ED FOR

AGENCY FOR INTERNATIONAL DEVELOPMENT

Cyprus Water Development Program

TUDOR ENGINEERING COMPANY, WASHINGTON, D. C.

JUNE 1962

PREPARED FOR

AGENCY FOR INTERNATIONAL DEVELOPMENT

Cyprus Water Development Program

TUDOR ENGINEERING COMPANY, WASHINGTON, D. C.

JUNE 1962

RALPH A. TUDOR
L. A. HELGESSON
LOUIS W. HIGGS
ARTHUR B. HEITTER
JOHN G. MARR

TUDOR ENGINEERING COMPANY

1413 K STREET, N.W.
WASHINGTON 5, D. C. STERLING 3-5313

MAIN OFFICE:
595 MISSION ST.
SAN FRANCISCO
CALIFORNIA
YUKON 2-0010

Department of State
Agency for International Development
3842 New State Department Building
Washington 25, D. C.

June 15, 1962
Ref: TEC-635-A-1

Attention: Mr. Robert L. Moorman
Deputy Director of Engineering

Gentlemen:

SUBJECT: CYPRUS WATER DEVELOPMENT PROGRAM

Task Order No. 635-A-1 calls for an investigation of all phases of the water development program of Cyprus; and for recommendation of specific projects suitable for immediate implementation and for guidance as to a long-term approach for watershed improvement.

Mr. Harold E. Hedger, Consulting Engineer, was assigned by the Tudor Engineering Company to make the field investigation called for by this task order. Mr. Hedger was in Cyprus from April 9 to May 19, 1962. He consulted available public records and documents, made field trips to various areas and conferred with officials of the Cyprus Government and the Water Development Department of the Cyprus Ministry of Agriculture, as well as with the U.S. Ambassador and the USAID staff.

Mr. Hedger's report is submitted herewith in full. It was prepared and reviewed by AID officials during his stay in Cyprus and reviewed and edited in Washington by the Tudor Engineering Company staff.

A summary of the conclusions and recommendations contained in the report are inserted herein immediately following this letter of transmittal.

Very truly yours,

TUDOR ENGINEERING COMPANY

John G. Marr

John G. Marr
Project Manager

JGM:rbm

TABLE OF CONTENTS

	Page No.
Letter of Transmittal	1
Summary of Conclusions	4
SCOPE OF INVESTIGATION	
1. Introduction	11
2. Specific Assignments	11
3. Acknowledgments	12
PERTINENT INFORMATION	
4. General Description of Cyprus	12
5. Topography	12
6. Geology	13
7. Ground Culture	14
8. Water Supply	14
9. Ground Water	15
PRINCIPAL WATER SUPPLY PROBLEMS	
10. Problem of Mal-distribution	16
11. Critical Areas	16
12. Surface Runoff	17
13. Wasteful Water Use Practices	17
14. Engineering Staff	18
RELIEF MEASURES NEEDED IMMEDIATE AND LONG-RANGE	
15. Sea Water Intrusion	19
16. Supplemental Water Supplies	19
17. Ground Water Recharge	20
18. Mal-distribution of Supply in Relation to Demand	20
19. Local Water Supply Problems	21
20. Ground Water Recharge Facilities	21
21. Recharge in Confined Aquifers	22
22. Direct Infiltration from Reservoirs	22
PROJECT ENGINEERING	
23. Importance of Adequate Staffing	23
24. Five Year Program of Economic Development	23
25. Budget Finances	24
26. Recruitment of New Engineers	24
27. Training of New Personnel	25
28. Need for Contract Engineering Services	26
29. Other Personnel Requirements	26
30. Land Acquisition	26

Table of Contents (Continued)

Page No.

PROJECT SELECTION

31. Regional Areas with Severe Water Shortage Problems 27
32. Principal Areas of Water Productivity 28
33. River Basins Suitable for Developmental Planning 28
34. Selected Projects 29
35. Engineering Services Required 30
36. Time Requirements for Engineering 31
37. Special Projects 32
38. Basic Hydrologic and Economic Data Available ... 32
39. Maps 33
40. Hydrologic Data 33
41. Economic and Cost Data 35

RECHARGE PROJECTS

42. Eastern and Western Mesaoria Plains 35
43. Suggested Ground Water Recharge Installations ... 36
    a. Famagusta Area 36
    b. Morphou Area 38
    c. Akrotiri Peninsula 39

PERTINENT GENERAL INFORMATION

44. Recruitment Potentials 41
45. Water Use Regulation 41
46. Soil Conservation 42
47. Activities of International Agencies 42
48. Methods of Construction 43
49. Construction Equipment 44
50. Economic Justification or Feasibility 44

Appendices

A Bibliography 47
B Kouris-Garyllis River Basins 49
C Ezuza-Xeropotamos-Dhiarizos-Khapotami River Basins (in the order named) 53
D Tremithios River Basin 59

Plates

I General Map 10
II Kouris-Garyllis River Basins 52
III Ezuza River Basin 56
IV Xeropotamos River Basin 57
V Khapotami River Basin 58
VI Tremithios River Basin 62

SUMMARY OF CONCLUSIONS

At this time, the Government of Cyprus (GOC) needs external assistance in meeting current water shortages and related problems and in carrying out a sound long-range water development program. The need is for the expansion of engineering, construction and other technical capabilities including personnel, procedures and equipment. There is no apparent need at this time for financial assistance in the form of loans or grants for construction of projects, since current and proposed GOC budgets provide adequate funds for all project construction that can be accommodated by the currently depleted staff of the Water Development Department (WDD). This agency is charged by GOC with water resources planning and development.

A. URGENT WATER NEEDS AND RELATED FACTORS

The principal and most urgent factors connected with growing water shortages and related problems in Cyprus are deemed to be:

1. A general decline in the ground water tables of the principal aquifers and basins, leading to critical instances of sea water intrusion and other salinity problems at a number of locations. This is attributable to several causes, including:

    a. Unregulated pumping.
    b. Illegal drilling of bore holes in spite of regulatory legislation.
    c. Inefficient usage of water for irrigation and domestic purposes.
    d. Excessive water losses from transpiration, canal seepage, etc.

2. An increasing demand for additional domestic and irrigation supplies for numerous towns and village areas.

3. The annual loss of water resulting from surface runoff to the sea, roughly estimated by the WDD to total 36,180 million Imperial gallons, (MIG) or about 134,000 AF, annually.

4. A need for broader planning of water resources development to take into account future needs for all forms of water utilization instead of the limited planning that must now be practiced with a depleted staff.

5. A need for more and better basic hydrologic and hydrogeologic data and investigation to support broader engineering and planning.

6. The inadequacy of the WDD staff, in number of qualified engineers and related services, to cope with the present demand for construction engineering and simultaneously undertake comprehensive water development planning.

B. GENERAL MEASURES OF RELIEF

The general measures considered as necessary in overcoming these deficiencies are:

1. The regulation of extraction of ground water by bore hole drilling and pumping, through enactment of stringent legislation and enforcement, to stop the continuing decline in water tables and increase in sea water intrusion.

2. Strengthening of the Cypriot Government Staff charged with water resources development, in number, training and equipping of new personnel, so that it can effectively deal with the currently budgeted construction program, water shortages and related problems listed above. Until this is accomplished, no real relief of water shortage problems can be expected.

3. To expedite the construction of dams and related projects which, although budgeted, cannot be started because of staff inability to turn out plans and handle construction as rapidly as funds are provided, the WDD should, in addition to being strengthened in size of staff, (a) initiate the procurement of services for the preparation of plans and specifications through contracts with private engineering firms with experience in this field; and (b) accomplish construction of larger projects through competitive bidding by local contracting firms affiliated with experienced foreign contractors.

4. Construction of local relief measures in the form of small dams, water supply, irrigation and recharge works should be continued and expanded, when possible, to the maximum program it is possible to finance in each year's budget. The current budget program of £1,500,000 for water development should be increased as soon as the engineering staff can handle it.

5. Construction of storage reservoirs which can be used to recharge ground water aquifers experiencing sea water intrusion or critical depletion should be given budget priority, and where warranted by feasibility investigation, should be supplemented by construction of surface spreading facilities.

6. Several of the more productive river basins, in terms of maximum annual surface runoff, should be subjected to comprehensive, long-range water resources planning and to determination as to the availability of water surplus to the ultimate needs of the basin and therefore suitable for export to areas of water shortage. This planning activity should be used to train new members of the engineering staff in this type of engineering and to serve as a guide to planning of water resources development on all river basins in Cyprus.

7. One or two recharge facilities, composed of surface basins overlying pervious soils which infiltrate directly into a ground water aquifer or basin in need of replenishment, and preferably located so they could be supplied from surface storage upstream, should be installed to test their adaptability to recharge requirements in Cyprus, and to demonstrate the capabilities of this method of water conservation.

C. SPECIFIC SUGGESTIONS FOR RELIEF

Specific measures suggested for carrying out the relief program set forth above would include:

1. Immediate Functional Needs. The minimum strengthening of the WDD staff needed to meet the demands of the regular budget program for construction of dams, irrigation works and water supply systems is estimated to require the addition of at least 6 qualified civil engineers and an equal

number of technicians. Since Cypriot engineers experienced in water development projects are not available to fill this need, it will be necessary to recruit inexperienced young Cypriot civil engineering graduates and technicians and train them in this field. A total of 4 senior civil engineers experienced in those phases of engineering and construction, dealing with the design, materials testing and soil mechanics, construction and general planning and operation, and the preparation and use of contract documents, respectively, would be needed for two or three years to supervise and train the recruited graduate engineers and technicians in the engineering of regularly budgeted projects. One of these positions, the expert on dam design, would be a replacement for a U.N. expert who will leave the WDD in August. The general qualifications for each of these 4 positions are set forth in Paragraph 27.

2. Long Range Planning. As an entirely separate proposal from that offered in C1, the preparation of a long-range comprehensive or master plan of water development and utilization should be carried out for the river basin groups of the Kouris-Garyllis, the Ezuza-Xeropotamos-Dhiarizos-Khapotami and Tremithios River Basins at once. The investigation and planning involved is expected to require a minimum of one year to accomplish. Such a project is well adapted to handling by an engineering firm experienced in this type of work and with a pool of experienced engineers available that can be assigned as needed. The project should be designed for the training of Cypriot engineering personnel inexperienced in water resources planning. The total requirements in personnel for this project are estimated to be 42 qualified engineers and technicians of which it is thought that 7 qualified engineers and 27 technicians should be Cypriots recruited for the purpose. The cadre to be supplied from non-Cypriot sources would therefore consist of at least 8 experienced senior engineers to direct and conduct the study and train the Cypriot recruits. Details of these estimates, and of the man-month requirements, appear in Paragraph 35 of the report.

3. Field investigation of surface conditions indicates that the location most suitable for initial installation of a basin waterspreading system for ground water recharge is in the upper area of the Akrotiri Peninsula, west of Limassol, using

clear water from the Kouris River or its tributaries. It is also suggested that the possibility of recharge in the citrus area a few miles north and west of Morphou be tested by installation of basins at the ends of irrigation channels supplied from Ovgos River, providing that this supply is found of low saline content. Another site at which installation of surface recharge facilities should be considered, if found feasible upon investigation, is at Famagusta, overlying the aquifer now served by water gallery infiltration. Surface spreading at this location should be experimental to ascertain its relative cost and effectiveness compared to subsurface infiltration, in this area of exceptional water shortage. These installations involve primarily the use of labor and earth moving equipment at low cost, and the WDD should be able to install and operate them within current budget allowances. Expert advice may be needed for the initial installation. See Paragraph 43 of the report.

4. The strict enforcement of both existing and strengthened legislation designed to balance the extraction of ground water for irrigation and domestic use with the replenishment to be expected from natural and artificial recharge is considered to be an essential phase of the Cyprus Water Development Program. Efforts of the United Nations staff to develop satisfactory legislation and secure its enactment and enforcement deserve full assistance.

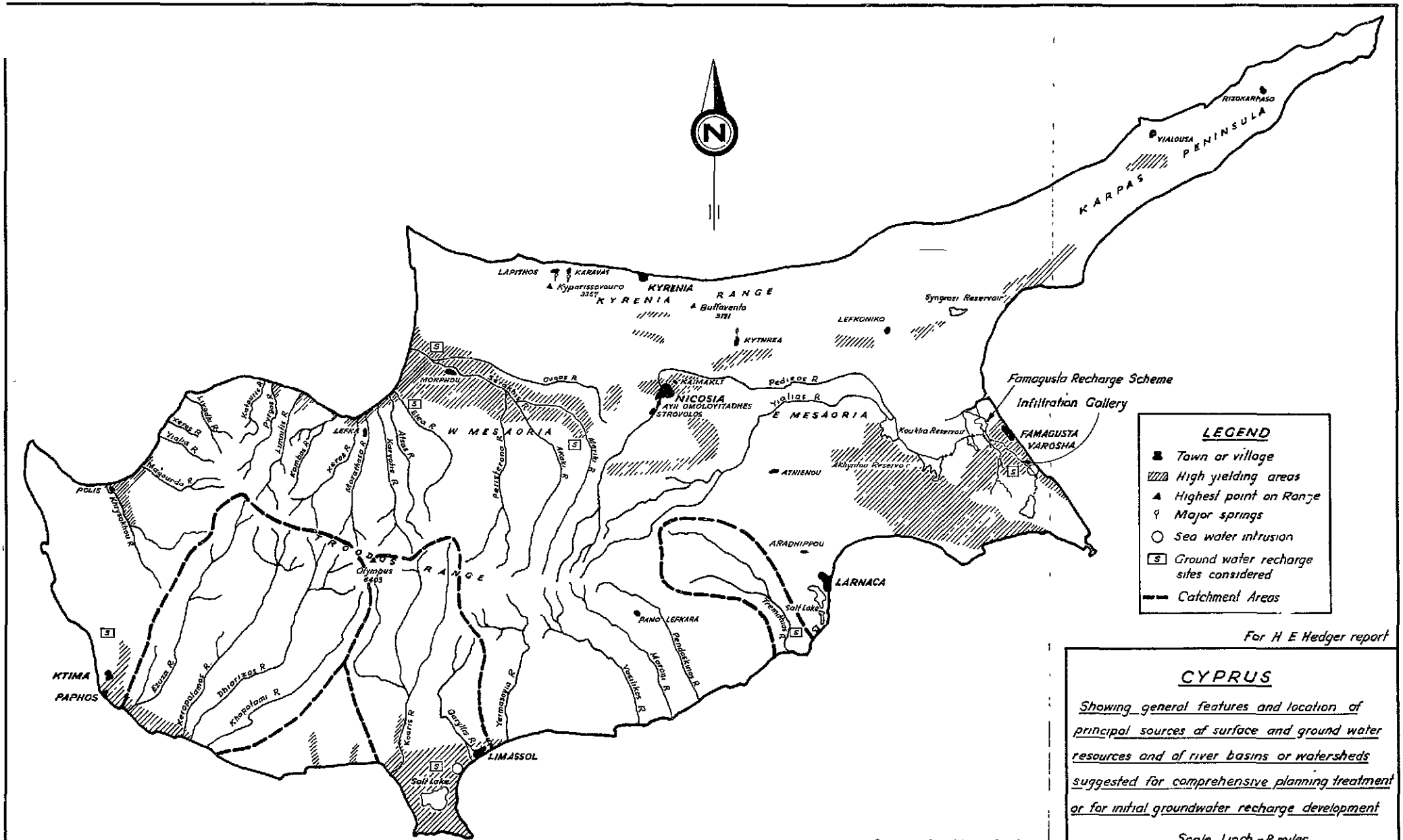
5. Investigation and determination of the boundaries and characteristics of the principal ground water basins and aquifers of Cyprus, particularly in the Mesaoria Plains is also considered an essential phase of the Cyprus water resources development, and the prospective undertaking of this work from the United Nations Special Fund merits every assistance.

6. Should the engineering personnel support suggested in Paragraph C. 1 and 2 above be favorably considered, such support should be conditional upon the recruitment and assignment of Cypriot personnel approximately as indicated for the length of the support program.

7. A need for additional support for the Cyprus Water Development Program in the form of funds, equipment

and materials may develop when the production of engineering plans attains satisfactory proportions, but it is doubtful if this will materialize in less than two or three years.

8. The GOC should launch a forceful program at once to curtail all wasteful practices and uses of water, both in irrigation and domestic supply. This should include advisory service to farmers as to the water requirements of various crops and most efficient methods of application, which may require the assistance of agricultural experts from other countries.



LEGEND

- Town or village
- High yielding areas
- Highest point on Range
- Major springs
- Sea water intrusion
- S Ground water recharge sites considered
- Catchment Areas

For H E Hedger report

Drawn by C Hadjilarzou D W D

CYPRUS

Showing general features and location of principal sources of surface and ground water resources and of river basins or watersheds suggested for comprehensive planning treatment or for initial groundwater recharge development

Scale 1 inch = 8 miles

Plate I

SCOPE OF INVESTIGATION

1. Introduction

The investigation upon which the following report was based was initiated by Task Order No. 635, issued to Tudor Engineering Company (TEC) on February 13, 1962, by the U.S. Agency for International Development (AID). This task order called for a review of the present water development program of the Government of Cyprus (GOC) and for recommendation of specific projects suitable for immediate implementation or detailed examination and of a character to provide guidance as to a long-term approach to the problem of watershed improvement and development in Cyprus.

2. Specific Assignments

Specific assignments cited in the task order were as follows:

(1) Review existing hydrologic data including areas of coverage, methods, reliability and deficiencies.

(2) Examine present watershed developments and utilization of water for irrigation and municipal and village supply and recommend suitable types of additional water development programs.

(3) Review existing plans for specific projects and identify those which appear to be physically and economically feasible.

(4) Advise for each apparently feasible project or group of such projects, a scope of services for inclusion in an engineering contract, which would cover field investigations, surveys, preliminary plans and cost estimates, an economic analysis including estimates of benefits, and recommendations as to any other problems involved, including rights-of-way, etc.

(5) Submit preliminary report to USAID/ Cyprus while in the field and final report to AID/W upon return to Washington.

3. Acknowledgments

This investigation was undertaken immediately upon the author's arrival in Cyprus on April 9, 1962, and was conducted with the generous assistance of officials and engineers of the GOC and of the USAID office in Nicosia. Particular mention is due for the cooperation and material information furnished by Mr. F. Plumer, the Minister of Agriculture, Mr. P. de Gruyter, the Director of the Water Development Department, Mr. Y. Hji. Stavrinou, the Assistant Director, Mr. Chr. Konteatis, Senior Engineer, and other members of the staff of the WDD. Valuable advice and guidance was also rendered by Mr. Frazer Wilkins, U.S. Ambassador to Cyprus, Mr. J. S. Toner, Director, and Mr. C. T. White, Controller, USAID/ Cyprus, and by staff members of the State Department and USAID in Washington, D. C.

PERTINENT INFORMATION

4. General Description of Cyprus

The Republic of Cyprus comprises an island area in the Eastern Mediterranean Sea of about 3,500 sq. mi., inhabited by a population presently estimated at nearly 600,000. About 100,000 inhabitants are concentrated in the vicinity of Nicosia, the Capital, and from 50,000 to 80,000 around the towns of Limassol, Famagusta, Larnaca, Morphou, Kyrenia and Paphos-Ktima, respectively. The remainder of the population is located in villages scattered over the entire area. These villages are larger and more numerous in the arable sections.

5. Topography

Cyprus has four dominant features: (1) the Troodos mountainous region, located in the south-southwesterly section, with peak elevations ranging from 4,000 feet above mean sea level to 6,403 feet at Mt. Olympus. The Troodos region occupies roughly 1,700 sq. mi. or about 50 per cent of the land mass of Cyprus; (2) the Kyrenia range, which extends along the north central shore for a distance of about 50 miles and rises to peak elevations of from 2,000 to a little over 3,000 feet above sea level; (3) the Karpas Peninsula, a strip of land of from 2 to 10 miles width, which is in effect an extension of the Kyrenia

range jutting north-easterly nearly 50 miles into the sea, and where maximum elevations do not exceed 1,000 feet above sea level; and (4) the Mesaoria Plain, which lies between these ranges, averages perhaps 15 - 20 miles in width and 55 miles in length, and varies in elevation from sea level to an elevation of about 500 feet at Nicosia and to 1,000 feet or more as it merges with foothills of Troodos and Kyrenia ranges. It occupies about 1,000 sq. mi. or 28 per cent of the area of Cyprus; and is divided into two hydrological areas, Eastern Mesaoria draining toward Famagusta Bay on the east, and Western Mesaoria draining toward Morphou Bay on the west.

6. Geology

A number of treatises on the surface hydrology of Cyprus, or sections thereof, are available as are the results of several subsurface investigations undertaken by geophysical methods, mostly for mineral exploration. In brief, the important features relating to surface runoff characteristics and water bearing formations are as follows:

The Troodos range is stated to be essentially a massif with an igneous cap lying in general above the 2,000 foot elevation, superimposed on a partly-crystalline diabase fringed with pillow lavas. While these formations are of low porosity, the upper areas are fractured and jointed so as to accommodate seepage sufficient to create numerous springs which are of importance to village water requirements.

The Kyrenia range is generally considered to be composed of an uplifted core of hard crystalline limestone. It is also fractured and jointed and subject to formation of fissures or caverns, so is adapted to infiltration and transmission of subsurface water. This formation overlies impervious formations so that an exceptional number of springs occur, including that at Kythrea, largest in Cyprus.

The principal water bearing aquifers are found in the sedimentary areas of more recent geological origin. The Mesaoria Plains contain the largest areas of sedimentary origin, but these vary considerably in thickness of water bearing formations according to location, the greatest thickness being estimated as 200 feet or more. Similar sedimentary deposits

of water bearing sand and gravels are found along the coastal fringe of Cyprus, the principal one of these being the Akrotiri Peninsula on the southerly coast.

Other sedimentary deposits of clays, chalks and marls occur in portions of the Mesaoria Plains and around the bases of the Troodos and Kyrenia ranges, but in general are of little porosity.

7. Ground Culture

A good deal of information on this subject is contained in U.N. Pub. ST/TAO/CYP/1 entitled "Cyprus - Suggestions for a Development Programme" and generally known as the "Thorp" report. In brief, the principal cultural developments are agricultural, about 2,350 sq.mi. (1,510,000 acres) or 65 per cent of the area of Cyprus, being devoted to private farms, mostly less than 20 acres in size. Principal crops are wheat, barley, grapes, citrus, potatoes and vegetables. State owned forests occupy about 670 sq. mi. (429,000 acres) or 18 per cent of the total area; grazing land about 360 sq. mi. (231,000 acres) or about 10 per cent; and the remaining 250 sq. mi. (159,000 acres) or 7 per cent of the total is devoted to town, village and other uses. About 340 sq. mi. (217,000 acres) are under irrigation. Several important mining developments are located in the Troodos range, the principal product being copper ore, with iron, chrome and asbestos also mined. Important industrial development has not yet taken place, although included in economic planning for the near future.

8. Water Supply

The water resources now available in Cyprus are limited to those attributable to rainfall and other precipitation on the island. They occur as surface runoff, as discharge from springs and as ground water. Rainfall varies from an average annual rate of about 12 inches in the Mesaoria Plains to over 40 inches at the highest elevations. A past Director of the WDD has estimated* the overall average annual precipitation at 19.4 inches per year,

*See "Hydrology and Water Development in Cyprus" by Ivan Lee Ward, B.E. MICE, et al.

representing a total average annual supply of about 1 million million Imperial gallons (MIG) or 3,700,000 acre feet (AF). Of this amount, he has estimated that evaporation, transpiration and other losses absorb all but about 1.4 inches of annual precipitation, or about 7.5 per cent of the 19.4 inch total. Of this, about 1 inch is considered as surface runoff and 0.4 inch as ground water replenishment. On the basis of these estimates, the average annual surface runoff would total about 52,000 MIG (190,000 AF) and ground water replenishment about 21,000 MIG (77,000 AF), although later WDD estimates revise these figures to about 70,000 MIG (260,000 AF) and 10 - 20,000 MIG (37,000 - 74,000 AF) respectively.

Roughly 85 per cent or more of the total estimated surface runoff of Cyprus originates in the Troodos mountainous region and from some 20 watersheds in this region, of which the largest is 177 sq. mi. in area. They discharge much of the surface runoff which now escapes to the sea. Only two principal watersheds, with a combined mountainous area of 73 sq. mi. discharge from this region into rivers traversing the Eastern Mesaoria Plain, and two others, with total mountainous watershed area of 82 sq. mi. into the principal river traversing the Western Mesaoria Plain. The Plains, particularly the Eastern Mesaoria, must therefore rely primarily on direct rainfall for surface moisture and ground water replenishment.

9. Ground Water

Several large springs occur at scattered locations in Cyprus, the largest, at Kythrea (near Nicosia) having reached a maximum discharge of 5.3 MIG a day (10 c.f.s.). Many smaller springs are found in the mountainous region, several serving both village domestic and irrigation needs.

To date 15 dams with total reservoir capacity of 1,350 MIG (5,000 AF) have been constructed, all for irrigation supply. Innumerable small irrigation and village water supply systems are supplied by diversion of surface waters.

The principal ground water basins and aquifers in Cyprus are located in the Mesaoria Plains, the southerly half of the Western Mesaoria being considered an area which overlies an aquifer of high yield. The south-easterly quarter of the Eastern

Mesaoria is also considered to be in this category. A third ground water aquifer of importance is located on the Akrotiri Peninsula on the southerly coast. Smaller areas at several other points along the coast are suitable for ground water extraction. However, the boundaries and characteristics of these basins and aquifers have not as yet been determined with accuracy.

The "Thorp" report indicates that somewhat more than 7,000 million cu. ft. (160,000 AF) represents the total input to the ground water resources annually, and that about 3,300 million cu. ft. (76,000 AF) of this amount are currently extracted and put to use from over 5,000 bore holes drilled to date. WDD has estimated that as much as 10,000 - 20,000 MIG (37,000 - 74,000 AF) of ground waters are lost to the sea annually by underflow from basins and aquifers. A large part of the current ground water extraction in Cyprus is from the principal aquifers of the Mesaoria Plains.

PRINCIPAL WATER SUPPLY PROBLEMS

10. Problem of Mal-distribution

The foregoing data clearly indicates that one of the principal water supply problems in Cyprus is that of mal-distribution of supply in relation to demand, since practically all natural waters available for development are located in the south-westerly portion of the country, whereas the principal demand is from the central and eastern sections of the Mesaoria Plains. Transfer of water from one area to another is not an easy solution to this imbalance. Since the ultimate water needs of the water productive and the water deficient regions have not been determined, it cannot be stated with any degree of certainty whether surplus water is available for transfer between regions.

11. Critical Areas

The most critical areas, from standpoint of water shortages, are at four or five widely separated locations along the coast, where sea water intrusion has extended inland a mile or more and has destroyed numerous wells for either domestic or irrigation use. In the Famagusta area citrus groves have had to be abandoned due to this condition. Heavy concentrations of bore hole pumping

during the past few years, some during drouth periods, have resulted in a continuous lowering of the ground water table over much of the Mesaoria Plain, in the Limassol and Larnaca districts along the south coast and elsewhere, causing springs and wells to go dry, necessitating the drilling of new and deeper bore holes, and causing general shortage and increased cost of water supply for town and village domestic use and for irrigation purposes.

12. Surface Runoff

Seasonal runoff surface water supplies, mostly in the Troodos region, are in many cases undependable for irrigation supply when needed in the growing season, and scarcely serve the barest domestic needs in years of drouth. Nevertheless, in normal years there is a considerable runoff of surface water to the sea during the peak of the rainy season (December-March) from the streams which arise in the Troodos region and flow West and South. Unfortunately, very few sizable ground water basins or aquifers exist in this location, although opportunities for expansion of irrigation are in general favorable.

13. Wasteful Water Use Practices

Nearly every report made by water use experts and agricultural specialists on the water problems of Cyprus has cited inefficient and wasteful methods of water development and utilization as prime factors in the shortages that have developed to date. Uncontrolled bore hole drilling and pumping, use of unlined water conveyance systems, spate flooding of fields, unmetered distribution of domestic supplies, ignorance of crop requirements, and other wasteful practices all contribute to excessive use of available water supplies in some localities and complementary shortages in others. While regulatory laws have been adopted, it seems apparent that inadequacy of such legislation, or of its enforcement, is a serious impediment to full utilization of existing water supplies, and that immediate corrective measures are mandatory. This phase of the water problem has had the recent attention of United Nations specialists in water legislation, and their recommendations will soon be available. External assistance that may be considered in behalf of a solution to water problems in Cyprus should contain as a conditional requirement effective action of the GOC in preventing further wasteful utilization of water supplies.

14. Engineering Staff

All major water development planning and most of its administration and construction are the responsibility of the WDD of the Cyprus Ministry of Agriculture. The WDD was given departmental status in 1937 and during the following twenty years was staffed with total personnel of about 60, including 17 college-trained engineers and geologists, largely non-Cypriots. Due to the departure of a large portion of this staff after the emergency period of 1955-58, the department was seriously depleted, and today includes but 8 college-trained engineers and geologists and a total office complement of 46, quite inadequate in number to handle the engineering, construction and operational phases of the £1,500,000 program of small dam and irrigation works installations, domestic water supply schemes, prospecting, drilling and hydrologic investigations, etc., financed in the 1962 budget. The department has a few vacant positions, but has been handicapped in filling them by Constitutional provisions for assignment of personnel and by a salary scale that will not attract experienced college graduates in engineering, geological and other professional fields, in comparison with salaries offered for similar positions elsewhere. The salary scale at present is as follows:

	Starting	Maximum	
Director, WDD	£ 1460	£ 1800	per annum
Assistant Director	1452	1644	" "
Senior Water Engineer	1236	1548	" "
Engineer Hydrologist	1236	1548	" "
Geologist, Class I	1236	1548	" "
Geologist, Class II	900	1200	" "
Executive Engineer, Class I	1236	1548	" "
Executive Engineer, Class II	900	1200	" "
Superintendent of Works	900	1200	" "
Senior Inspector	900	1056	" "
Inspector of Works and Surveyors	642	810	" "
Technical Assistant	300	594	" "

A cost-of-living allowance of 28.5 per cent is at present added to the above listed salaries. The present salary ranges for the Director, the Assistant Director and the Senior Water

Cyprus £ = US$ 2.80

Engineers were reduced in 1959 from set salaries of Ł2000, Ł1700, and Ł1650, respectively.

A new Director of the WDD has just been appointed and it is understood that renewed efforts will be initiated to build up an adequate engineering staff. Even so, several years will undoubtedly be required for this purpose, even with more favorable recruiting conditions, but correction of the worsening water situation cannot be postponed for such a period. More effective means of obtaining competent, experienced services in the engineering, geological, construction and accounting fields must be found.

RELIEF MEASURES NEEDED IMMEDIATE AND LONG-RANGE

15. Sea Water Intrusion

The most important immediate action needed is to stop the advance of such intrusion inland, the area already strongly contaminated being lost insofar as early correction of this condition is concerned. Build-up of the ground water table at the inland fringe of intrusion is the most practical measure immediately available. This may be accomplished by reduction of ground water extraction through stringent regulation of bore hole drilling and pumping; and/or by increase in sweet water input to the affected ground water basin or aquifer by development of supplemental supplies through (1) construction of dams and resulting reservoir storage, (2) transfer of surplus water from other watersheds, and (3) by reduction in wasteful usage of existing water supplies.

16. Supplemental Water Supplies

Other methods of developing supplemental water supplies suitable for long-range development include artificial nucleation, or "cloud-seeding", and desalinization of sea or briny water. The first method demands specific meteorological conditions for effectiveness which would require exploratory investigation in addition to a preliminary examination already conducted of this possibility. If present, it would probably contribute but a small additional percentage to normal precipitation on the basis of experience to date. The second method is very expensive and not economic for supply of large quantities of water for irrigation,

although it constitutes a possible solution for urgent domestic needs, such as at Famagusta. However, both methods should be considered in long-range planning of water resources development.

17. Ground Water Recharge

Amelioratory measures will vary according to specific conditions encountered at any given location, but in general, effective regulation of ground water pumping to balance ground water input and output, and, if possible, increase the balance in favor of input, offers the most immediate opportunity to stop the advance of sea water intrusion. This, in effect, would mean in some cases a reduction in irrigated areas which have been overdeveloped. The construction of dams and reservoirs in watersheds which discharge substantial quantities to the sea, and installation of the most efficient types of ground water recharge facilities are deemed to offer the next best method of resisting sea water intrusion, but until more is known about the ultimate water needs of such watersheds, this solution should be limited to aquifers within their boundaries.

18. Mal-distribution of Supply in Relation to Demand

This problem will demand long-range treatment. It will eventually involve transfer of surplus water from one watershed to another, and it will undoubtedly be necessary to prove that such surplus is in excess of all reasonably foreseeable needs before such a proposal be offered. This will require comprehensive long-range planning of water resources development for the watersheds involved, taking into account all the alternative possibilities and considering all factors involved, including demographic studies, ultimate needs for domestic and irrigation supplies, flood control, industrial potentials, existing uses and water rights; and consideration of the potentials, if any, of such presently undeveloped water uses as hydroelectric power generation, recreation and even fish propagation. Social environment should be studied as to impact of project developments under consideration. It seems reasonable that thorough investigation and planning of this nature may indicate that important surplus water resources could be developed in some of the more productive watersheds of the Troodos range over and above any future needs that may arise within the watershed, to an extent that would justify a project for accumulation of such surpluses and their conveyance and delivery to areas of perennial need such as the Mesaoria Plains.

19. Local Water Supply Problems

Most of the town and village domestic water supplies are delivered through distribution systems installed and maintained by Water Boards or Village Councils, and it is logical to expect that such local responsibility for distribution should remain unimpaired. Distribution systems for irrigation supplies also seem to warrant a substantial degree of local responsibility, although planning and construction of such systems may have to be assumed as a government function. The important field in which WDD leadership appears to be needed is in the development of presently unused or wasted water resources to supplement existing sources of supply such as springs, streams and ground water aquifers. Since these sources are scattered over each watershed, as are the villages or towns which depend upon them, the normal solution seems to be the development of supplemental supplies as discussed in methods of resisting sea water intrusion, i.e., by installation of numerous small dams to trap and store water which would otherwise be wasted, and using it to supplement surface domestic or irrigation supplies, or to recharge ground water basins and aquifers at strategic points which will raise the ground water table and, in some instances, increase the flow of springs.

20. Ground Water Recharge Facilities

The few instances in which ground water recharge has been undertaken in Cyprus have in general been unsatisfactory as to results, probably because of the dependence on subsurface tunnels or water galleries for aquifer recharge. The planning of further recharge facilities should be based, when possible, on full information as to the hydrogeological characteristics of the aquifer or basin to be replenished. The opportunities for surface recharge through installation of an efficient system of spreading basins located at the point of maximum potential infiltration and as close as possible to the point of maximum benefit to the depleted ground water table should be investigated first. Basins should be planned for rotation in use to provide rest periods during which they can be cleaned of silt deposits, scarified for aeration, and otherwise prepared for re-use. Provision should be made for uniform distribution of recharge water to all parts of each basin. The size and number of basins should be determined by field tests of the proposed site and they should overlie a ground water basin or aquifer having underflow capacity adequate to remove all recharge

water reaching the ground water table without permitting a water mound to form which will rise to the surface. Proper operation and maintenance of a recharge basin system are essential to efficient utilization.

21. Recharge in Confined Aquifers

The spreading basin method of recharge may also be applied to aquifers which are overlaid with impervious layers or crusts through excavation and removal of the impervious material if of limited thickness or by drilling of large diameter auger holes (equipment is available for drilling holes as large as 48 inches in diameter) into the gravel or other water bearing material of the aquifer. Such holes must then be refilled with clean sand or gravel and capped with a mound of gravel and rock extending above the basin floor. Usually such auger holes are drilled in sufficient numbers to develop the capacity of the basin. Alternation of use is of course required for cleaning and renovation of mounds and basin floor.

Effective use of bore holes or galleries for injection will necessitate complete desilting and chlorination of recharge water if it is to be effectively maintained. Filtration may in some cases be necessary to remove suspended material, although use of a flocculating agent, such as Separan, in a special desilting basin may prove a less expensive alternate.

22. Direct Infiltration from Reservoirs

In some instances it may be possible to construct dams at locations which place the reservoir or catchment area over pervious soils and river bed so that recharge of the underlying ground water basin will be accomplished directly. Sealing of the ground surface will gradually take place as siltation occurs, however, and this will gradually reduce the rate of infiltration to the point that the coat of silt must be removed by sluicing or mechanical methods. In short, this type of recharge facility must be maintained, as will any alternative recharge facility, if it is to remain effective.

Since effective replenishment of the ground water reservoir resources of Cyprus must be developed to far greater extent and efficiency than heretofore if existing water shortages are to be relieved, it is important that special attention be given this phase

of water resources planning and that recharge facilities be installed in favorable locations at the earliest opportunity to demonstrate the proper techniques and test their adaptability to geological conditions in Cyprus.

In long-range planning, use of spreading basins for conservation of runoff can be effectively combined with conservation of effluents from domestic sewage once proper treatment has been applied. When installation of sewage systems is planned in the future, treatment plants should always be located and designed to avoid wasting this water resource. This practice should be given early consideration in meeting urgent needs for domestic water supply and improved sanitation at Nicosia and at Famagusta. In the latter instance, it is probable that aquifer recharge with reclaimed effluent could be accomplished at but a fraction of the cost of desalting sea water, although the proportion of recovery would be much less.

PROJECT ENGINEERING

23. Importance of Adequate Staffing

The supervisors, qualified engineers and technicians of the present WDD staff are to be complimented on the excellent job accomplished with such limited numbers and facilities, but it cannot be expected that they can turn out finished plans and supervise construction of the number of small dams, irrigation works, water supply systems, etc. envisioned by the GOC Five Year Program of Economic Development, until the staff is strengthened by additional personnel, equipment, building space and training. This is the foremost need of the Cyprus Water Development Program at this time.

24. Five Year Program of Economic Development

This program which was announced by GOC in August 1961, contemplated the following program of water resources development:

Construction of dams and irrigation works	£ 10,000,000
Improvement of village water supply systems	4,000,000
Improvement of urban water supply systems	1,000,000
Construction program	£ 15,000,000
Research for discovery and development of new water resources	2,000,000
Total water development program	£ 17,000,000

25. Budget Finances

Provision has been made, or is contemplated, for the following overall water development expenditures:

	Dams & Irrigation Works only	Total Program
1961 Budget	£ 500,000	£ 1,522,678
1962 Budget	£ 490,000	£ 1,500,000
Proposed 1963 Budget	£ 750,000	£ 1,500,000

It is estimated that the WDD as presently staffed would have difficulty in processing an annual construction program of dams and irrigation works in excess of £ 400,000 unless it were confined to two or three large installations, which is not practical in Cyprus.

26. Recruitment of New Engineers

In view of these budget programs the current depletion of engineering staff in the WDD requires both immediate and long-range attention. The long-range objective must be to build and maintain an adequate staff of engineers, in both qualified professional and subprofessional grades, trained in all phases of water resources investigation, planning, construction, maintenance and operation. Considerable time will probably elapse before a supply of college-educated Cypriot engineers, geologists, hydrologists, etc., will be sufficient to meet this need. The status of these positions in

Cyprus £ = US $2.80

WDD must apparently be improved by granting full professional standing, an improved salary scale reflecting such standing, adequate technical equipment and better working space if an adequate staff is to be recruited and maintained.

27. Training of New Personnel

Assuming that such improved recruiting requirements are provided, the immediate need for training personnel will depend upon the GOC's efforts and success in recruiting both graduate engineers and technicians such as draftsmen, computers, surveyors, etc. The minimum recruiting goal should be at least 6 graduate engineers and a similar number of technicians.

The WDD would then need a training cadre of several experienced engineers to serve as supervisors and instructors in the planning and design of dams, particularly of earthfill and rockfill structures, and irrigation and water supply systems; to organize a materials testing and soil mechanics laboratory and train personnel thereof; to develop and direct the use of contract procedures, drawings, specifications and documents; and to supervise and inspect construction performed by independent contractors and government forces. Such engineers are not now available in Cyprus and assistance of international agencies is needed for their procurement. The positions most urgently needed are:

1	Dam Design Expert	- to replace U.N. expert who will leave in August.
1	Senior Civil Engineer	- with general planning and construction background including experience in irrigation.
1	Testing Engineer	- with experience in soil mechanics relating to dam design, and in materials testing.
1	Construction Engineer	- with experience in contract supervision and in construction of dams and irrigation works.

These specialists would be needed for a minimum of two years, and preferably three years, to adequately assist in organizing and training recruits in their respective functions.

28. Need for Contract Engineering Services

In the meantime, budgeted projects will have to await their turn for engineering attention and construction, and pressure may be exerted to get them started without the benefit of competent engineering - a most dangerous procedure. The solution to this unfortunate situation appears to be the engagement of external engineering assistance to take over the investigation, planning, design, economic analysis, and preparation of final plans and specifications for those budgeted projects which the WDD is unable to handle with its regular staff. Furthermore, it would be desirable that construction of such projects should be performed by competent contractors and supervised by the engineering group responsible for the planning and design if substantial progress is to be made in meeting budget programs. The WDD should be able to contract for these services with its own funds if provided with training personnel experienced in obtaining and supervising such services.

29. Other Personnel Requirements

Should engineering and contractural assistance be considered for an accelerated water development program in Cyprus along the lines heretofore discussed, it seems certain that the WDD staff would need to expand its functions as well as its personnel strength.

30. Land Acquisition

A new function that should be added will be that of land acquisition. If a reasonable construction program is to be carried on, and it is understood that delays in obtaining lands and rights-of-way needed for projects already engineered and financed are now preventing construction of these projects from starting, then some improved methods are necessary. Land acquisition laws have very recently been enacted which authorize the taking by the Government of private land for public water development, and provide for immediate occupancy upon payment of due compensation. A land acquisition or right-of-way division will quite certainly be needed to process these measures and to negotiate settlements with owners of lands and of water rights.

Since the successful accomplishment of the water development program under consideration is contingent upon the effectiveness of all of these activities, it is evident that the

rendering of external assistance in performing engineering and construction services should be contingent upon agreement of the Cyprus Government to provide these auxiliary functions and services.

PROJECT SELECTION

31. Regional Areas With Severe Water Shortage Problems

While many localities suffer shortage of water supply in the dry seasons, and in years of drouth, the more regional and persistent problems are considered to be:

a. Areas suffering sea water intrusion:

Famagusta District - (1) just south of the town of Famagusta, (2) north of Cape Greco, and (3) just west of Cape Greco.
Morphou District - just north of the Serakhis River mouth.
Limassol District - near Zakaki, southwest of the town of Limassol.

b. Ground water aquifers showing serious signs of depletion:

1. Eastern Mesaoria Plain:

(a) Southeastern area, serving the town water supply for Famagusta and all local domestic and irrigation uses.

(b) Central western area, serving Nicosia and local areas.

2. Western Mesaoria Plain:

(a) Central western area, serving supplemental water supply to Nicosia and local domestic and irrigation needs of the town of Morphou and villages of the area.

(b) Central eastern area, serving Nicosia and local needs.

3. Akrotiri Peninsular serving local needs for domestic and irrigation supplies.

4. Scattered areas of local importance, such as town supply for Kyrenia and vicinity.

5. The Pergamos-Xylophagou area, which serves the domestic needs of military bases at Dhokolia and local needs of neighboring villages.

c. Seasonal shortages of town and adjacent village supplies, from both surface flows and ground water extraction, such as at Larnaca.

32. Principal Areas of Water Productivity

According to data compiled by WDD, the most productive watersheds in Cyprus, considering both surface flows and ground water recharge, are as follows:

Watershed	Area Sq. m.	Estimated Average Annual Flow: MIG	Estimated Average Annual Flow: AC FT	Estimated Annual Waste to Sea: MIG	Estimated Annual Waste to Sea: AC FT
1. Serakhis	349	6, 750	25, 000	1, 000	3, 700
2. Kouris-Garyllis	177	6, 700	24, 800	5, 500	20, 400
3. Dhiarizos	98	5, 450	20, 200	4, 000	14, 800
4. Xeropotamos	90	4, 650	17, 200	3, 500	13, 000
5. Yermasoyia	70	3, 300	12, 200	1, 700	6, 400
6. Khrysokhou	76	3, 050	11, 200	1, 950	7, 200
7. Ezuza	91	2, 750	10, 200	2, 500	9, 200
8. Karyotis	38	2, 650	9, 800	750	2, 800
9. Vasilikos	59	2, 200	8, 200	750	2, 800
10. Marathasa	35	2, 000	7, 400	400	1, 500
11. Limnitis		1, 750	6, 500	600	2, 200
12. Tremithios	72	1, 550	5, 700	450	1, 700
13. Pendaskinos	65	1, 550	5, 700	650	2, 400
14. Elea	46	1, 600	5, 900	200	700
15. Xeros		1, 500	5, 500	150	600
16. Yialias (upper)	44	1, 500	5, 500	negl.	---
17. Khapotami	48	1, 300	4, 800	1, 200	4, 400

33. River Basins Suitable for Developmental Planning

Probably the most important factors to be considered in selection of certain river basins or watersheds for priority in planning and execution of water resources development are: (1) the critical nature of the water shortages and related problems

concerning the affected area; (2) the feasibility of developing supplemental supplies, which depend on such factors as water productivity of the basin, magnitude of annual waste to the sea or other losses which may be recoverable, quality (both present and future) of the surface and underground flows, physical potentials for surface storage and ground water recharge, and other factors requiring hydrological, geological and engineering analysis; (3) the regional importance of the affected area and its potential for future expansion; (4) the economic justification for such development, or for elements thereof, and (5) the social environment of the affected area and the effect of proposed developments upon this environment.

34. Selected Projects

Applying the above considerations within the brief time available for investigation, the following river basins have been selected as of prime importance for initial comprehensive water resources planning:

1. The Kouris-Garyllis watersheds and Akrotiri Peninsula, of regional importance in the vicinity of Limassol.

2. The Ezuza-Xeropotamos-Dhiarizos-Khapotami group of watersheds, of national importance in potential development of surplus water for export to adjacent areas, such as the Paphos district, or more remote areas.

3. The Tremithios watershed, of regional importance to the Larnaca district.

The comprehensive water resources planning contemplated for these river basins would be a thorough engineering investigation of all water resources available in each basin in years of maximum, average and minimum precipitation; of the surface storage, irrigation, water supply, ground water recharge facilities and other projects needed to accomplish maximum utilization of the safe yield of the basin; of the ultimate water needs of each basin for all forms of potential development; of the surplus waters available for transfer elsewhere annually, if any; and determination of the benefit-cost ratio of the overall program, and of the separate elements, needed to serve these objectives. This planning should be followed as rapidly as

financing can be arranged for construction of the elements that are found to be economically justified in the order of their importance in meeting critical needs and their rating in benefit-cost ratio.

35. Engineering Services Required

As an aid to estimating the magnitude of the engineering services involved in the projects selected for implementation, there is added to this report a sketch of each watershed to be given comprehensive treatment, outlining the general locations deemed suitable for dam site investigation, irrigational development and ground water recharge facilities. A summary of the pertinent basic data, hydrological, geophysical and economic, presently available for each river basin or specific project is furnished as Appendices B through D.

The staff requirements for engineering assistance to the Cyprus Water Development Department needed to conduct the investigations, planning, design and related activities for the comprehensive studies heretofore described are estimated to be as shown in the following table:

Comprehensive planning of water resources development in the Kouris-Garyllis, Ezuza-Xeropotamos-Dhiarizos-Khapotami and Tremithios River basins through the investigational and preliminary planning period to consummation of a long range plan for optimum utilization of all available water in these basins.

Title	No. of Positions Preferably		Desirable Allocation in man months	
	Cypriot	Non-Cypriot	Cypriot	Non-Cypriot
Director-Engineer		1		12
Senior Hydrogeologist		1		9
Asst. Hydrogeologist	1		12	
Senior Hydrologist		1		12
Asst. Hydrologist	2		24	
Testing Engineer		1		9
Dam Design Expert		1		12
Asst. Design Engineer	1		12	
Civil Engineers		2		24
Asst. Civil Engineers	2		24	
Engineer-Economist		1		12
Asst. Economist	1		12	

Title	No. of Positions Preferably Cypriot	Non-Cypriot	Desirable Allocation in man months Cypriot	Non-Cypriot
Agriculturist	1		12	
Engineering Assistants	4		48	
Senior Engineering Assistants and Draftsmen	6		72	
Senior Surveyors	4		48	
Asst. Surveyors	4		48	
Junior Surveyors	8		96	
Clerk-Bookkeeper	1	1	12	12
Typist	1		12	
Total Technical Positions	36	9	432	102

Note: One of the Senior Non-Cypriot engineers should have extensive experience in irrigation planning, construction and operation.

36. Time Requirements for Engineering

It is estimated that the investigation of resources and preparation of a comprehensive plan for each watershed should average about twelve months if staffed as above. Should elements of each plan be found economically justified and approved for budget financing, an additional six to twelve months, depending upon complexity of the project, would be needed to properly explore damsite foundations, design dams and other structures, and prepare plans and specifications for construction. Another three months would be required for receipt and analysis of bids and award of contract should the work be performed by competitive contracting, and the construction period would normally occupy from twelve to eighteen months. Thus, the time element involved between initiation of the comprehensive planning and completion of construction of any element would be a minimum of nearly three years.

The above estimate of man month requirements, however, includes only the initial twelve months phase of comprehensive planning, since there is no way of determining in advance what the detailed planning needs would be. The following estimates of average requirements for special projects will furnish a guide as to average requirements for this purpose, however.

37. Special Projects

Detailed planning and supervision and inspection of construction of special projects. The detailed surveys and exploration of sites for dams and other structures, testing of foundation and structural materials, layout and design of works, preparation of plans and specifications, and the supervision of construction and inspection are estimated to require the following engineering personnel; should units of the watershed master plans be financed for construction or should GOC plan to have some of its budgeted projects engineered through contract services:

Title	No. of Positions		Man Months	
	Cypriot	Non-Cypriot	Cypriot	Non-Cypriot
Resident Engineer		1		30
Geologist- Structural		1		3
Testing Engineer		1		30
Senior Design Engineer		1		12
Asst. Design Engineer		1		30
Engineering Assistants		4		84
Specifications Writer		1		6
Senior Surveyor		1		18
Asst. Surveyors	2		42	
Junior Surveyors	6		126	
Senior Inspector		1		18
Asst. Inspector	2		36	
Clerk-Typists	2		114	
	12	12	318	231

It is possible that engineers experienced in more than one of the above categories might be available to engineering firms which would reduce the overall personnel requirements accordingly.

38. Basic Hydrologic and Economic Data Available

Should consideration be given to obtaining proposals for the organization and support of an engineering team to perform the investigational, planning, design and other services heretofore discussed, an inventory of the hydrologic and economic data now available will be of value in formulating such proposals. For this reason, the following list of general geophysical data on file with

the WDD has been prepared, and an appendix will be added to this report listing additional data on hand for selected studies:

39. Maps

A variety of good maps exist which cover all of Cyprus in one or more sheets. These include:

a. Topographic Maps: Several types available, varying from general maps of the island with scale of 1:506,880 and contour intervals of 500', to Military maps (in 16 sections), scale 1:50,000 contour interval 100'.

b. Geologic Maps: Showing surface geology of all of Cyprus, scale 1:253,440. Sub-surface geologic explorations have been conducted in a few locations, primarily for minerals. A United Nations investigation of sub-surface hydrogeology of most of the plains area of Cyprus over a 5-year period is contemplated in the near future.

c. Land Registry Maps: Showing property boundaries, in sections, covering all of Cyprus, scale 1:5000.

d. Aerial Photographs covering all of Cyprus, in contact prints, scale 1:25000.

e. Classification Maps: Land use maps, covering all of Cyprus, in 16 sections, scale 1:50000.

40. Hydrologic Data

a. Precipitation records: Records from 85 standard rain gauges are available, many continuous since 1916; and from 5 automatic rainfall recorders, of 32 years duration at 2 installations, and of 3 years duration for 3 stations.

b. Stream-flow records: Records are available from 34 automatic depth recording gauges, mostly continuous since 1956.

c. Ground water records: Records available of depth to ground water at but few locations, ground water contour maps have been prepared in 2 or 3 instances.

d. Sediment movement: No continuous record maintained. A few samplings have been taken on certain streams. A report by Dr. D. J. Burdon on soil erosion and reservoir silting in Cyprus is available.

e. Water quality data: In general limited to spring and ground water sources.

f. Temperature - humidity data: Observed at about 32 meteorological stations.

g. Evaporation data: No continuous record maintained but scattered available data has been summarized.

h. General hydrologic studies: Following studies have been performed by the WDD:

(1) Isohyetal maps of maximum, minimum and average annual rainfall for all of Cyprus.

(2) Graphic record of daily runoff volume at gauging stations in 40 watersheds for each year from about 1956 to date, and comparable record of daily precipitation from nearest appropriate standard gauge.

(3) Computations of rainfall-runoff relationship in majority of watersheds (based on short term runoff records).

(4) Estimated maximum, minimum and average annual runoff, and of discharge to the sea, for 40 principal watersheds

(5) Estimated surface storage potentials, including suggested dam site locations, proposed storage volumes, proposed use of water for irrigation, village supply, etc., and a very rough estimate of benefit-cost ratios, for the 40 principal watersheds.

(6) General review of hydrogeology and estimate of underground water resources of Cyprus made by Dr. D. J. Burdon in 1953.

i. Seismologic data: No seismic instrument is now maintained in Cyprus.

j. Data relative to consumptive use of water by crops is being developed by the Department of Agriculture.

k. Some data on seepage losses in canals and natural channels has been assembled by the WDD.

41. Economic and Cost Data

a. Population Statistics: Census data for 1946 and population estimates for 1956, with projection to 1966, have been developed by the WDD for Cyprus as a whole, and for the principal towns. *

b. Industrial development and future potential. In general industrial development in Cyprus is at present limited to three or four large plants devoted to reduction and partial processing of mineral products, some small processing plants for agricultural products and small community industries. The UN Mission is working with GOC toward initiation of greater industrial development but no definite plants have as yet been formulated.

RECHARGE PROJECTS

42. Eastern and Western Mesaoria Plains

Invesitgation of ways and means of meeting the urgent problems of sea water intrusion and rapidly lowering ground water table on both the Eastern and Western Mesaoria Plains is not included in the recommended long-range planning program for the reasons that necessary information concerning the ground water basins and aquifers of these Plains has not yet been developed. An investigation and program to obtain this information over a five year period is expected to be undertaken through the United Nations Special Fund. Currently there is practically no loss to the sea of surface waters indigenous to Eastern and Western Mesaoria Plains and consequently no supplemental water to develop except by depriving one area of water in favor of another. The

* Cyprus Water Development - 1959" by I. L. Ward, former Director, WWD.

quickest and most equitable way of relieving this situation appears to be effective government regulation of all water development and utilization in these areas to a degree that will stop the current decline of water table elevations. This can probably be best accomplished by uniform reduction of pumping from ground water sources after wasteful use of water, either domestic or irrigational, has been halted. Another method of improving ground water conditions in definite areas often found practical is to impound all local surface runoff possible that is of satisfactory quality and use it to recharge the depleted aquifer. The installation of recharge works has been practiced to a very limited degree in Cyprus and should be more generally applied.

The WDD has developed a list of 34 dams that have been requested by various localities, of which 14 are dams intended for early construction to meet urgent water supply, irrigation, and in one or two cases, ground water recharge needs.

43. Suggested Ground Water Recharge Installations

In order that utilization of surface recharge basin systems (sometimes referred to as water spreading grounds) may be investigated and encouraged if found adaptable to Cyprus conditions, it is sugested that one or two such installations, as described in Paragraph 20, be planned in connection with construction of the dams to be financed by the 1963 budget.

In the selection of locations for installation of surface water spreading grounds, or recharge basin systems, it is necessary to meet several requirements, such as (1) sufficient unused stream flows to warrant the installation, (2) satisfactory infiltration and transmissibility rates in the surface area to be occupied and in the ground water basin or aquifer underneath, respectively, (3) satisfactory quality of water to be used for recharge and (4) lands having low procurement and development costs in order to obtain a satisfactory benefit-cost ratio. Such installations should initially be installed at points where a declining water table or increase in salinity of ground waters is occurring, if possible, and the Famagusta, Morphou and Akrotiri areas warrant consideration in this respect.

a. Famagusta Area

The WDD has developed and operates a ground water recharge system designed to replenish the aquifer paralleling

the coast for some distance north and south of the town of Famagusta. This system consists of several low earth dams and small reservoirs which intercept surface runoff from the local watersheds, direct it to a central point (the Ayios Loukas Reservoir) and there deliver it to a 2 x 3 foot tunnel-gallery of about 4 miles length which is located along the aquifer with its invert about 10 feet above mean sea level (see General Map for location).

By judicious control of releases from the reservoirs, silt movement is kept to a minimum and does not seem to be a very serious problem although cleaning of the tunnel has been necessary on occasions.

The catchment area of a new low dam upstream from Ayios Loukas Reservoir is located over a pervious area and on three occasions this Spring the catchment area has substantially filled and shortly thereafter dried up due to the high porosity at this location. This infiltration has raised the water table in the vicinity several feet. The WDD plans to install more of this type of recharge facility in the area.

It is possible that locations can be found for surface spreading grounds which would overlie the depleted Famagusta aquifer and that these could be supplied with catchment water pumped from Ayios Loukas Reservoir. It is probable that surface installations of this nature would be more efficient than the tunnel-gallery system and also much easier and less expensive to maintain. Care must be taken to seek locations at which the building of a fresh water barrier mound will not cut off a substantial section of highly salinized aquifer, as the saline water would be trapped in the area where good water is desired.

It is not expected that the excellent program of water recharge devised and being expanded by the WDD will be sufficient to overcome the current overdevelopment of bore holes and overdraft of ground water supply attributable to pumping of the same. The extremity of need of more water for domestic use may necessitate consideration of facilities for desalting of sea water or for installation of a sewerage system equipped to reclaim effluent and deliver it to recharge installations.

b. Morphou Area

This area is experiencing increasing salinity problems in the citrus region several miles northwest of the town of Morphou, some bore holes now producing water of 1, 300 p.p.m. saline content as compared to a maximum tolerance of 800 p.p.m. recommended by the Department of Agriculture for citriculture in that area. The increased salinity does not seem directly attributable to sea water intrusion, although the area is but 3 or 4 miles from the coast and salinity is increasing. The land surface is about 160 feet above mean sea level, and the static water table lies about 60 feet above m.s.l., although a drawdown of 70 feet is experienced after several hours of pumping. It is probable that the sub-surface recharge of the aquifer is of high salinity and that increased pumping has reduced dilution formerly experienced and thereby encouraged concentration of the saline content.

There are two rivers which traverse the Morphou aquifer. The Serakhis, on which the WDD is now constructing a 40 foot high earth fill dam with 400 MIG (or 1480 AF) reservoir capacity is expected to infiltrate directly into and recharge the aquifer about 5 miles from the sea coast. The second is the Ovgos, on which construction of a similar dam is planned for 1963, and several rivers, including the Meriki, Akaki and Peristerona, are tributary to the Serakhis from the northerly slope of the Troodos range, and several others, of which the Elea, Karyotis and Marathasa are most important, are considered to contribute to recharge of the Morphou aquifers.

Inspection of these streams for sites conducive to effective surface water replenishment reveals, however, that local diversions of stream flow now utilize practically all normal discharge, and that though additional water may be produced by construction of new dams and reservoirs which the WDD plans on all of these streams, such new water is certain to be utilized for surface diversion. Since such use would be during the Spring months, no extensive holdover of reservoir storage would be involved and there is little need for recharge facilities in this area, particularly since the annual escape to the sea from the Serakhis is small and may be reduced to nil by operation of Morphou Dam when completed.

One prospect for recharge development appears in the citrus area northwest of Morphou which is suffering from salinity.

The underlying aquifer seems to be separated from the main Morphou aquifer and dependent on natural recharge from the Ovgos River and from irrigation flows diverted from this stream. It is suggested that very temporary spreading basins formed by earth dykes be installed at the end of a few of the irrigation canals and that they be tested for infiltration rates by filling with water diverted from the Ovgos River prior to the regular irrigation season. If the infiltration rates are found satisfactory, say in excess of 1 to 2 feet per day for a period of several days, then the number of spreading basins should be increased soon after completion of the Ovgos River dam if it is determined that the water impounded is of good enough quality for aquifer recharge.

c. Akrotiri Peninsula

This is one of the principal agricultural areas of the southern coast of Cyprus due to such factors as the relatively level character of the land, the excellent ground water aquifer serving it, and the substantial replenishment received by the latter from the nearby Kouris River, which is one of the largest of the southerly watersheds of the Troodos Range. In spite of these advantages, it has been overpumped, particularly in the portions some 3 or 4 miles from Limassol, and sea water intrusion is being experienced at this point. A contributing factor to the water table decline is sealing of the bed of the Kouris River, through which most of the aquifer replenishment infiltrates, by asbestos fibres washed down from the waste dumps of the mines high up in this watershed.

The WDD intends to request that funds be provided in the 1963 budget for improvement of the recharge of this aquifer. It contemplates the excavation of a channel along the course of the Kouris River, but separate therefrom, in which the unpolluted flow of a major tributary, the Limnitis River, may be brought to the aquifer. Measures are also being taken to correct the conditions at the mine dumps which cause the pollution, and in time it should be reduced to acceptable proportions.

An investigation and report on this situation was made for GOC in 1961 by Prof. L. D. Doneen, FAO Consultant, who suggested that recharge of the aquifer be expedited by continuous irrigation of a strip of land about 1/4 mile wide and 1 - 1-1/2 miles long when water was available during the Winter and Spring

months of 1961-1962. Care would need be taken to protect existing grape and citrus plantings from damage caused by irrigation.

The urgent need for increased recharge of this aquifer, particularly just inland from the edge of serious sea water intrusion is concurred in. The suggestion is offered, however, that the feasibility of installing surface basin recharge facilities (spreading grounds) be investigated as a means of concentrating recharge at point of need and for efficiency in operation. Such a system would involve a study of the sub-surface geology for determination of the points at which recharge would be most effective and the probable rates of transmissibility; the conducting of tests of small plots of ground in these areas to determine average rates of infiltration; computation of the wetted area of basins needed to accept the maximum available flow to be spread; and installation of basins connected by temporary type overflow weirs. Sufficient basins should be installed to permit rotation and they should be instrumented for determination of their effectiveness, both in observation of input to the aquifer and of resulting effectiveness indicated by rise of the ground water table in nearby bore holes and by reduction in saline content determined by chemical analysis of samples.

The cost of supply of clear water from the Limnitis River should be checked with the cost of removing the asbestos fibres from water taken directly from the Kouris River several miles downstream, which would involve installation, operation and maintenance of desedimentation basins and possibly of the use of flocculating agents.

Probably the most extensive development and use of this type of recharge basin has been in the Southern California area, the Los Angeles County Flood Control District in particular having a large number of such recharge facilities in successful use. Advice of this organization as to the detailed planning of the recharge facilities would be of great assistance.

Since the initial installation would involve mostly use of earthmoving equipment and temporary wooden structures, it would be inexpensive to construct except for the recording instruments required.

The General Map included in this report indicates the approximate locations suggested for initial recharge installations.

PERTINENT GENERAL INFORMATION

44. Recruitment Potentials

Inquiry was made as to the current availability of qualified (college graduate) engineers living in Cyprus who might be interested in WDD employment at this time. The following information was obtained.

Engineering Society	Qualified Total Members	Members Working Part Time
Turkish	13	5
Greek (two societies)	45	

The WDD is investigating the opportunities for recruiting Cypriot expatriate engineers in Greece, England, etc.

A number of Greek and Turkish student engineers will graduate this year and will be solicited for recruitment.

It is understood that one of the past causes of failure to recruit new qualified personnel has been insistence upon British schooling which has eliminated graduates of Near Eastern universities. With adequate training as discussed heretofore, this requirement could be moderated from the technical standpoint.

45. Water Use Regulation

This subject has been given passing comment only due to the thorough treatment being given this phase of water conservation by a UN team, headed by Dr. Krausz. Its importance cannot be overstressed, and it should be given immediate and persistent attention until needed legislation is enacted and enforced.

Perhaps the most practical method of accomplishing satisfactory regulation of water extraction would be the gradual conversion of pumping by individuals to centralization of all pumping in irrigation divisions or water supply authorities. Legislation providing for organization of such divisions and authorities has been enacted, and many such agencies have been formed, particularly for distribution of surface water supplies. Greater application of such agencies to the extraction and distribution of ground water supplies would certainly facilitate proper

management of ground water resources and reduce the problems connected with managing and policing of pumping by thousands of individual pumpers.

46. Soil Conservation

The limited time available has not permitted detailed analysis of soil erosion and movement but it is certain that sedimentation and depositing of debris will be a troublesome factor in the planning of dam and reservoir construction and operation in many watersheds. This factor will have to be given consideration in the preparation of both special project plans by WDD and in the comprehensive planning suggested for the southerly watersheds of the Troodos Range. It is probable that the construction of a number of dams within a river basin will tend to reduce sedimentation movement over a period of years, but special measures may be required in some instances, such as installation and operation of sluicing gates in the dams, or of stream bed stabilization through installation of small check-dams on erodable sections of the river system. A report on silting of reservoirs caused by soil erosion by Dr. Burdon is available (see Bibliography).

47. Activities of International Agencies

The following agencies are known to be conducting or proposing hydrological or hydrogeological investigations in Cyprus at the present time.

The French Government has three hydrologists assigned to the WDD for the purpose of assisting in the development of data concerning surface runoff and ground water fluctuations. They are assigned by WDD to the Morphou Basin and are not expected to extend their activities elsewhere.

The United Nations is expected to organize a Special Fund investigation of the mineral and ground water resources of Cyprus. This is greatly needed for definition of the boundaries, depths and characteristics of the principal ground water basins and aquifers, and completion of this investigation is a prerequisite to comprehensive planning of water utilization in the Eastern and Western Mesaoria Plains. This should not preclude, however, installation of amelioratory measures, such as provision of surface storage and recharge installations, at points of great need during the course of the investigation.

The German Government has offered the assistance of a few geologists in the investigation of water resources but information obtained from WDD indicates that this offer has not been detailed. It is expected that this activity will be devoted to the Kyrenia Range and northern areas.

The Israeli Water Agency, Tahal, has indicated its interest in obtaining a contract for performing the UN Special Fund investigation, and has prepared a preliminary report which proposes, in addition, studies of surface water hydrology and planning of water resources development. However, study of the Cypriot proposal for UN Special Fund investigation indicates that it contemplates only sub-surface investigation.

Every effort has been made to limit the scope of this report to water problems and suggestions for relief measures to phases and areas of water development that would neither conflict with nor seriously duplicate the activities of the international agencies mentioned above.

48. Methods of Construction

It is probable that progress in development of the Cyprus water resources will be retarded if the WDD continues to rely solely on construction of all works by means of its own forces. A much sounder procedure would seem to be one that would use this method for a fairly uniform program of annual construction of smaller dams, irrigation and water supply works, and for maintenance and operation of all works - which will grow each year - and would rely on contracting firms to build the larger structures and to meet abnormal work programs. Inquiry indicates that while a number of Cypriot firms engage in contract construction of road work and of both public and private building, none has undertaken important water development construction, such as dams, irrigation works, etc., with the exception of bore hole drilling. Development of the know-how for dams and related construction would apparently necessitate an affiliation between Cypriot and non-Cypriot contracting firms for a period of time during which such know-how could be cultivated. However, the WDD is at this time entirely inexperienced in the procedures involved in contract methods of construction, including preparation of contract drawings, specifications and documents - and in supervision and inspection of contract work. This experience would be gained if the training personnel and program heretofore suggested were followed.

49. Construction Equipment

The WWD now obtains the heavy equipment it uses in construction of earth fill and concrete gravity dams by rental of the same from private agencies. Most of the equipment used is of a type also suitable for road construction or for farm irrigation and cultivation. It may be desirable to consider accumulation of its own construction equipment pool for its regular force account work, and even for rental to future contractors, but this should be conditional upon organization of an adequate shop and service division. It should also be studied as to economy in comparison with continued rental of equipment, which is reported to be very reasonable in cost.

In any event, increased programing of the construction of earth fill, rockfill and concrete dams will necessitate acquisition by WDD of materials and soil testing equipment for field and laboratory use, that is essential to proper control of the materials used in such construction.

50. Economic Justification or Feasibility

Since the principal requirements for water utilization are for domestic and irrigation purposes, financial feasibility will depend to a considerable extent on revenues derived from sale of water for these purposes. Preliminary estimates have been prepared by the WDD for many of the small dams, irrigation and water supply systems it has proposed which indicate a rather surprising ratio in favor of such projects.

This is probably due to the relatively high returns estimated from such agricultural enterprises as deciduous and citrus fruits, vegetable and other irrigable crop production. The Director of the Department of Agriculture estimates the average annual net returns per acre for various crops as follows:

	Est. Ave. Annual Gross Value to Grower per Acre	Est. Ave. Annual Cost of Production per Acre	Est. Ave. Annual Net Value to Grower per Acre
Irrigated Crops			
Citrus (mostly oranges)	£ 400-420	£ 150	£ 250-270
Deciduous (apples, peaches, cherries, pears, plums, etc.)	£ 1000	£ 150	£ 850
Carrots*	£ 750	£ 300	£ 450
Truck (tomatoes, cabbage, etc.)	£ 750	£ 300	£ 450
Potatoes (2 crops)	£ 240	£ 90-100	£ 140-150
Watermelons*			£ 150-200

* Carrots and watermelons seasons permit one crop of each every year from the same land.

Dry Farming			
Wheat (one crop in 2 years)	£ 8.5 to 9	£ 5.5 to 6	£ 3
Barley	£ 10	£ 7	£ 3
Carobs (natural stands, very few plantings)			£ 22
Olives (mostly natural stands)	£ 21	£ 10	£ 11
Grapes	£ 21	£ 10 - 11	£ 10-11

Cyprus £ = US $2.80

The Director, Dr. Loizides, estimates that good unimproved arable land with surface or ground water available, is valued at £ 1,000 per acre, and that a well developed full yield citrus grove is worth from £ 2,500 to £ 3,000.

He also states that arable land suitable for dry farming only, due to non-availability of water, will bring from £ 10 to £ 50 depending upon its situation.

These values were so high as to occasion reevaluation but the estimates quoted were confirmed. For instance, carrots were stated to yield 10,000 okes per donum or 30,000 okes per acre and to sell at 1/2 shilling per oke (2.8 pounds) at the farm, a gross value of £ 750 per acre.

Dr. Loizides pointed out that the figures quoted were based on the prices paid the grower, and that the value of the crops to the Gross National Product would be much higher.

It is obvious that the very high return from irrigated crops in comparison to dry farming products will be an important element in economic justification of water development projects. However, the income derived from some of the vegetables, such as potatoes, tomatoes and carrots, vary from year to year depending upon the availability of markets, climatic conditions and difficulty with plant diseases.

APPENDIX A

BIBLIOGRAPHY

BIBLIOGRAPHY

"Cyprus - Suggestions for a Development Programme" by Wilford L. Thorp, Director of Merrill Center for Economics and Professor of Economics, Amherst College, published by U. N. in 1961.

"A Concise Report on the Possibilities for the Impoundment of the River Waters of Cyprus" by C. A. C. Konteatis, B. Sc. (Eng.) A. M. I. C. E., A. M. I. W. E. - August, 1961.

"Report to the Government of Cyprus on Some Major Irrigation and Drainage Problems" by Prof. L. D. Doneen, FAO Consultant, 1961, Irrigation Dept., U. C. B.

"Hydrology and Water Development in Cyprus" Paper by Ivan Lee Ward, BE, M. I. C. E., David Patric McGregor, B. Sc., and Michel Grehan, B. Sc. (Eng.), A. M. I. C. E. published by the Institution of Civil Engineers, 1958.

"Cyprus Water Development - 1959" by I. L. Ward, C. B. E., B. E., M. I. C. E., published by the Cyprus Government Printing Office, April 1959.

"The Underground Water Resources of Cyprus" by David J. Burdon, Ph. D., M. Sc. B. E., D. I. C., A. C. S. M.

"Soil Erosion and Silting Up of Reservoirs in Cyprus" by David J. Burdon.

"Water Resources of Cyprus" by M. Grehan, August 1958.

Records, plans, reports and other data on file in the Cyprus Department of Agriculture and Water Development.

APPENDIX B

KOURIS-GARYLLIS RIVER BASINS

KOURIS-GARYLLIS RIVER BASIN

Detailed Basic Data Available

Type	Rainfall Stations	Elevation Above MSL	Length of Record	Location
R_m#250	Pano Platres	3600	1927-to date	Within watershed
R_m 270	Troodos	5720	1929 - 1945	Within watershed
R_m 300	Pano Amiàndos	4250	1926-to date	Within watershed
R_m 320	Saittas Nursery	2100	1930-to date	Within watershed
R_m 330	Phassouri Plantations	50	1954-57, 1959	Within watershed
R_m 390	Limassol	40	1916-to date	Within watershed
R_s 260	Kilani	2600	1916-to date	Within watershed
R_m 230	Trikoukkia Nursery	4400	1925-to date	Adjacent to watershed
R_s 220	Pedhoulas	3550	1936-to date	Adjacent to watershed
R_s 310	Platania	3680	1934-to date	Adjacent to watershed
R_s 400	Kalokhorio	2200	1916-to date	Adjacent to watershed
R_s 410	Ayios Theodhoros	3300	1948-to date	Adjacent to watershed
R_s 420	Alona	3500	1959-to date	Adjacent to watershed

R_m - Standard gauge, 24 hour rainfall, temperature and humidity readings.

R_s - Standard gauge, 24 hour rainfall observations.

Stream Flow Recording Stations

R_a	Trimiklini	1900	Dec. 1955-to date	Kouris R., catchment 19.6 sq. mi.
R_a	Kandou	350'		Kouris R., catchment 122.3 sq. mi.

R_a - Automatic stream flow depth recorder

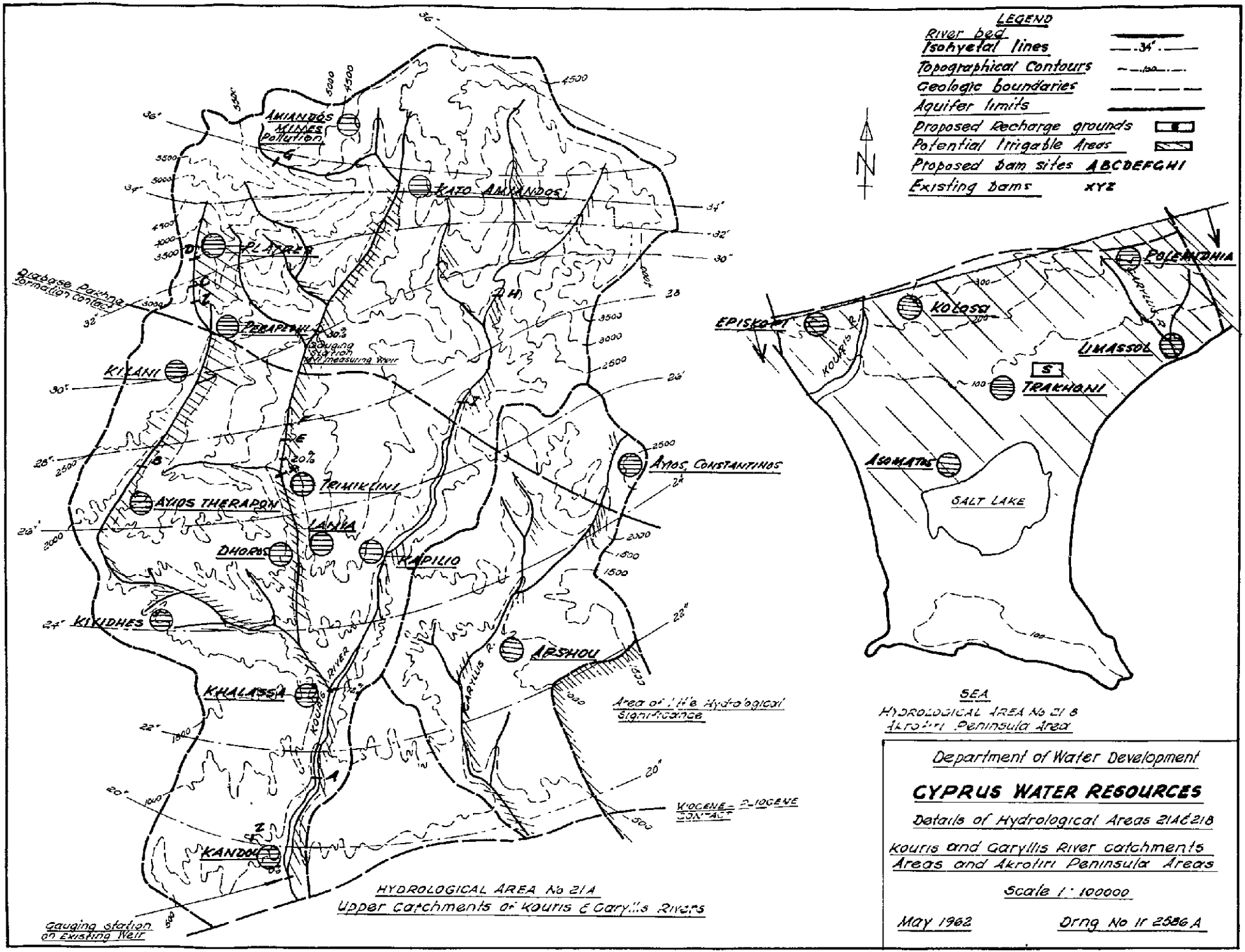
KOURIS-GARYLLIS RIVER BASIN

Damsites Studied by WDD

Stream	Site	Type	Height	Storage Capacity	Area of Catchment
Kouris R.	Kandou	Earth	50'	206 MIG or 760 AF	120 sq. mi.
Amiandos R.	Lania	C. G.	110'	81 MIG or 300 AF	12 sq. mi.
Amiandos R.	Dhoros	C. G.	110'	92 MIG or 340 AF	12 sq. mi.
Amiandos R.	Loumata	C. G.	65'	76 MIG or 280 AF	1.5 sq. mi.
Kryos R.	Ayios Therapon	C. G.	70'	130 MIG or 480 AF	12 sq. mi.
Kryos R.	Kilani	C. G. or R. F.	100'	200 MIG or 740 AF	6 sq. mi.
Kryos R.	Platres	C. G.	100'	53 MIG or 200 AF	3 sq. mi.
Limnitis R.	Kapilio	C. G.	90'	160 MIG or 600 AF	15.5 sq. mi.
(Alternate Sites)	Ayios Mamas	C. G.	100'	103 MIG or 380 AF	15.5 sq. mi.

Note: E. F. - earth fill; C. G. - concrete gravity; R. F. - rock fill.

Preliminary investigation has included topographic survey of dams and reservoir sites, tentative selection of type of dam, typical sections, storage capacity curve, volume of construction materials required and capacity/volume relationship curves.


LEGEND
River bed
Isohyetal lines
Topographical Contours
Geologic boundaries
Aquifer limits
Proposed Recharge grounds
Potential Irrigable Areas
Proposed dam sites ABCDEFGHI
Existing dams XYZ
AMIANDOS MINES Pollution
KATO AMIANDOS
PLATRES
PERAPEDHI
KIKANI
AYIOS THERAPON
TRIMIKLINI
LANIA
DHOROS
KAPILIO
KIVIDHES
KHALASSA
KANDOU
ARSHOU
AYIOS CONSTANTINOS
Diabase Pachna Formation contact
Gauging station on Measuring Weir
KOURIS RIVER
CARYLLIS R.
Area of little Hydrological significance
MIOCENE - PLIOCENE CONTACT
Gauging station on Existing Weir
HYDROLOGICAL AREA No 21A
Upper Catchments of Kouris & Caryllis Rivers
EPISKOPI
KOLOSSI
LIMASSOL
TRAKHONI
POLEMIDHIA
ASOMATOS
SALT LAKE
SEA
HYDROLOGICAL AREA No 21 B
Akrotiri Peninsula Area
Department of Water Development
CYPRUS WATER RESOURCES
Details of Hydrological Areas 21A & 21B
Kouris and Caryllis River catchments Areas and Akrotiri Peninsula Areas
Scale 1 : 100000
May 1962
Drng No Ir 2586 A

APPENDIX C

EZUZA-XEROPOTAMOS-DHIARIZOS-KHAPOTAMI RIVER BASINS (IN THE ORDER NAMED)

EZUZA-XEROPOTAMOS-DHIARIZOS-KHAPOTAMI RIVER BASINS

Detailed Basic Data Available-

Rainfall Stations

Type		Station	Elevation Above MSL	Length of Record	Location
R_m	#250	Trikoukkia	4400	1925 to date	Within watershed
R_s	80	Anatoliko	200	1924 to date	Within watershed
R_s	109	Asproyia	2000	1958 to date	Within watershed
R_s	120	Stavros Psokas	2590	1921 to date	Within watershed
R_s	140	Kelokedhara	1700	1916 to date	Within watershed
R_s	150	Alekhtora	750	1916 to date	Within watershed
R_s	180	Kykko Mon.	3700	1916 to date	Within watershed
R_s	200	Ayios Nikolas	2400	1916 to date	Within watershed
R_m	20	Kato Paphos	33	1946 to date	Adjacent to watershed
R_m	30	Ktima	300	1938 to 1958	Adjacent to watershed
R_m	250	Pano Platres	3600	1927 to date	Adjacent to watershed
R_m	250	Troodos	5720	1929-1945	Adjacent to watershed
R_m	300	Pano Amiandos	4250	1926 to date	Adjacent to watershed
R_m	320	Saittas Nursery	2100	1930 to date	Adjacent to watershed
R_s	50	Ayios Neophytos	1400	1916 to date	Adjacent to watershed
R_s	110	Ayia Forest Station	2000	1916 to date	Adjacent to watershed
R_s	170	Phissouri	550	1935 to date	Adjacent to watershed
R_s	190	Evdhimou	300	1916 to date	Adjacent to watershed

R_m - Standard Gauge; 24 hour rainfall, temperature and humidity readings.

R_s - Standard Gauge; 24 hour rainfall observations.

EZUZA-XEROPOTAMOS-DHIARIZOS-KHAPOTAMI RIVER BASINS

Stream Flow Recording Stations

Type	Location	Elevation	Length of Record	Catchment Area
R_a	Xeropotamos River Sta., near Mandria	30'	Oct. 1956 to date	88.2 sq. mi.
R_a	Dhiarizos River Sta., near Kouklia	50'	Oct. 1956 to date	102. sq. mi.

R_a - Automatic stream flow depth recorder

Damsites Studied by WDD

Stream	Site	Type	Height	Storage Capacity	Area of Catchment
Ezuza River	#1	C. G.	100'	325 MIG or 1200 AF	
Ezuza River	#2	C. G.	170'	1600 MIG or 5900 AF	15 sq. mi.
Ezuza River (Ayia)	#3	C. G.	100'	210 MIG or 800 AF	
Ezuza River (Ayia)	#4	C. G.	100'	1200 MIG or 4400 AF	
Ezuza River	#5	C. G.	100'	1300 MIG or 4800 AF.	61 sq. mi.

C. G. - Concrete gravity type.

Preliminary investigation has included topographic survey of dam and reservoir sites, tentative selections of type of dam, typical section, storage capacity curve, volume of construction materials required and capacity/volume relationship curves.

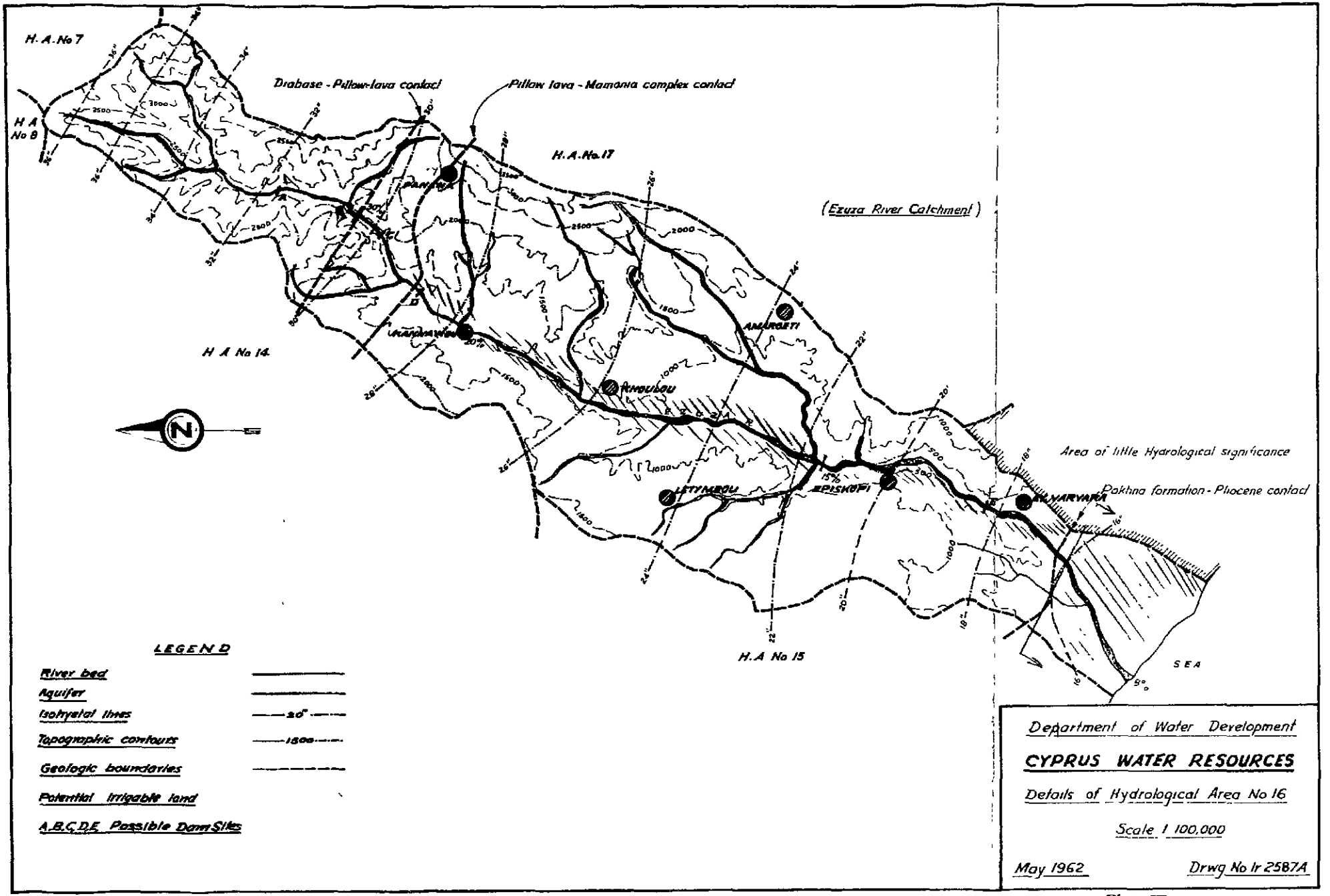
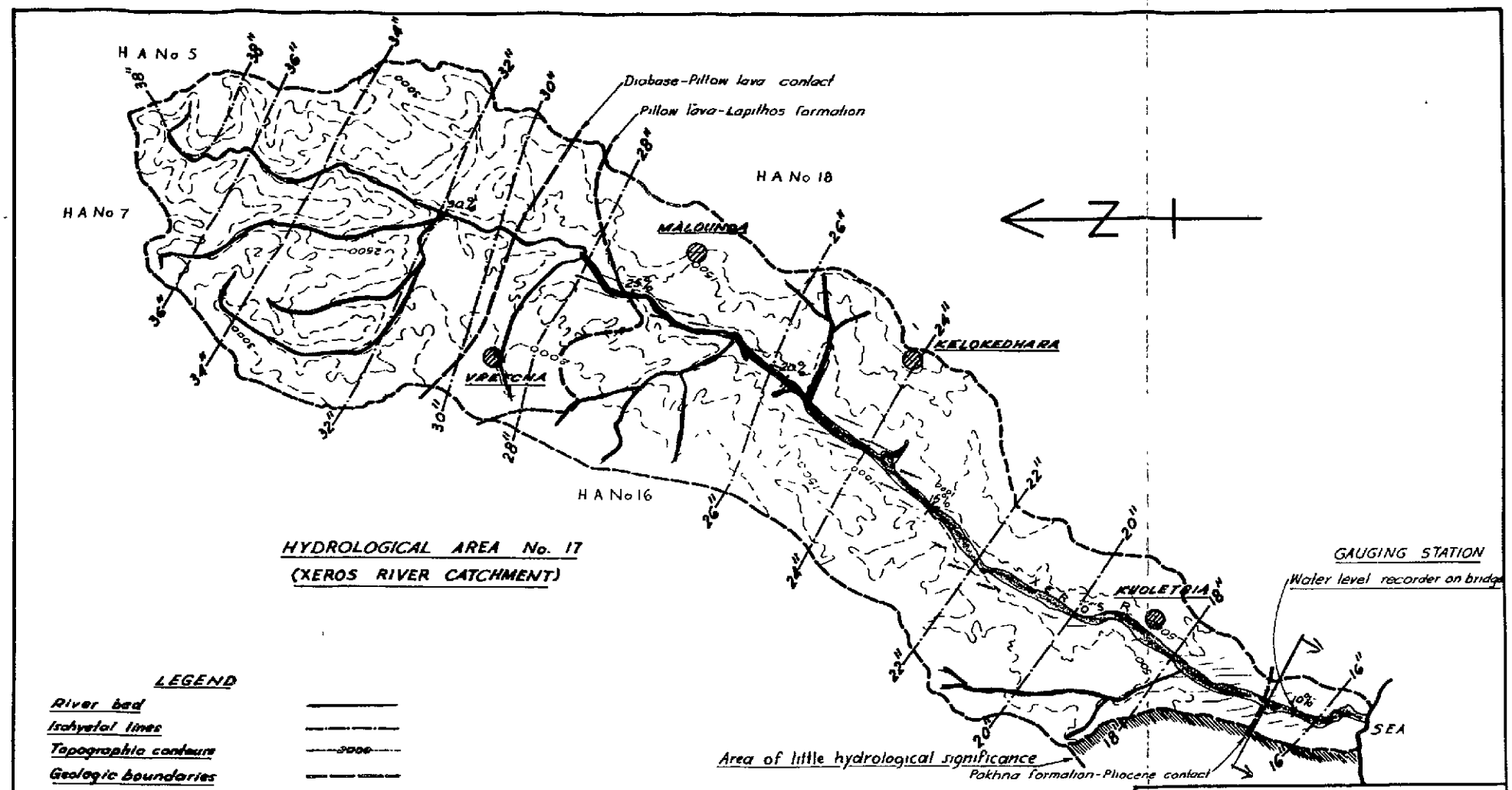

H.A.No 7
H A No 8
Drabase - Pillow-lava contact
Pillow lava - Mamonia complex contact
H.A.No 17
(Ezuza River Catchment)
H A No 14
AMARGETI
ARGOULOU
LETYMBOU
EPISKOPI
PAPHOS
Area of little Hydrological significance
Pakhna formation - Pliocene contact
H.A No 15
SEA
LEGEND
River bed
Aquifer
Isohyetal lines
Topographic contours
Geologic boundaries
Potential irrigable land
A,B,C,D,E Possible Dam Sites
Department of Water Development
CYPRUS WATER RESOURCES
Details of Hydrological Area No 16
Scale 1 100,000
May 1962
Drwg No Ir 2587A

Plate III



Department of Water Development

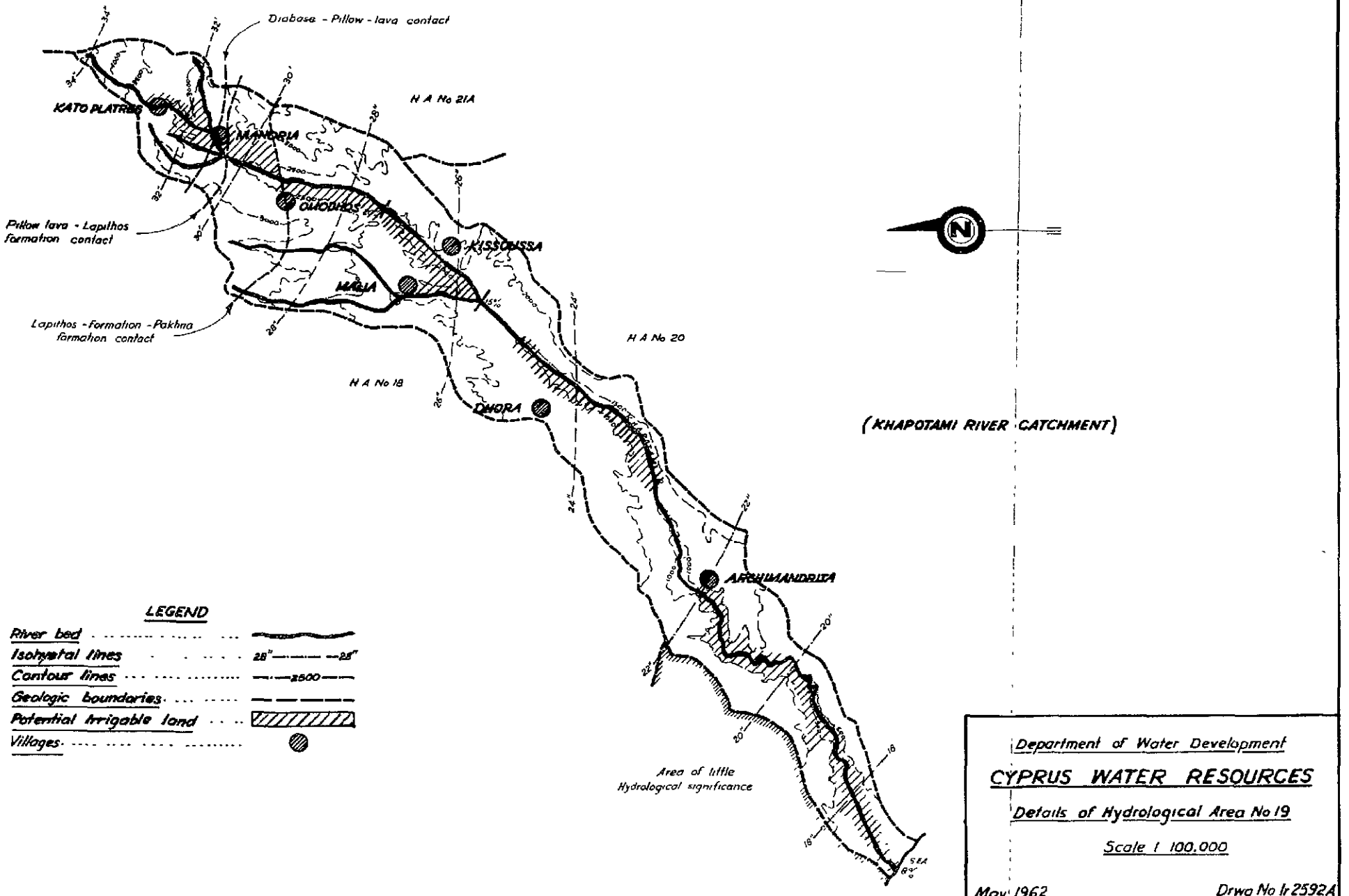
CYPRUS WATER RESOURCES

DETAILS OF HYDROLOGICAL AREA

No 17

Scale 1 100 000

May 1962 DRWG No G 2587/A


Diabase - Pillow - lava contact
KATO PLATRES
MANDRIA
OMODHOS
KISSOUSSA
MAGIA
Pillow lava - Lapithos formation contact
Lapithos - Formation - Pakhna formation contact
H A No 21A
H A No 20
H A No 18
OMORA
AFRODHANDRITA
(KHAPOTAMI RIVER CATCHMENT)
Area of little Hydrological significance
SEA
LEGEND
River bed
Isohyetal lines
Contour lines
Geologic boundaries
Potential irrigable land
Villages
Department of Water Development
CYPRUS WATER RESOURCES
Details of Hydrological Area No 19
Scale 1 100,000
May 1962
Drwg No Ir 2592A

APPENDIX D

TREMITHIOS RIVER BASIN

TREMITHIOS RIVER BASIN

Detailed Basic Data Available

Type	Rainfall Stations	Elevation	Length of Record	Location
R_m #660	Kornos	1100	1918 to date	Within watershed
R_s #710	Kiti	60	1937 to date	Within watershed
R_m 730	Larnaca	10	1946 to date	Adjacent to watershed
R_s 600	Pano Lefkara	1900	1916 to date	Adjacent to watershed
R_s 650	Parakhorio	790	1941 to date	Adjacent to watershed

R_m - Standard rain gauge, 24 hour rainfall, temperature and humidity readings.

R_s - Standard rain gauge, 24 hour rainfall, observations only.

Stream Flow Recording Stations

Type	Location	Elevation	Length of Record	Catchment Area
R_a	Ayia Anna	450	1957 to date	35.0 sq.mi.
R_a	Near Kiti	75	1956 to date	59.0 sq.mi.

R_a - Automatic stream flow depth recorder.

TREMITHIOS RIVER BASIN

Damsites Studied by WDD

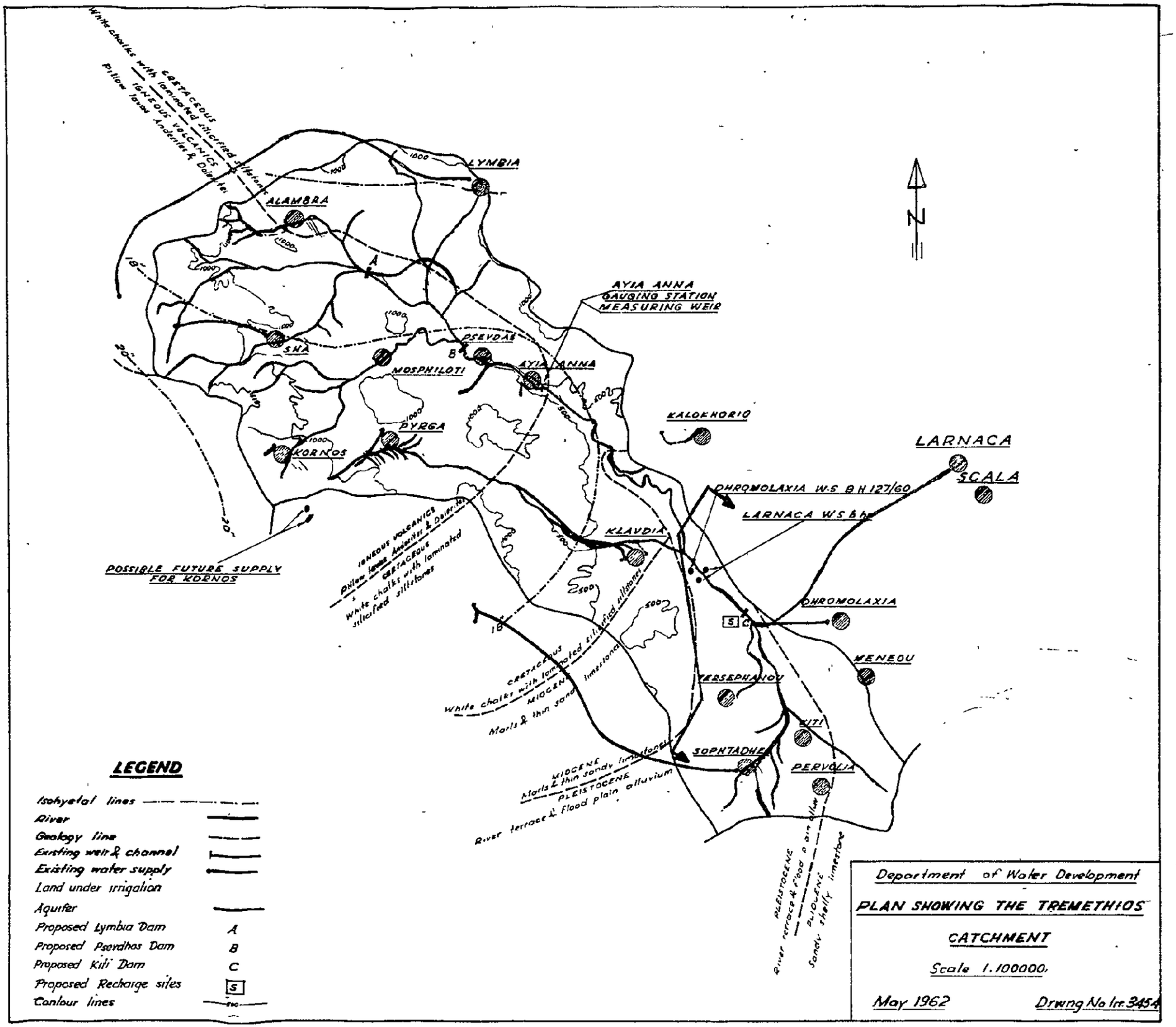
Stream	Site	Type	Height	Storage MIG	Capacity AF	Area of Catchment
Tremithios River	Kiti	E.F.	40'	353	1320	
Tremithios River	Psevdhas	C.G.	70'	1120	4100	28.6 sq.mi.
Tremithios River	Lymbia	E.F.	48'	100	370	12.5 sq.mi.

E.F. - earthfill; C.G. - concrete gravity.

Water rights problems - private as well as church holdings, both Greek and Turkish.

Geology: several auger holes drilled at sites and boreholes nearby. A general geophysical survey of the river has been made.

Preliminary investigation has included topographic survey of dam and reservoir sites (scale 1:2500), tentative selection of type of dam, typical sections, storage capacity, curve, volume of construction, materials required and capacity volume curves.



Department of Water Development

PLAN SHOWING THE TREMETHIOS CATCHMENT

Scale 1.100000.

May 1962 Drwng No Irr 3454

Plate VI