase in population at Famagusta (65.4%) during the period 1946-56 was higher than in any other town and that an additional 1.75 million gallons per day will be needed to satisfy the estimated demand of 50 gallons per person per day in 1966.

23. In 1956 a scheme was prepared for supplying 1.00 million gallons per day in the first instance to Famagusta from Liopetri and Xylophagou at an estimated cost of £325,000. Some of the equipment has been ordered but otherwise the scheme is at present held up through lack of money.

24. It will not of course be possible to extract very large quantities of water for Famagusta from the Xylophagou and Liopetri areas because the villagers need all the water they can get for irrigation and because it would be unwise and unfair to deprive them of all the water occurring under their own lands. It is not therefore possible at present to foresee how the large additional requirement of Famagusta can be met after the next few years. One possibility is the use of winter water from the Kythrea spring, where large quantities are not fully utilised between November to February each year. If these were piped to Phrenaros they could be used partly for re-charging the boreholes and partly for supplying the town directly with winter water. This would enable the Phrenaros boreholes to accumulate a reserve in winter so as to be capable of producing more water in summer according to the practice already adopted at the Chiftlikoudhia chain-of-wells in Limassol. The cost of a 15″ pipe, sufficient to convey about 2.60 million gallons per day or say 260 million gallons in a winter season, would be about £350,000 which is high but possibly justifiable.

25. If the population of Famagusta continues to increase at its present rate for very many years it is probable that serious consideration will have to be given to de-salting sea-water either near Famagusta or at the Dhekelia power station. Present day costs are excessive and are of the order of 10/- per 1,000 gallons or possibly from 6/- to 8/- if combined with the generation of electric power. If, in future, better methods or cheap electricity reduce the cost of de-salting then, for Famagusta, the sea may well prove a satisfactory source for part of the town water supply.

26. If the establishment of the separate British base at Dhekelia makes it inadvisable to proceed with the Liopetri and Xylophagou scheme as proposed in 1956 then Famagusta might still take water from the Liopetri area but the Xylophagou sources would have to be replaced by others at Kalopsidha. Such a re-arrangement would require the scheme to be re-designed to the extent of omitting the Xylophagou branch of the pipeline and of reducing the size of the proposed 15″ pipe from the Liopetri collecting tank to Famagusta. The pipe from Kalopsidha should be of a large diameter so that in future it could form part of the projected scheme for recharging Phrenaros from Kythrea. To the extent that Kalopsidha lies in the direction of Kythrea it would be in the interest of the Famagusta Water Board to lay the new pipe to Kalopsidha and from the point of view of adequacy of supply there would be little to choose between Xylophagou and Kalopsidha areas if the supply for the Dhekelia base were to be drawn from Xylophagou instead of from Kalopsidha as at present.

Limassol.

27. Until 1953 Limassol obtained its water from the Chiftlikoudhia chain-of-wells within the town. These wells were overpumped and the water became brackish because of sea water infiltration. In 1951 the Water Board was formed

and in 1952-55 a new scheme was carried out by the Department of Water Development for the Board at a cost of £375,000. This brought good quality water to the town in 1953 from the three mountain springs Kephalovryso, Kria Pigadhia and Mavrommata and included the reservoir near Ayia Philia and a completely new distribution system. The three springs more than satisfy the winter demand but they are insufficient in summer. The surplus winter water is, however, discharged into the old chain-of-wells where it accumulates for use in summer. This re-charge operation has thus revived the old wells which now act as a seasonal storage reservoir of large capacity, and yield sweet water in the summer when it is most needed. In an average year the quantity of summer water now available in Limassol from the springs and the wells is about 1.50 million gallons per day. In 1957, which was a dry year, only 1.25 million gallons were available in September.

28. Outline plans have been considered for piping more water to Limassol through the existing main pipe line from the springs. This pipe is large enough to convey 1.50 million gallons per day to the town but in summer, when the springs are low, only 1.00 million gallons or less is available. To fill the pipe in summer it is proposed to pump half a million gallons or more as required from boreholes in the Kouris valley or from a gallery under the river bed. An additional reservoir in the town and other improvements are also required. The cost of these improvements, which would bring the total water available in summer up to about 2.00 million gallons per day, would be some £120,000. On the latest estimate of population this proposed scheme would now, in 1959, be insufficient to supply 50 gallons per person per day but it would enable the present rate of consumption (40 g.h.d.) to be continued until 1962.

29. The stretch of river which appears to be most favourable for prospecting according to the recently completed seismic survey, is the first 4,000 feet upstream of Erimi bridge where it is anticipated that a gallery under the river similar to that at Akhelia (Paphos) would be successful.

30. Following the establishment of sources in the Kouris valley, the next stage of development might be sought by drilling in the Yermasoyia river basin. If water is found it may be at a low level which would require pumping to the Limassol reservoir. Until successful boreholes are drilled and proved by testing it is not of course possible to estimate the cost of delivering water to Limassol from this area but as a rough guide it may be said that a supply of half a million gallons per day would require capital expenditure of the order of £100,000 to £150,000.

Larnaca.

31. The water supply of Larnaca still comes from an old chain-of-wells constructed in about 1745 by the Turkish Pasha, Abu Bekir. It is managed by the Evcaf Department. In 1941 the old open aqueducts were replaced by pipes but the "saccoraphi" system of distribution by shares was retained. Meters are now being introduced as opportunity occurs and in 1959 the proportion of the total water sold by meter was about 20%. The water available in summer varies between about half a million gallons per day in a very dry year to well over a million in a good year. In an average summer a quantity of 900,000 gallons per day is available and is sufficient to provide nearly 50 gallons per person per day. Although this overall rate is reasonably satisfactory local shortages occur in the higher parts of the town because there is no reservoir and no satisfactory zoning of the street mains into distribution areas.

32. An outline scheme for a reservoir, a new pipe line from the chain-of-wells, and the division of the town into 6 independent distribution areas was prepared in 1954 and now requires detailed planning. This scheme, together with other minor improvements, would cost about £200,000 at 1959 price levels. It would provide for the storage of water that is now frequently wasted at night, for a more uniform distribution of water to the higher parts of the town, and for the installation of fire hydrants. It would not provide more water.

33. The present volume of water, if distributed evenly by the proposed scheme, can supply nearly 50 gallons per person per day to the 1959 population (19,000) in an average year but only 25-30 gallons in a very dry year. If no additional water is provided the quantities available in 1966 will be 40-45 gallons per person per day in an average year and 20-25 in a very dry year at the present rate of increase in population.

34. No suitable sources of additional water exist near Larnaca. The small quantities of ground-water that could be tapped around Pergamos, Xylotymbou or Kiti are not likely to be very satisfactory for a permanent town supply and in any case if the water were piped to Larnaca local irrigation would suffer. The Xylophagou area may be retained as part of the British base but if not its water should be reserved for Famagusta which is in a worse plight than Larnaca.

35. Consideration may be given to an impounding reservoir in the Tremithios River just upstream of the village of Psevdas, where a suitable site exists for a large dam. In above-average and normal years this would store more water than is required for Larnaca and it could then be used for local irrigation as well as for domestic use but in dry years all the water would be needed by the town. Such a scheme would be fairly costly because it would involve an expensive dam, a 10 mile pipe line and filtration works. The total cost to Larnaca of a supply of a million gallons per day during the summer months only might be of the order of £175,000 to £200,000 excluding any compensation payments for the use of water or land.

36. If future measurements show that in dry years the above Psevdas scheme cannot supply enough water, an alternative project would be the distillation of sea water carried out in conjunction with proposed extensions to the Dhekelia power station. In that case the distilled water would have to be pumped from Dhekelia to a service reservoir in Larnaca.

Paphos.

37. The present town water supply of Ktima and Kato Paphos is drawn from a number of small sources near the town and is under the control of the Municipality. In the summer of 1958 these sources comprised 3 small springs, the Mesoyi chain-of-wells, and three boreholes and they supplied a combined average of about 150,000 gallons per day which is equivalent to 19.5 gallons per person per day of a population of 7,700. The water is distributed chiefly by saccoraphi, that is by a system of division into small shares.

38. A scheme costing £20,000 was caried out by the Department of Water Development for the Municipality in 1952. This provided a new pipe distribution system for the greater part of the town and a small reservoir of 70,000 gallons capacity. In December 1958 another relatively small scheme was started by the Department, estimated to cost £17,000, for extensions to the distribution sytem, the provision of consumer meters, and the addition of a further small source from a borehole on the outskirts of the town.

39. The present supply of less than 20 gallons per person per day is clearly not sufficient and there is some doubt as to whether the existing sources will be capable of maintaining their present output even in an average year. It is certain they will not be able to do so in a dry year.

40. A scheme has ben prepared in outline for piping water to Paphos from the Trozena springs near Yerovasa. This will involve a 24 mile pipe line of 6″ diameter and a 300,000 gallons reservoir just outside the town. The yield of the Trozena springs usually falls to a low level in summer when, in order to fill the pipeline, it will become necessary to make up any deficiency by pumping directly into it from boreholes or wells in or near the Dhiarizos river bed. The scheme is expected to deliver 300,000 gallons per day to the town at a capital cost of £200,000. Allowing for a reduction in output of the present sources the total quantity then available will be about 400,000 gallons per day, or sufficient to provide 40 gallons per person per day until the population reaches 10,000 persons which on present indications will be in about 1970.

Kyrenia.

41. The water supply of Kyrenia town is under the control of the Municipal Council. The sources which consist of two artesian boreholes in the pass on the Nicosia road through the Kyrenia Hills and several small springs in the same area, yield about 90,000 gallons per day in summer. This represents 23 gallons per person per day of the 1958 population which is estimated at 3,900.

42. Efforts spread over many years to find sufficient water from boreholes have met with only partial success and there now appears to be no alternative but to acquire water for a new scheme from the Lapithos and Karavas springs. Proposals have accordingly been made for piping up to 200,000 gallons per day from the two springs, 133,000 gallons per day from the former and 67,000 from the latter. The cost of these proposed works, including a 200,000 gallons service reservoir and some improvements to the distribution system was estimated to be £65,000 in 1957 exclusive of acquisition costs. The acquisition costs are difficult to estimate but might be of the order of £25,000 making a total of £90,000.

43. The water made available by the proposed new works combined with those now existing would amount to 290,000 gallons per day. This is more than the town requires for domestic use at present and so it might be sufficient at first to acquire only 100,000 gallons per day from the springs. This would give a total supply, including the present sources, of about 190,000 gallons per day or sufficient for a population of nearly 5,000 at 40 gallons per person. This population may be reached soon after 1966, after which more water will probably be needed.

Morphou.

44. The Morphou water supply is controlled by the Municipal Council and is drawn from a chain of wells and a borehole which in summer can produce approximately 250,000 gallons per day. This is enough to satisfy the present demand but because the distribution system is old and unsatisfactory the water cannot be distributed evenly to all parts of the town.

45. An entirely new water supply system is recommended with new sources, reservoir and distribution system. It is proposed to drill 4 new boreholes in an area about a mile to the east of the town, to build a new 300,000 gallons service reservoir near the boreholes and to lay a 15″ diameter supply main to the town to feed into new street distribution pipes none of which will be less than 3″ diameter. The cost of these proposed works was estimated to be £105,000 in 1958.

46. The population which in 1956 was 6,100 is expected to reach 7,000 by 1966, when a supply of about 280,000 gallons per day will probably be required. The new scheme, with 4 boreholes, should produce this quantity and could be extended as necessary later.

Lefka.

47. The population of Lefka was 3,800 in 1946 and only 3,500 in 1956. It is the only town in Cyprus in which the population fell in the ten years 1946-56.

48. Water from springs in the upper Kafizes valley was piped to the town in 1956 and as a result the total supply was then brought up to about 120,000 gallons per day, equivalent to 35 gallons per person of the present population. This is probably sufficient in the present circumstances but if the population increases or if standards rise it may be necessary to find additional water. This may be sought in the upper Kafizes valley or, if none is available there, from boreholes in the river gravels between the Mavrovouni mines and Karavostassi. In this latter case pumping charges will be high. Improvements to the distribution system may also be required.

Village Water Supplies.

49. Every village in Cyprus will ultimately have to be provided with piped domestic water and it is probable that in almost every case house connections will eventually be needed instead of the old-style system of street fountains.

50. Under present conditions 20 gallons per person per day is sufficient for domestic use in villages where there are only street fountains but about 25 gallons per person is wanted where there are house connections. As living standards rise the demand for water is likely to increase and it may well be that before many years villages will be demanding 30 gallons per person per day in summer or perhaps more.

51. At the end of 1958, 517 of the 627 villages in Cyprus had piped water but only 366 had water supplies that could be considered satisfactory. The number requiring new supplies or improvements was thus 261. The problem for the future is therefore first to provide water or to improve conditions in the 261 unsatisfactory villages and then, at a later date, to add house connections in the many villages which for the time being may be satisfied with street fountains. The addition of house connections will usually require more water, larger storage tanks and bigger distribution pipes and is therefore expensive. Concurrently with the carrying out of new works and major improvements there will be a continuous demand for minor improvements, increased water, and general maintenance. In some cases the yield of old sources will be adversely affected by nearby water development works and they will thus require replacement. The villages still without piped water are, on the whole, situated far from reliable sources, and the cost and difficulty of supplying them will in most cases be greater than in the past.

52. It will be seen from the above paragraphs that a long programme of development and much expenditure is required to provide every village with a satisfactory domestic water supply. In the writer's view a steady annual expenditure of not less than £250,000 per annum is required to tackle this problem. At that rate the works will take more than 10 years to complete and a higher rate of expenditure can certainly be recommended if the money is available.

GROUNDWATER.

"Have ye considered if your waters on the morrow should have sunk, who is to bring ye flowing water?"—Koran.

53. In the past ten years 2,300 boreholes have been drilled for water by the Department of Water Development and, together with older wells and boreholes and others that have been sunk privately, they now produce some 20,000 million gallons per annum. The area under pumped irrigation has risen from about 60,000 donums in 1949 to 150,000 donums in 1959, an increase of 150%. This fast development has been of immense importance and benefit to the economy of the island, but it has caused a general lowering of the water table in most pumping areas, making it abundantly evident that the high rate of expansion cannot continue and that in some places the rate of pumping will have to be reduced.

54. Among the places where the high rate of expansion cannot continue and where further drilling should therefore seldom be permitted are the well developed areas around Morphou, those in the Xylotymbou-Avgorou-Xylophagou triangle, and that between Limassol and Phassouri. Three places where pumping will have to be reduced if established wells are not to go dry or perhaps brackish are Kokkini Trimithia, Phrenaros and Pergamos. Two places that have given severe trouble in the past, the urban areas of Famagusta and Limassol, from which the town water supplies were once drawn, can perhaps be pumped at the present rate without further deterioration if proper advantage is taken of the new recharge works.

55. It is unlikely that any major areas for new groundwater production will be opened up in future but some relatively small development, which is nevertheless of considerable value, may be expected in some places after further investigation by geological examination and trial drilling. Geophysical seismic or electro-resistivity surveys may sometimes be useful. Places requiring examination by trial drilling are to be found near Yermasoyia, Polis, the western end of the Kyrenia range, and the gravel beds of many rivers including those between Limassol and Paphos and some in the Tylliria. The recently completed seismic geophysical survey will be helpful in siting prospecting boreholes in many of these places.

56. With the increasing use of groundwater and the continuing decline of the water table in many parts of the island the question of the control of pumping and the sinking of new boreholes becomes a matter of the greatest importance. If existing capital investment is to be protected it will become necessary in the common interest to restrict the output from many old established wells and boreholes as well as from new ones. This can perhaps best be done by controlling the hours of pumping and the areas to be irrigated and by limiting the size of new machinery or replacements. New boreholes should not, of course, be permitted where there are signs that an area is over-developed. If control measures are not rigidly enforced the inevitable result will be the failure or partial failure of many sources of water upon which much money and labour has been spent in the past, with resultant hardship to the owners and to the island generally.

57. Much capital has been invested both directly and indirectly in the development of agriculture and public water supplies from pumped groundwater. In some areas where supplies appear to be failing it is not unlikely that there will be a strong demand for artificial recharge works and the expenditure of large sums of money on such works will be justified providing careful technical planning and investigation indicate a reasonable prospect of success.

58. Recharge works in Cyprus will necessarily be somewhat experimental and it will be advisable to proceed cautiously. A major factor limiting the use of recharge works is the scarcity of water for this purpose, as most flood water is already used for spate irrigation and in future most of the remainder may be stored in reservoirs for direct surface irrigation. A necessary preliminary to any

major recharge scheme is therefore a series of systematic measurements spread over not less than say five years to determine the quantity of water that is likely to be available following maximum surface water development. A further technical difficulty, which will probably be different in every case, will arise from the method of introducing the surface water into the aquifer. The danger of clogging the aquifer with suspended silt will probably call for preliminary experimenting by means of trial-and-error pilot schemes.

59. Recharge works will no doubt be considered in future at a number of places where the groundwater level is declining. The Phrenaros area, from which the Famagusta water supply is now drawn, is rapidly failing and the water level is falling at the rate of about 2.5 feet per year. Unless the aquifers are replenished artificially or unless the draw-off is reduced, many wells and boreholes will go dry or nearly dry. The only suitable source for replenishing this area is the Kythrea spring where the water is not used to best advantage in the winter months, say from November to February. A 15″ pipe from the spring to the Water Board's boreholes at Phrenaros would convey about 2.60 million gallons per day or say 260 million gallons per season. This might be sufficient to enable the Phrenaros boreholes to maintain their present yield indefinitely. Some of the water could be piped directly to Famagusta through the existing Phrenaros pipe lines, a process which would save the Water Board from pumping in winter and in effect be the equivalent of a recharge operation. The pipe from Kythrea to Phrenaros would be about 28 miles long and the cost would be about £350,000 at 1959 price levels.

60. The Kokkini Trimithia area is one that would benefit enormously from artificial recharge works but unfortunately prospects of obtaining water for this purpose are not very hopeful. The most likely method is by means of a dam in the Meriki River upstream of Ayii Trimithias from which water could be piped to special recharge wells to be sited in the area of depressed groundwater level about half a mile to the south-east of Kokkini Trimithia village. A possible site for a dam may be found at N 580, E 908.

61. The Morphou Bay region would certainly benefit from artificial recharge works if water could be made available. In this case it would be necessary to use flood water which would have to be stored in expensive reservoirs formed by dams in the chief rivers and thereafter piped to a suitable recharge site which could no doubt be found in the area of the former Syrianokhori marshes. The water would probably have to pass through sand filters to remove suspended silt before passing into the aquifers. A possible storage site, if there is sufficient water in the river, might exist on the Elea river bed where an earth dam is feasible just upstream of Elea village. Other sites might be found on the Skylloura River (about 2 miles south of Skylloura village) and perhaps on the Ovgos near Kyra and on the lower Serakhis about a mile below the bridge on the Morphou-Myrtou road. All these works would, however, be very expensive and they should not be embarked upon until measurements show that sufficient water is available to justify the works and until pilot experiments indicate that the water can be introduced satisfactorily into the aquifers.

62. The Morphou Bay area derives its groundwater partly from the rain that falls directly upon it and partly from the rain of the eastern Troodos mountains which flows on the surface down the rivers to the plains where it then percolates into the porous ground and so into the underlying aquifers. Very little rainwater can be retained in the igneous rocks of the mountains which are dense and virtually impervious. Of the rain that falls on the hills, the lesser part, less than 20%, reaches the porous plains and is thus available thereon either for direct surface irrigation or for the natural replenishment of the aquifers ; the larger part, more than 80%, is lost by evaporation or consumed by transpiration in the hills, and most of the transpiration occurs in forest areas. It is an

established fact that tree growth, although sometimes useful in reducing the frequency of flooding, is expensive in the use of water and in Cyprus it is probable that the forests consume twice as much water in transpiration as all the irrigated crops together. Large scale tests in America, England, Holland and elsewhere have shown that stream flow can be increased by the removal of forests and there would seem to be no reason why this should not be done in Cyprus.

63. Having regard to the vital necessity of maintaining and improving the groundwater yield of the Western Mesaoria, it is therefore for consideration whether the forests growing in the upper catchments should be removed for the purpose of increasing stream flow. The progressive reduction of the Adelphi Forest, combined with soil conservation works, and carried out in conjunction with measurements of flow on the Elea and other rivers would provide useful information regarding effects of the Cyprus forests upon stream flow and upon the island's main natural underground reservoir in the Western Mesaoria. The cost of the removal of the forest and the necessary soil conservation works would no doubt be met by revenue obtained from the sale of timber. It should be remembered that as much as 19% of the island is forest land, a percentage which might with advantage be reduced in view of the demand for water and land for agricultural purposes.

RIVER TRAINING AND LAND DRAINAGE.

64. The rivers of Cyprus are dry or nearly dry for most of the year and it is only after heavy rain that they carry much water. In many cases the river beds consist of broad unstable stretches of gravel and silt which even in high flood, are seldom wholly covered with water owing to the natural tendency of a stream to wind from side to side between the widely separated permanent banks. In these conditions it should be possible to confine the river to a relatively narrow central channel and to reclaim a strip of land on either side. Some of this land might be too stony for agriculture but much of it is comprised of good alluvial soil which could be cultivated after the removal of the larger stones. Frequently ground-water from under the river bed is available for irrigation.

65. Although some minor and more or less experimental work has been done here and there in reclaiming riverside lands or in protecting them from erosion, no large scale river training has yet been attempted in Cyprus. However an engineering survey of the Akaki river bed from Meniko to Morphou was completed in 1958 and in 1959 plans were drawn up for restricting the whole of this twelve miles of river bed to a carefully aligned channel only 250 to 300 feet wide in place of its present width of up to 1,000 feet or more. The method proposed for keeping the river within the stabilised channel includes a combination of reinforced concrete wired staking and gabion groynes and the average cost is estimated at about £6,000 per mile. This is exclusive of the cost of clearing the reclaimed land of large stones and of other agricultural measures necessary to make it fit for cultivation.

66. It is suggested that since this is a new type of work in Cyprus it must be considered as experimental and it will be advisable to carry out only one or two miles in the first instance in order that results may be observed and the nature of the works modified or changed as necessary. It will be useful to observe closely the actual cost of such works for comparison with the benefits.

67. Among the river beds that appear to be suitable for reclamation by the above means are those of the Ezuza, Xeros, Dhiarizos and Sarama rivers in the Paphos District, the lower Xeros near Lefka, and the Elea, Serakhis, Peristerona and Akaki rivers in the Western Mesaoria.

68. River training of a different type will eventually be required on the Lower Pedias and Yialias rivers where they cross the Eastern Mesaoria. In this region works will consist chiefly of re-alignment and widening so that flood water will get away easily without causing damage by erosion to the soft clay soil.

69. A new and carefully designed main drain and flood channel is required between Kouklia Reservoir and the sea. All but the largest floods will of course be retained in the reservoir or used for recharging the Famagusta aquifers but there is nevertheless a need for a through flood channel to carry excess water to the sea. This through channel will be required to serve also as a main drain for the low-lying saline lands which under present conditions are probably deteriorating under the accumulation of salts from evaporating irrigation and drainage water. The impervious soil and sub-soil in this region does not permit of natural vertical drainage into the underlying aquifers as in the case of the Western Mesaoria. The proposed main drain, together with a system of tributary drains, will enable both irrigation and rain water to wash out the soil and to carry away salts in solution. This process continued over a period of years should reduce the salinity of the soil and make it fit for better agriculture.

70. The Kouklia main drain, as described in the foregoing paragraph, will have to be provided with a system of feeder drains and flood channels to collect water from both north and south. Those from the south will collect such drainage from Akhyritou and the Ayios Lucas recharge system as cannot be

used for recharge while those from the north will be chiefly extensions or improvements to the natural drainage lines for the purpose of disposing of flood water without damage. To provide for the washing out of the saline land for agriculture numerous ditches will be needed to connect with the main tributaries.

71. Cyprus has few fresh-water marshes requiring drainage but some works will no doubt be required along the coast north of Larnaca and at Akrotiri. In neither of these two cases should the water table be lowered below sea-level because of the danger of infiltration of salt water. Around Larnaca a satisfactory method drainage would appear to be that used successfully in the St. Lazarus area where perforated concrete pipes were laid in ditches surrounded by gravel. At Akrotiri pumping will be required and the water should be used either for surface irrigation or recharge. At Syrianokhori it now seems unlikely that an elaborate drainage scheme will be needed because of the general lowering of the water-table in that area by widespread pumping for irrigation. Any surplus surface water could no doubt be got rid of by vertical drainage through boreholes, which would thus serve for artificially recharging the aquifers.

72. In all drainage works such as those described in the several preceding paragraphs the question of maintenance is of the greatest importance. There is little profit in carrying out expensive works if they are permitted to become ineffective through lack of regular attention. An example of how a formerly useful drainage system has become of negligible value exists in the Akhyritou-Famagusta area where the old drains excavated near the turn of the century have now almost passed out of existence. Part of this system has recently been revived by the construction of the Ayios Kendeas drain and its tributaries near Akhyritou and the Ayios Lucas recharge drain.

73. In a few places some fairly costly river training works will be required to protect buildings and streets from flood damage. The most notable requirement in this category is the River Pedias where it passes through Nicosia. Here an engineering survey is needed in order that plans may be prepared for realigning the banks of the river from Lakatamia to Mia Milea. After an alignment is decided upon works should be carried out by stages to stabilise the river's course within the planned fixed limits. For this purpose groynes would be suitable in some places and concrete walls in others. Thereafter all development near the river such as roads, buildings and tree planting should conform to the new alignment without encroachment and without in any way interfering with or influencing the free flow of the river.

74. The floods of some rivers may be controlled by building detention dams to hold back flood peaks and to release the water slowly. Reservoir capacity used for flood control in this way is not available for storing irrigation water for a long period because, to be effective, a flood control reservoir must be kept empty in readiness to receive an unexpected flood. Winter irrigation, however, may benefit because the water in being released slowly is under some control and may be diverted from the river into small channels which would not be big enough to take all the water of a high flood. Dams for flood control have been proposed for Aradhippou and Exometokhi and many others are no doubt possible but under Cyprus conditions they may be found to be expensive in comparison with the value of the protection they provide.

SURFACE WATER IRRIGATION AND STORAGE.

75. In the past decade the irrigated area of Cyprus has increased by 36% from about 440,000 donums to 600,000 donums. More than half of the increase of 160,000 donums is the result of sinking boreholes for pumped irrigation and less than half is the result of gravity irrigation works. For reasons explained in the Groundwater section of this report it is unlikely that any further large expansion of borehole irrigation will take place. Future development of irrigation is therefore likely to arise from improvements in the utilisation of surface water resources rather than from the extraction of more underground water. Because of the great need for irrigated crops and the scarcity of water it will pay to spend large sums of money upon irrigation works and in 1959 the limit of justifiable expenditure under the most promising circumstances is probably as high as £300 per donum.

76. It would seem that the means by which the island's surface water resources can be fully utilised for irrigation will be chiefly the following : —

(*a*) The lining of irrigation channels and the piping of irrigation water to prevent losses between source and field.

(*b*) The improvement of irrigation methods and practices so that waste is prevented by using no more water on a crop than is necessary to produce the best economic yields.

(*c*) The storage of water in impounding reservoirs to prevent wastage to the sea.

Lining of Irrigation Channels.

77. In recent years the benefits of lining irrigation channels in concrete have become well known to Cypriot irrigators who have learned that lined channels prevent wastage of water by leakage, save time in irrigating, and require less maintenance than earth channels. Over the past eight years the Department of Water Development has spent about £500,000 in lining 125 miles of channels at numerous places throughout the island among which are the Solea Valley, Lapithos, Trimiklini and Kythrea. The last named is the largest single work of this type so far completed and comprises some 18 miles of channels costing £80,000.

78. Many schemes involving the lining of channels await execution, some fully planned and others still requiring examination. Among the existing earth channels to be lined are those at Syrianokhori, Kato Lakatamia, Pano Zodhia and Angolemi, Polis and the lower Kouris. A large lined trunk channel will be of great value to the Solea Valley and should be carried out as soon as an improved distribution schedule is worked out and agreed upon by the present irrigators. Many miles of lining will also be wanted for distribution channels to carry water from future dams to new lands not yet irrigated. Government will be well advised to spend large sums of money on works of this description as the saving in water and the consequent extension of irrigation and the increase in production will soon repay the capital expenditure.

Improvement of Irrigation Methods and Practices.

79. It is not generally realised to what extent agricultural production can be increased by the better use of the water that now reaches the fields for irrigation. The ordinary irrigator applies water to his field according to the methods used by his forefathers, or according to what he thinks is necessary, or perhaps according to what is available to him at any particular time or season. He is well aware in a general sense that some crops need more water than others and that more water is needed at certain times of the year or at certain periods of growth than at others. He is not, however, aware of the extent or degree to which his crops

would benefit or suffer from too much water or too little water, or from a fast application of water or a slow application of water, or from a given quantity supplied early in the season as compared with the same quantity supplied later in the season. Similarly he knows little of the tolerance of different crops to brackish irrigation water or of how the use of brackish water can be extended by occasional sweet water irrigations or by good subsoil drainage.

80. In Cyprus the quantity of water that can be made available for irrigation will never be sufficient to irrigate all the cultivable land. To obtain the maximum possible overall agricultural production it will therefore be necessary to use every unit of water to the best advantage, and the most favourable economic yield is likely to be the best yield per unit of water rather than the best yield per unit of land. In other words it may pay to distribute the available water over a large area, even though the crop yield per donum is not the highest rather than to irrigate some areas intensely leaving others entirely without water.

81. In order to obtain the best economic yield per unit of water it is necessary to adapt irrigation methods and practices to local conditions which, in Cyprus, vary from village to village. Some of the factors to be considered are the climate, the weather, the physical and chemical properties of the soil, the chemical properties of the water, the availability of the water at different seasons, and the nature of the crop. These may differ greatly within a space of a few miles, for instance between Pedhoulas in the hills with its deciduous orchards and Lefka in the foothills with its citrus groves. It is therefore impossible to lay down general rules to cover all the many conditions which vary so much from place to place.

82. Research carried out in other countries will always be very helpful in providing useful information for the efficient use of water in Cyprus but it cannot provide all the answers to local problems, which must be settled by research on the spot. It is suggested therefore that a Water Use Research Station should be set up in Cyprus for the purpose of carrying out practical experiments with a view to advising irrigators on the irrigation methods and practices that are most likely to produce the best economic yield under each particular set of local conditions. Such a station might consist of a large central headquarter farm in the Morphou area controlling numerous small experimental plots in villages throughout the island. Expert specialist advice will be required for settling it up and well qualified staff will be needed for its operation.

83. It is not inconceivable that the introduction of better irrigation methods and practices in Cyprus will eventually increase the yield of early summer and perennial irrigation by say 20%, in which case the annual value of production from irrigated lands will be increased by several million pounds annually. The capital cost of establishing the station is likely to be less than £200,000 under present price conditions.

Storage of Water in Reservoirs.

84. In order to control and conserve flood water and thus to prevent its waste into the sea a large number of dams will be required in Cyprus. The aim should be at least on every large river and sometimes several.

85. A start has been made by the construction of a number of dams in recent years, and 17 small impounding reservoirs are now in operation with a combined storage of some 1,150 million gallons. The highest of the existing dams was recently completed at Trimiklini ; its height is 105 feet above foundation and its storage capacity 55 million gallons.

86. The cost of dams in Cyprus, compared with the cost in other countries, will usually be high in relation to storage capacity as the valleys are usually too steep and narrow to hold large quantities of water without disproportionately

high dams. Because of the extremely high value of water for early and late summer irrigation, and of its scarcity, there are, however, many places where the construction of dams up to about 100 feet high or more will be economically sound. A preliminary assessment of the possibilities made on the basis of information available in 1959 indicates that under present conditions at least 25 or 30 additional dams of this type are likely to be feasible in practice both technically and economically. Changing economic conditions and a growing population may well give rise to the need for a still greater number.

87. Investigations for many large and small dams that can be built as money becomes available have been made by the Department of Water Development and in some cases plans have been completed and construction could start as soon as required. In other cases further investigation and planning is necessary, or the schemes that have been prepared are dependent upon the adjustment of water rights. There are also many other sites which have not yet been examined and which may turn out to be suitable when they are examined in due course.

88. A list of 31 sites that are probably suitable for impounding dams together with approximate information regarding height, capacity, cost, etc., is included at Appendix III.

89. Among the dams which could be started at once are those at Pyrgos (Katouris), Marathassa, Ay. Marina and Argaka-Magounda. Estimates for these works have been put up to the villagers and in one case (Pyrgos) work was actually started and the dam was half built when operations were stopped during the disturbances. At both Marathassa and Ay. Marina some work has been done on the distribution system but a start has yet to be made on the dam itself. The Argaka-Magounda scheme has not yet been started.

90. Considerable improvement works are possible on the Akaki River and its tributaries where detailed investigations have been completed in respect of 5 dams, the highest of which will be some 112 feet above the river bed. The uppermost dam (Sklidros) will benefit Palekhori village and three others (Spithia-tous-Papadhes, Satas and Malounda) will provide summer water for Meniko and Akaki. The fifth, which is on the Gourri branch of the river is for Kalo-khorio, Klirou. Applications from the villagers have been received for the Sklidros and Kalokhorio dams but because the water rights probably belong to Meniko and Akaki it will be necessary to come to an agreement among all the villages before work can proceed. It is suggested that one of the lower dams and a lined channel down to the Kourkousa intake near Meniko should provide suitable compensation for the lower villages. The cost of these five large dams, together with the conveyor channel to the Kourkousa intake will amount to about £800,000. If the Spithia-tous-Papadhes and Malounda dams are omitted in the first instance, as may be advisable, the cost will be about £425,000. These costs are exclusive of the acquisition of any land or water that may be required.

91. In the upper Pedias River there are several sites that are topographically and geologically suitable for irrigation dams but there will not be sufficient water for them all. Near Kambia there is a site which is very favourable as regards storage capacity but which has for long been suspect geologically. Recent investi-gations, however, have produced favourable results and the site may now be accepted provided that reasonable precautions are taken with the construction of the foundations. An alternative would be two smaller dams near the deserted village of Philani, one opposite the village and the other half a mile downstream at Lekani locality. The dams of this paragraph would benefit Politiko, Pera, Episkopio and Psomolophou and possibly Argates and Anayia.

92. Two large dams are feasible in the Kouris river near Saittas, upstream of the existing Trimiklini dam. The first would be used by Lania village which has already submitted its application and the other by Dhoros and Monagri. A

common main pipe would carry the water from the two reservoirs to a point near Lania at which it would divide into two branches, one for Lania and the other for Dhoros and Monagri. The cost of the two dams and the main pipe exclusive of distribution channels would be of the order of £325,000.

93. The proposed dams described above are all in the deep narrow valleys of the basic igneous or volcanic rocks of the central part of the island and they will therefore all be built of concrete, but in the northern half of the island, in the clay of the Kythrea beds which form the southern foothills of the Kyrenia range, suitable reservoirs can be formed by means of long low earth embarkments which will be cheaper. Preliminary investigations which appear promising for earth dams have been made at a number of places which include Skylloura (N 865 E 716), Geunyeli (N 754 E 985), Knodhara (N 814 E 309), Lapathos (N 821 E 449) and Koma tou Yialou (N 956 E 730).

94. A large number of investigations at other sites throughout the island has been made and some are included in the list of Appendix III. Some rivers not yet examined and which require investigation are the Pomos, Yialia (Polis), Stavros Psokas, Ezuza, Upper Xeros (Paphos), Upper Dhiarizos, Khapotami, Yermasoyia, Vasilikos, Syrkates and Ovgos. In a few cases such as Kafizes (Lefka) and Perapedhi additional dams may be required near those already existing in order to supplement the supply of stored summer water.

95. The Department of Water Development, at its present strength, is capable of undertaking the construction of only two large concrete dams at any one time. Since each dam would normally require nearly two years for completion this means that under present conditions, dams can be built only at the rate of about one a year. In the writer's view the capacity for dam construction in Cyprus should be stepped up so that about ten are under construction at a time and say 5 are completed each year. To achieve this rate of progress the employment of consulting engineers for design and supervision, and contractors for construction might be advisable. This would also make possible the employment of modern methods of design and construction so that many of the dams could be of the arched type which requires less concrete than the gravity type now in use. The cost of dam construction would then amount to some £400,000 per year.

LEGISLATION.

96. At the time of writing there are seven principal water laws in Cyprus. In the writer's opinion two of these need considerable amendment and in addition two new laws are required on other subjects relating to water.

97. The present laws are : —

1. Government Waterworks Law.
2. Irrigation Divisions (Villages) Law.
3. Irrigation (Private Water) Association Law.
4. Water (Domestic Purposes) Village Supplies Law.
5. Water (Development and Distribution) Law, 1955.
6. Wells Law.
7. Water Supply (Municipal and Other Areas) Law.

Of the above seven laws, the last two require amendment. Additional legislation is required to cover Land Drainage and the special case of the Nicosia town water supply.

98. The Government Waterworks Law vests most underground water and all waste surface water in Government and it provides machinery for ascertaining the nature of water rights and for making surveys to determine the practicability of undertaking waterworks. The Irrigation Divisions Law and the Irrigation Association Law are similar to each other in that they both provide the means for land and water owners to combine together for the purpose of executing and maintaining irrigation works. The individual members of a Division have no private rights to the use of the water, which is controlled by an elected committee. Members of an Association on the other hand retain right to private ownership and an elected committee has a duty to regulate the water so that each member receives his correct share. Government usually provides greater financial assistance to a Division than to an Association. The Water (Domestic Purposes) Village Supplies Law provides for the setting up of Village Water Commissions to supply domestic water to villages.

99. The Water (Development and Distribution Law), 1955 provides for the compulsory acquisition of privately owned water where it appears to the Governor that its better use and equitable distribution, or the execution of an island wide policy relating to water, may be more effectively secured thereby. Upon the declaration of an Area under this Law a committee appointed by the Governor takes over the control of all water rights, and waterworks within the Area. This relatively new law has so far been used only once, for the acquisition of the Kythrea spring and the supply of domestic water to 13 villages in the Eastern Mesaoria, but it was framed also with the object of facilitating water development by catchment areas. For instance the full development and canalisation of water in the Solea, Kouris, Akaki and other large valleys is unlikely to proceed efficiently without the use of this law either in its present form or after some modification.

100. The Wells Law provides that no well or borehole may be sunk without a permit and that private well drillers must be licensed. Where special measures are necessary for the protection of groundwater sources the sinking of new wells may be forbidden. The very great expansion in the use of groundwater over the past decade and the consequent general lowering of the water tables of the main pumping areas has caused this law to become out of date, in spite of amendments in 1951 and 1953. Additional powers are now required to provide for the inspection of all wells and boreholes by Government officers, and to control the repair and replacement of old wells, the works carried out by private drillers and, what is most important, the quantity of water extracted from over-pumped areas. Because of the many changes needed to bring this law into line with present-day requirements it may be advisable to re-write it in its entirety rather than to add amendments.

101. The Water Supply (Municipal and Other Areas) Law provides for the setting up of Water Boards to manage urban water supplies. A Water Board of any particular town is comprised of three members appointed by the Governor and three nominated by the Municipal Council. This Law will require amendment to enable the Turkish Municipal Councils to be represented when they are set up. A number of relatively minor matters, some of them relating to fire-fighting, should also be included in the amendment.

102. A new law is required to cover the special case of Nicosia Water Supply. This should provide for a new water authority to take over the existing water-works which consist of the Government's Greater Nicosia Scheme, the works of the present Nicosia Water Board and those of the Water Commission. It will also be advisable in the writer's opinion to provide for the same new authority to take over the airport water supply and all village supplies within an 8 to 10 mile radius of Nicosia.

103. A Land Drainage Law is required to provide for the maintenance and improvement of rivers, the execution of river training works and the prevention of the pollution of streams. The latter is particularly necessary for the prevention of the contamination of irrigation water. A draft bill has been prepared but is being re-examined following a proposal to combine it with land reclamation.

REVIEW OF REQUIREMENTS.

104. It wil be seen from this report that many expensive works are required if the best use is to be made of the island's valuable but limited water resources. A comprehensive programme of water development may be divided into the four following parts : —

(*a*) Investigations and Planning of Major Schemes.
(*b*) Domestic Water Supplies.
(*c*) Groundwater Development and Control.
(*d*) Irrigation including dam construction, river training and land drainage.

Investigations and Planning.

105. If money and effort is not to be wasted it is essential that the planning of all major schemes and of all programmes of works should be carried out carefully and thoroughly. To obtain the necessary basic technical information a large staff will be required for collecting and analysing hydrological and geological data, for making engineering surveys, and for preparing detailed designs of works. Because it is frequently impossible to know beforehand if a proposed scheme is feasible, or if it is to be preferred to some alternative proposal, it will be necessary to examine many more schemes than are actually executed ; and because the planning takes so long it is necessary to start well in advance even though the money for construction is not in hand or in sight. The degree of success which a large scheme may obtain, both as regards the cost of construction and the subsequent operation may well depend upon the care exercised in planning.

Domestic Water Supplies.

106. The most urgent schemes are those for Nicosia and Famagusta. Fortunately these schemes have already been prepared and construction can start as soon as money is available except that in the case of Famagusta, if the Kalopsidha sources are to replace those at Xylophagou some re-designing is necessary. Work can also start if required upon the Kyrenia town improvements. In addition to the construction of works, many investigations are needed for town water schemes, among which are the following : —

(*a*) *Nicosia.*—To provide for the future, the completion of the drilling and testing of the boreholes for Stage II of the Morphou Bay Scheme is required together with the preparation of detailed designs. Prospecting in the western Kyrenia Hills should now be started.

(*b*) *Famagusta.*—If water from Xylophagou is not now available plans for pumping from Liopetri should be adjusted and if water is to be piped from Kalopsidha a scheme should now be prepared. Preliminary surveys could, with advantage, be started for piping winter water from Kythrea to Phrenaros, for recharge and direct consumption. Investigations regarding the possibility of de-salting sea water are required.

(*c*) *Limassol.*—It is most important that trial boreholes near the Kouris and perhaps a gallery under the river should be proceeded with at an early date so that the sources will be available for the next stage of development. Prospecting in the Yermasoyia area should also proceed.

(*d*) *Larnaca.*—Surveys for new works to utilise the present sources are needed together with investigations for future additional water from Psevdhas and from the sea by distillation.

(*e*) *Paphos.*—Trial boreholes are needed in or near the Dhiarizos river bed to ascertain if sufficient water can be found to supplement the flow of the Trozena springs in summer so that the proposed 6″ pipe line will always run full.

107. The organisation and technical management of the urban water supplies is most important. The present system of water boards is reasonably satisfactory in the dictrict towns but in Nicosia a new authority is required to control all water supplies within about a ten mile radius of the town centre and to be responsible for future planning as well as for normal day-to-day operation. Good technical management of all urban water supplies is of course essential if the works are to be properly maintained and if revenue is not to be lost through wastage of water. If, however, qualified and experienced officers of the Department of Water Development are available to advise the water boards of the district towns these smaller boards might perhaps carry on for the present without engaging highly paid staff. With regard to Nicosia, it is the writer's opinion that fully qualified staff with experience of modern water supplies should be employed directly by the town water authority.

108. The planning and execution of new village water supplies can best be carried out according to demand. Maintenance will be an increasing problem and there will doubtless be many requests for improvements. A larger proportion of new works should be planned to be suitable for future house connections. It is important that village water supply works should be carried out at a steady rate of annual expenditure in order that staff may be kept continuously employed and so that materials may be ordered regularly in advance.

Groundwater Development and Control.

109. Only relatively minor extensions in the use of groundwater are expected but the possibility of artificial recharge should be studied in a number of places in particular at Phrenaros, Morphou Bay and Kokkini Trimithia.

110. Careful consideration should be given to improving natural recharge by removing hill forests from places where they prevent the water from reaching the aquifers, which exist mostly on the plains. It is probable that if the forests on the impervious north-eastern slopes of Troodos in the Adelphi area were progressively removed more water would descend to the central plain where it could be used either for surface irrigation or for replenishing the aquifers.

111. In many cases heavy pumping is continually lowering the water table and artificial recharge is not feasible. In such cases it is now necessary to try to control and limit the quantity of water pumped both by prohibiting new drilling and by regulating the output from existing wells. This latter will undoubtedly prove most difficult in practice but it may perhaps be achieved by limiting the hours of pumping throughout a controlled area to certain periods of the day as well as by placing restrictions on the size of the pumping machinery, and the area irrigated.

Irrigation.

112. Here the best prospects for improvement lie in saving water by lining irrigation channels, by the improvement of irrigation methods and practices so that water will not be wasted after it reaches the cultivated fields, and by building dams to prevent valuable flood water from passing out to sea. The lining of channels can be carried out by the Department of Water Development at a steady rate more or less in accordance with demand but the maximum improvement of irrigation practices can be obtained only by setting up a Water Use Research Station. Dams for surface water conservation can be built with advantage in large numbers but they require much advance planning which should proceed at once on an island-wide scale whether or not money is immediately available for a large scale programme of construction. Land can be reclaimed by river training and drainage works which may be carried out according to demand.

113. In each of the years 1957 and 1958 the annual expenditure of the Department of Water Development from all sources was just over one million pounds. Having regard to the high value of water in Cyprus for irrigation and domestic use, the disastrous effects which might result from the deterioration of many groundwater areas through excessive pumping, and the hardship that will result if water supplies in the towns do not expand with demand, the writer is of the opinion that the Department's expenditure should be increased well above the present level and he suggests that a reasonable sum would be from £1,500,000 to £2,000,000 per year. Appendix I shows how, apart from ordinary expenditure, a little more than £7,500,000 might be spent on water development over five years at an average rate of £1,535,000 per year.

April, 1959.

I. L. WARD,
Director.

Appendix I.

PROPOSED FIVE-YEAR PROGRAMME OF DEVELOPMENT EXPENDITURE.

	Paragraph Number in this Report	Approximate Capital Expenditure	
		Per Year £	Total in 5 years £
1. Hydrological Research & Surveys ..	105	10,000	50,000
2. Prospecting	55, 106	10,000	50,000
3. Major Projects Investigations	4, 105; 67–74; 86–95	10,000	50,000
4. Nicosia Water Supply	12–20	—	1,625,000
5. Famagusta Water Supply	21–26	—	400,000
6. Limassol Water Supply	27–30	—	250,000
7. Larnaca Water Supply	31–36	—	200,000
8. Paphos Water Supply	37–40	—	200,000
9. Kyrenia Water Supply	41–43	—	80,000
10. Morphou Water Supply	44–46	—	120,000
11. Village Water Supplies	49–52	250,000	1,250,000
12. Irrigation, Drainage and River Training excluding dams.	64–74; 75–78	150,000	750,000
13. Dam Construction	84–95	400,000	2,000,000
14. Phrenaros Recharge	24, 59	—	350,000
15. Other Recharge works and experiments	57–61	—	100,000
16. Establishment of Water Use Research Station	79–83	—	200,000
Total Capital Expenditure over 5 years			7,675,000

Average Development Expenditure over 5 *years* .. £1,535,000.

Appendix II.

PROPOSED FIVE-YEAR PROGRAMME OF INVESTIGATIONS FOR MAJOR SCHEMES.

Nature of Investigation	Paragraph Number in this Report
1. Nicosia Water Supply—Completion of drilling and testing of boreholes and preparation of detailed plans for Stage II of the Morphou Bay Scheme—Prospecting along the western end of the Kyrenia range	18, 106
2. Famagusta Water Supply—Re-design scheme of 1956 omitting Xylophagou sources. Investigations for recharging the Phrenaros wells from Kythrea and for de-salting sea-water at Famagusta and Dhekelia. Prepare plans for inclusion of Kalopsidha sources	24–26 106
3. Limassol Water Supply—Prospecting in the Kouris and Yermasoyia river valleys, and preparation of detailed plans for a new scheme	29–30 106
4. Larnaca Water Supply—Surveys and preparation of detailed plans for the proposed improvements to the present system. Examine the Psevdas Dam Scheme. Investigations for de-salting sea water	32–36 106
5. Paphos Water Supply—Prospecting in the Dhiarizos river bed	40, 106
6. Investigations for recharge works for the Morphou Bay area ..	61
7. Investigations for recharge works for the Kokkini Trimithia area	60
8. Prospecting in the gravel river beds covered by the recent seismic survey	55
9. Adjustment of the existing water distribution schedules in the Solea Valley and the planning of a lined trunk channel..	78
10. Investigations and surveys for about 25 large dams	84–95
11. Detailed design of about 25 large dams, including some of Item 10 above and some of Appendix III	84–95
12. Investigations of the effect of forests on stream flow and groundwater	62–63 110
13. Surveys for a main drainage channel from Kouklia reservoir to the sea	69–70
14. Surveys of gravel and other river beds for land reclamation and flood protection, including the Pedias at Nicosia ..	64–68 73

Appendix III.—LIST OF DAM SITES.

For Nos. 1 to 14 and No. 31 surveys and investigations have been carried out in detail.
For Nos. 15 to 30 only preliminary surveys or reconnaissances have been made.
Nos. 27 to 31 are earth dams.
The estimated cost is only roughly approximate and excludes all compensation payments.
For more information see paragraphs 84–95.

No.	Name of Dam	Co-ordinates (approx.) N	Co-ordinates (approx.) E	Village to benefit	Height above river-bed (approx.) feet	Storage capacity (approx.) Millions of gallons	Cost of construction excluding channels (approx.) £	Purpose and Remarks (Ir. = Irrigation)
1.	Pyrgos (Katouris) ..	6,650	3,960	Kato Pyrgos	60	60	30,000	Ir.
2.	Marathasa	5,710	5,620	Lefka	85	80	70,000	Ir.
3.	Ay. Marina	6,030	2,790	Ayia Marina	60	28	35,000	Ir.
4.	Argaka-Magounda ..	5,400	2,770	Arkaga-Magounda	50	27	30,000	Ir.
5.	Kalokhorio (II)	46.60	84.65	Kalokhorio	60	45	55,000	Ir.
6.	Sklidros	42.20	82.00	Palekhori	87	152	100,000	Ir. Future heightening to 102 ft.
7.	Spithia-tous-Papadhes ..	51.00	85.20	Meniko–Akaki	112	370	220,000	Ir.
8.	Satas	52.18	86.20	Meniko–Akaki	80	358	240,000	Ir. Compensation for 5 and 6.
9.	Malounda	54·45	87.30	Meniko–Akaki	80	420	150,000	Ir.
10.	Philani	49,00	90.40	Psomolophou, etc.	100	250	170,000	Ir.
11.	Lekani	49·52	91.09	Psomolophou, etc.	81	95	65,000	Ir.
12.	Kambia	49·75	92.65	Psomolophou, etc.	90	350	150,000	Ir. Alternative to 10 and 11.
13.	Lania	35.12	63.60	Lania	99	80	130,000	Ir. (from Kouris at Saittas).

No.	Name of Dam	Co-ordinates (approx.) N	Co-ordinates (approx.) E	Village to benefit	Height above river-bed (approx.) feet	Storage capacity (approx.) Millions of gallons	Cost of construction excluding channels (approx.) £	Purpose and Remarks (Ir. = Irrigation)
14.	Dhoros	36.02	63.98	Dhoros and Monagri	99	89	150,000	Ir.
15.	Pyrgos	6,150	4,250	Kato Pyrgos	—	150	—	Ir.
16.	Limnitis	6,140	4,250	Limnitis	80	160	130,000	Ir.
17.	Ayios Theodhoros ..	5,210	6,490	Ay. Theodhoros and Petra	65	50	45,000	Ir.
18.	Asinou	5,420	6,760	Nikitari and Asinou	50	20	20,000	Ir.
19.	Elea	6,400	6,500	Morphou Area	15	100	30,000	Recharge.
20.	Panayia	5,370	7,830	Orounda & Peristerona	—	—	—	Ir.
21.	Perapedhi (II)	35.70	58.70	Perapedhi	80	25	70,000	Ir.
22.	Kapilio	3,140	6,810	Kapilio	75	—	—	Ir.
23.	Psevdas	4,444	1,250	Larnaca, Psevdas and Ay. Anna	40	190	90,000	Ir. and domestic water.
24.	Archangelos	46.10	20.75	Aradhippou	50	30	20,000	Ir.
25.	Avdhellero	47.40	25.20	Aradhippou and Livadhia	50	50	20,000	Ir.
26.	Goshi	45.20	20.00	Aradhippou and Livadhia	50	40	20,000	Flood detention.
27.	Geunyeli	7,540	9,870	Geunyeli	33	55	20,000	Ir.
28.	Denarga	8,150	30.90	Knodhara	35	—	—	Ir.
29.	Lapathos	8,200	4,500	Lapathos	45	150	20,000	Ir. and flood control.
30.	Koma tou Yialou ..	9,550	7,310	Koma tou Yialou	—	100	—	Ir.
31.	Korivas	5,950	8,450	Meniko–Akaki	30	260	15,000	Ir. Alternative or supplementary to 7–9.

Appendix IV.

SOME USEFUL FACTS ABOUT WATER RESOURCES.

	Sq. miles. (approx.)
Areas :	
Cyprus, total	3,572
Arable land	2,000
Cultivated land	1,700
Forests	670
Seasonal gravity irrigation	185
Perennial gravity irrigation	47
Pumped groundwater irrigation	78
Total irrigation	310

(1 square mile = 1,936 donums)

	Inches per year.
Rainfall :	
Average in Cyprus, 1908–1957	19.8
Average in a very wet year (1929/30)	27.0
Average in a very dry year (1931/32)	9.7
Average at highest point in island	40.5
Average at Nicosia	14.8
Average at driest place on island, Morphou Bay	11.0

Average total volume per year 1,020,000 million gallons.

	Percentage of Rainfall.
Run-off (approximate averages) :	
Reaching sea, whole island	4– 6
Crossing 1,000 ft. contour, whole island	15–20
Crossing 2,000 ft. contour, whole island	30–40
Reaching sea from rivers :—	
Pedias–Yialias, Serakhis–Ovgos	0– 5
Elea, Karyotis, Marathassa, Xeros, Kambos	2– 8
Limnitis, Pyrgos, Katouris, Pomos, Yialia, Magounda	3–12
Khrysokhou, Ezuza, Xeros, Dhiarizos, Khapotami	5–15
Kouris, Yermasoyia, Vasilikos	4–12
Maroni, Syrkatis, Tremithios	2–12

Water used for Irrigation and Domestic Purposes :	
Surface water irrigation	3.2
Groundwater irrigation	1.8
Surface water (springs) for domestic purposes	0.3
Groundwater for domestic purposes	0.2
Total for irrigation and domestic purposes	5.5

Approximate discharges of some large springs.

Spring	Discharge in Gallons per day		
	Maximum	Minimum	Average
Kythrea	5,300,000	1,900,000	3,400,000
Lapithos	2,000,000	550,000	1,100,000
Karavas	1,400,000	450,000	650,000
Dhikomo	1,400,000	125,000	400,000
Kephalovryso (Limassol)	1,100,000	150,000	500,000
Kria Pighadhia (Limassol)	1,250,000	125,000	500,000
Mavrommata (Limassol)	2,000,000	125,000	700,000
Deplopotamos	300,000	50,000	175,000
Kissoussa	2,100,000	75,000	500,000
Appidhes	600,000	125,000	250,000
Papa Lucas	325,000	60,000	125,000
Harchi (Prodhromos)	950,000	100,000	300,000
Arkolahania (Mesapotamos)	625,000	125,000	300,000
Koshinas (Pharmakas)	225,000	75,000	125,000

Table of Equivalents.

1 cubic metre of water weighs 1 ton (approx.).
1 cubic metre=220 gallons (approx.).
1,000 gallons=4.546 cubic metres.
1 cubic foot=6.227 gallons.
1 acre-foot=43,560 cubic feet.
1 donum=0.33 acres (approx.).
1 square mile=1,936 donums.
ghd.=gallons per head per day.
mgd.=million gallons per day.

The gallon used in this report is the Imperial gallon which equals 1.201 U.S. gallons.

The ton used in this report is the long ton of 2,240 lbs.