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Hydrology and water development in Cyprus †

by

Ivan Lee Ward, B.E., M.I.C.E.

David Patrick McGregor, B.Sc.

and

Michel Grehan, B.Sc.(Eng.), A.M.I.C.E.

Discussion

The Authors, when introducing the Paper, showed a number of slides including some typical landscapes to illustrate the class of country from which water was drawn.

They drew attention to an error in the original Paper in § 27, where, in line 4, the figure 30,000 acres should read 60,000 acres.

Mr Gerald Lacey said that at the request of the Cyprus Government, and as drainage and irrigation adviser to the Colonial Office, he had visited Cyprus to advise on water policy.

63. The Paper was extraordinarily complete in its presentation. The engineering, the geological, and the hydrological aspects of the problem in Cyprus were all dealt with adequately. It would be difficult to find elsewhere within so small a compass so many examples of irrigation works of different types.

64. In the east of the island there was the Kouklia reservoir. This was very like what was called a tank in India, and had been designed by an engineer from India. A disappointing feature of this reservoir was that it filled only once in 5 years, but nevertheless, it did trap such water as found its way there.

65. The irrigation in that part of the area was "spate" irrigation. Those who were familiar with spate irrigation in the Sudan, or irrigation of the same type in the Abyan scheme in the Aden Protectorate, would be interested in the examples found in Cyprus.

66. In the more elevated part of the island small perennial canals were encountered and finally there were the masonry dams. It was unfortunate that the slopes of the valleys in the Troodos were so severe that they did not permit of large storage works; but they did provide just sufficient storage to give the final watering so necessary to mature the winter crops.

67. It was of interest to compare Figs 1 and 2 and observe how the isohyets reflected the contours of the ground. At Morphou the actual rainfall was less than anywhere else, and yet that district was most favoured, not because of the big streams, certainly not because of local rainfall, but because of the very fine ground-water resources.

68. To the east there was very much the same rainfall as at Morphou, but the situation was very different. He had seen the trouble at Famagusta from salt water infiltrating from the sea. A very interesting attempt had been made to raise the level of the ground-water by recharge from the local reservoir, and it was to be hoped that it would be successful. This problem occurred in other islands, notably in Malta, in some of the West Indian islands, and in fact, in almost every island.

† Proc. Instn civ. Engrs, vol. 9, p. 233 (Mar. 1958).

69. It had been a very sad sight to see the way all the coastal citrus groves at Famagusta had gone out of commission. The windmill pumps had been taking a reasonable quantity of the ground-water resources, and the groves were ruined not by this local abstraction, but by overpumping further inland. Since those days, legislation had been introduced and the abstraction of ground-water was now very strictly controlled.

70. The method of lining the channels was ingenious. It was very simple and, apparently, there was very little leakage. The manner in which water was abstracted by constructing sub-surface dams was also extraordinarily interesting.

71. Mr Lacey was glad to see that the Department of Water Development had secured the services of an engineer hydrologist. Engineers in the past had built large works and taken very great care with the foundations, but often the hydrological foundations were very meagre, and those were needed as much as anything else. In his experience it was very difficult to get governments interested in hydrology or in putting in gauges, and so forth, because it was a long-term activity. The fact that full use could not be made of the observations for design purposes until there had been faithful recording over a number of years was seldom appreciated.

Mr H. H. Dixon said that to a very great extent the rehabilitation of the Morphou Bay area had been brought about by the efforts of Mr Ward and the people who had helped him. He then showed a number of slides.

73. A very great problem in Cyprus was whether to impound the water in the mountains or to let it flow down and go into underground storage.

74. Above the 2,000-ft contour, the run-off was 70,000 million gal/year, and the percentage of run-off to rainfall was 35. At the 1,000-ft contour, there was the same total run-off which now represented only 18% of the rainfall. The Troodos range was an igneous formation which was fairly impermeable. Mr Dixon suggested, therefore, that there would be a considerable advantage in intercepting run-off in a number of high-level impounding reservoirs, situated above the 2,000-ft contour. The balance of 50,000 million gal/year, which now got down to sea level and was lost, would then be reduced without unduly affecting the recharge of the permeable strata which act as underground storage reservoirs. The disadvantage was that the very steep river gradients in the mountains would require the construction of high dams if adequate storage was to be provided.

75. In Matabeleland, where the rainfall was also of the order of 20 in., in the last 20 years certainly, there had been a very intensive programme of irrigation by surface reservoirs and the African Affairs Department had constructed vast numbers of small dams. These had the effect either of functioning as surface reservoirs or of encouraging percolation into underground sources where there was no evaporation loss of any consequence. There was, of course, a good deal of work being done on the reduction of evaporation from open water surfaces. These experiments were still in progress and some success had been achieved. Transpiration and afforestation were important subjects and a comprehensive paper by Dr A. J. Rutter¹ had recently been presented at a meeting of the Institution of Public Health Engineers.

76. The desalting of water by distillation could be combined with the production of electricity if, instead of a condenser, one used a multi-effect evaporator. Provided that the consumers of water and of electricity were substantially identical, a very small increase in the unit charge for electricity would permit the sale of water at charges which were quite reasonable.

77. The ill effects of overpumping were often apparent near the sea; and it was a normal hazard in the case of an island and a seaside town when the supply came from

¹ A. J. Rutter, Ph.D., A.R.C.S. "The effects of afforestation on rainfall and run-off." A paper presented to a Meeting of the Institution of Public Engineers on the 13th of February, 1958.

wells near the coast. In Haifa, for instance a water supply was drawn from the dunes to the North and while he had been there the wells which were nearest the River Kishon were being spoilt; the rest water level had not fallen much, but the salt content had increased vastly, and in spite of warnings given against overpumping, overexploitation continued and the saline zone extended. Much the same thing had happened in New Providence in the Bahamas. The principal source for the town of Nassau had been rendered completely useless in a period of about 10 years by overpumping. There had been some excuse because of the war but nevertheless the danger had been known and had just been ignored. The extent of pumping should have been of the order of 1,000 gal/day from each acre, but that had been greatly exceeded, and when the salinity reached about 2,500 p.p.m. pumping had to be given up altogether. He had thought that by 1956 the rain (about 35 in/year) would have recharged the wells, but when sampled then the salinity was much the same as when they had been abandoned. Therefore, unless one could artificially recharge, as had been done in Cyprus, it seemed that it took a very long time to restore a salt affected source merely by rainfall, at any rate in those particular conditions. He would not like to generalize, however, because he did not know. Artificial recharging had been tried by an oil company in Trinidad, but there the sands were so fine that they soon got silted up and nothing went in.

78. In Trinidad, as long ago as 1922, there had been an engineer hydrologist who had later become Director of Public Works in Singapore, Major R. L. Nunn. He had done yeoman work, and his ancient monuments were still there—weirs that were encrusted with limestone, and with no one ever taking a reading after the first few years. That sort of thing was common in colonial engineering experience. Such works were put in, and then the next generation of administration could not find the money, or the enthusiasm, to keep the records going; so data were lost and were made valueless by lack of continuity. It was a great tragedy.

79. Mr Dixon said that one of the values of sewage was that it could replace in the ground what had been abstracted for human use, and the other was that the water could be used for irrigation. In seaside towns there had always been the tendency to dispose of sewage directly into the sea. That policy would have to be reversed in time and sewage works would have to be built on the land behind the towns and the sewage—however expensive it might be—pumped and treated so that one got the benefit of irrigation and recharge and also the use of sludge for manure. From Cairo, sewage was pumped northwards into what had been desert. When he had visited the disposal works about ten years before, they were treating the sewage from about 750,000 people; there was only primary tank treatment followed by broad irrigation without filtration. Crops worth £70,000 a year were being produced and the sale of sludge also brought in a good revenue.

Dr S. H. Shaw explained the basic principles of geophysical survey by refraction seismology.

81. The Geophysical Section of the Overseas Survey was providing the instruments and the geophysicists for the survey in Cyprus, and the total cost, based on a 6-month programme would be roughly £6,500. The same amount of money spent on drilling would give about 110 boreholes of an average depth of 50 ft, that was, one borehole every $\frac{1}{2}$ mile of the 55 miles of river bed which it was hoped to examine. Geologically there was plenty of room every $\frac{1}{2}$ mile for unexpected changes, so that if the seismic method proved satisfactory it would clearly give more detailed information than exploratory drilling and lower the risk of the best sites being missed.

82. In 6 months time, with 6 months work, the Water Department would have a considerable backlog of information for investigation in the next few years. Although seismic work was not a substitute for all the drilling work on a project, it could probably eliminate some of it and give important assistance in directing the remainder.

Mr Herbert Addison asked the Authors if there was any difficulty in persuading the

landowners to take advantage of the new methods. Had there been any legal difficulty? In other parts of the Middle East the fragmentation of holdings was a very serious problem.

84. He asked if electro-submersible pumps were used in the boreholes and if there had been any maintenance problems owing to weeds in the small concrete irrigation channels. Had there been any difficulty owing to the walls cracking or breaking away?

Mr N. A. F. Rowntree referred to the relative use in the widest terms of the water falling on the island in rain, as set out in the Tables 3 and 4 and related this to the measurement of the various hydrological data.

86. It was stated that 12½% of the rainfall was accounted for, and that 87·5%, or an average of 17 in. over the island, was allocated to evaporation in all its aspects. This evaporation loss was not entirely loss where it was economically used for agriculture. Had the Authors any information on the relative requirements for different crops? Allowing for 60% of the island as being cultivated and for 19% so-called forest area, that loss, averaged over that part of the island, amounted to 24·5 in. But the real losses to the sea, given in the Paper as 7% of the rainfall, were an average of about 1·35 in. only. If this amount could be conserved and used for agriculture on the cultivated area at present, it amounted to only 2½ in. available. Re-use of domestic water by agriculture would supply only a very small further percentage.

87. It thus appeared that the 87·5% represented by far the largest proportioned source from which to try to obtain more usable water on the island. The method of attacking that part of the problem might be the choice of suitable crops which gave a maximum useful yield with a minimum water requirement for transpiration, the elimination of losses by evaporation from useless vegetation, and strict regulation of the amount of water used according to the particular crop requirements. Such methods could bring other problems of soil conservation, storage of flood run-off and so on.

88. However, converting those figures to millions of gallons per day, it seemed that the 17-in. average loss by evaporation over the island as a whole represented no less than 2,400 m.g.d. Attacks on wasteful irrigation and cropping might perhaps lead to the quickest and most tangible benefits if the assumed losses by evaporation could be justified.

89. The percentage of water used was only a very small part of the total rainfall, and was probably less than the error in measurement of the rainfall. It was extremely important to know the accuracy of the 87·5% losses, because 1% of 87·5% was only just under 1% of the total precipitation on the island. The 1% of the measurement of the water used for domestic purposes was infinitesimal in comparison.

Mr R. C. S. Walters said that the best area for water seemed to be the central plain to be developed perhaps by many small boreholes worked by many electrically driven submersible pumps automatically controlled (provided electricity was readily available) and pumping into a central treatment works comparable to that recently built by the East Surrey Water Company.

91. In some respects the problems in Cyprus were similar to those in England, and although the average annual rainfall was generally more in this country, locally, in the south-east, it was the same.

92. Problems of salt sometimes arose in England. The Eastbourne waterworks of 1896 were ruined by the influx of salt. At Broadstairs and Ramsgate the pumping level was limited by Act of Parliament to -2 O.D.

93. At the Amsterdam waterworks a regular practice had been established of fresh water "riding" on salt water in 24 miles of trench with 486 boreholes pumping from it, and he believed the trench was now being recharged with Rhine water.

94. Were there any signs of the salt water being got out and replaced by fresh water around Famagusta, because it seemed to be impossible to do this below mean sea-level?

Mr. H. W. Underhill asked if the Authors had any figures for evaporation loss in different parts of the island either from pans or from some method such as Penman's for estimating potential evaporation?

96. Regarding the use of cetyl alcohol to reduce evaporation loss from reservoirs, the latest information from East Africa showed that a reduction of 35% was a reasonable figure to expect; recent papers by the manufacturers showed that similar results had been obtained in Spain and Australia. Had the use of cetyl alcohol been considered in Cyprus?

97. Water loss by transpiration was most serious where the vegetation could draw directly on ground-water and so transpire freely all the year round. Had the areas where the water table was within the root zone been mapped as of special significance?

98. On the measurement of river flows, had the effects of silting and scouring on the calibration of the weir shown in the slide been considered? Regarding the flash floods, were current meters used in such turbulent conditions, assuming that the engineer could reach the site before the flood had passed, or what other methods of flash-flood peak discharge and total volume measurement were used by the Authors?

The following contributions were received in writing.

Mr Samuel McConnel considered that Cyprus, despite its comparatively low rainfall, was very fortunate to have sufficient water available to irrigate such a large proportion of its total area. This relative abundance was greatly in excess of that possible elsewhere, where similar conditions prevailed, but appeared to be due to local geological conditions.

100. The statement that forests almost always decreased run-off was timely in view of claims frequently made by advocates of afforestation. It was well known that eucalyptus trees were responsible for so much transpiration that they were commonly planted to drain swamps. Bamboo was another serious culprit, and so was vegetation growing in and around stream-beds. It had been found in Australia that areas covered with Mallee Scrub were subject to maximum transpiration while grassy plains under the same conditions were responsible for much lower losses. Saline underground water was found in the Mallee areas and good water elsewhere. Since terracing and contour ploughing retained the water in the soil and reduced run-off, it seemed to be a sound principle to utilize water in the area where it was produced, instead of subjecting it to further transmission and evaporation losses.

101. Cyprus was also fortunate in the number of flow and its springs and the large number of successful boreholes.

102. The method of abstraction from dry river beds had been frequently used elsewhere, but Mr McConnel had never encountered such rivers with gravel beds. In most areas the sand was fairly fine and the underground flow so small and slow that the water available was not sufficient for irrigation. Substantial supplies were often obtainable from the fissured and disintegrated rock below such stream beds.

103. The gallery in Fig. 7 seemed abnormally small in cross-section and the minimum practical size was usually twice as large. If the winter flow was surplus to requirements and could not be put to any profitable use its employment to replenish ground-water supplies was justified; but quite a substantial proportion of it was unlikely to be recovered for use.

104. In view of the costly means employed to provide water for irrigation, there appeared to be no justification in arid and semi-arid countries to fail to utilize sewage effluent for irrigation.

Mr Peter Noble recalled his experience in Cyprus in 1906-10 when a deep-well boring machine drilled unsuccessfully for water in the Mesaoria Plain to a depth of about

2,000 ft. He had at that time made studies for the improvement of water supplies at Troodos, Platres, Paphos, and Akhyritou.

106. He did not concur with the statement in § 22 that there was little evidence to support a popular belief that forests attract rain. His experience in Cyprus in 1907-10 and in Palestine in 1922 had shown that newly established forests in the Kyrenia Hills and on the Acre Plain had in the opinion of those concerned caused considerable increase in water supplies.

107. Finally Mr Noble stressed that when collecting basin dams were raised too high by inexperienced workers much water was lost by leakage.

The Authors, in reply, agreed with Mr Dixon that it was difficult to decide whether, as a matter of general policy, it was better to impound the water in the mountains or to let it flow down to the plains for natural underground storage. There were advantages in building dams in the southern (Troodos) range because not only were the rainfall and run-off high but in addition the bedrock was generally impervious. In the northern range the rock was cracked and fissured and unsuitable for impounding water on the surface. Dams would no doubt continue to be built in the valleys of the southern range until most of the run-off to sea was stopped. Thereafter a decision would have to be reached as to whether the expensive but technically efficient surface reservoirs were preferable to the natural but probably wasteful underground storage. An important consideration would be the necessity to maintain a supply of underground water for the two thousand boreholes already operating on the plains. At the present time one dam was under construction and two more were about to be started. Preliminary plans existed for about twenty others of various sizes up to about 120 ft high and of storage capacities up to 350 million gallons.

109. The question of the utilization of sewage was mentioned by Messrs Dixon and McConnel. Fortunately very little sewage was wasted to sea in Cyprus and although the existing methods of disposal, as explained in § 43, were not entirely satisfactory, it was expected that when sewage-disposal schemes were carried out none of the effluent would be wasted. In some parts of Cyprus, notably Famagusta, the balance of the ground-water-table might be seriously upset if the sewage were piped away to disposal works instead of being permitted to seep into the porous sand underlying the town through numerous soakaways. A lowering of the water-table in this area would encourage further infiltration of sea-water. In the Episkopi area, west of Limassol, the purified effluent from the large military camp, amounting to about 500,000 gal/day, was used to recharge an aquifer from which water was pumped for both irrigation and domestic use.

110. Mr Addison asked if there were difficulties in persuading landowners to take advantage of new methods. In the case of smaller schemes it might be said there was no difficulty and in fact the pressure for new works usually came from the landowners rather than from Government. This was particularly true of the drilling programme under which about 2,000 boreholes were drilled in the past 10 years, usually one borehole only for one family. For the larger irrigation schemes involving the diversion of water from rivers or springs the question of disturbance of water rights caused very great difficulty and it was to be expected that as the more straight-forward schemes were completed those difficulties would increase. A law was enacted in 1955 to enable Government to take possession of water resources for development and distribution within large or small areas including complete river catchments.

111. The use of submersible pumps in boreholes was steadily increasing, chiefly because of lower installation costs. In the recently completed town water-supply schemes about half of the borehole pumps were of this type. Popular opinion among private landowners, who probably owned about 90% of the borehole pumps in the island, was that the conventional deepwell turbine was generally more reliable than the

electro-submersible type although more costly in the first instance. Electric motors were frequently used to drive the turbine pumps.

112. The concrete linings of irrigation channels did not usually give trouble from cracking except where there were rock falls on steep hill-sides. There was little difficulty from weeds where standard channels were used. These were made rectangular in section for ease of construction and the sides were 3 to 4 in. thick. They were built of 1:2:4 concrete in 15-ft sections, lightly reinforced. They were seldom laid at gradients of less than 1 in 1,000 and the water velocity was therefore relatively high which was, perhaps, a factor in reducing weed growth.

113. On the subject of the recharge of aquifers mentioned by Messrs Walters and Dixon the Authors agreed that where salt-water contamination had occurred a very long recovery period was usually required, unless sweet water was introduced artificially as at Limassol and Famagusta. At Limassol the recharged water appeared to ride upon the underlying salt water, which itself might not have improved much in quality. At Famagusta there appeared to be more diffusion and the result had been so far to check the further deterioration that would undoubtedly have occurred. It was hoped that positive improvement would follow. Mr Walters had referred to the Amsterdam waterworks where a 24-mile recharge trench was filled with Rhine water. Compared with Cyprus, conditions in Holland, both geologically and hydrologically, were almost ideal for this type of recharge works. The Authors had, however, been considering a somewhat similar arrangement to trap flood-water from the Serakhis River near Morphou in the western Mesaoria. In this case impounding basins would be formed at intervals along the river course. One of the chief difficulties was that no reliable supply of water could be made available, the intermittent flooding being too irregular to justify any large expenditure.

114. Mr Walters had considered the development of the central plain by means of many small borehole pumps delivering into a central works. This was the method that had been adopted for the domestic water supplies of the towns but for irrigation, which required most of the water, it had been found administratively convenient to drill separate holes for each landowner who then installed his own pump and irrigated his own land. Usually the borehole was drilled and tested by the Department of Water Development at subsidized rates, but the installation of the pump and its operation was carried out by the landowner at his own expense.

115. Dr Shaw had enumerated some of the advantages of the seismic method of determining the depth to bedrock in river beds. The Authors wished to add that an additional advantage in mountain country was the simplification of transport. The expense of an access road good enough for a drilling rig could be justified only if there was a large quantity of drilling to be done, whereas rough tracks were usually sufficient for the Landrovers carrying the geophysicists and their instruments.

116. Mr McConnel commented upon the abnormally small cross-section of the gallery for extracting ground-water from under a dry river-bed. While the Authors agreed that this section was very small compared with most infiltration galleries elsewhere, it had been adopted by them as a standard size in Cyprus for many miles of such works. This type of low-cost tunnelling was carried out by special workers who had inherited their particular skill from the days when long chains-of-wells were built for water without the use of machinery or surveying instruments. The small quantities of spoil could be removed through the vertical shafts without the use of trolleys in the horizontal galleries. The tunnels were oval in section and were lined with precast half-sections. The shafts were frequently lined with circular precast concrete pipes.

117. Replying to Mr Rowntree's queries in §§ 86 to 89 the Authors considered that the quantitative estimate of the total losses by evapo-transpiration could only be arrived at as a residual after deducting losses to sea, surface-water collected, and ground-water extracted from the total rainfall. So far as the estimate of the average to tal annual rainfall was concerned it was thought that the probable error was less than 1%, although the rainfall figures for some individual stations might be as much as 5% in error for some years. The isohyets had been drawn using the averages of various ranges of years

and remarkable agreement had been found between them. The accuracy of the estimate of the total evapo-transpiration loss, therefore, was dependent on the accuracy of the estimate of water used for irrigation and wasted to sea.

118. The Authors agreed with Mr Rowntree when he said that not all of the 87.5% (17 in.) evaporation in all its aspects was entirely lost where it was economically used for agriculture. In fact a large proportion of the island's agricultural production was the result of direct rainfall on unirrigated arable land. A more rewarding approach to the problem of the utilization of losses was, perhaps, to regard all water resources on the island, apart from surface and underground wastage to the sea, as ultimately destined to evaporate, so that the task was to increase the proportion of that evaporation which would be of benefit to man. Thus, because evaporation losses were inevitable and because the large proportion of evaporation losses direct from land surfaces could never be much modified, particularly in the hot dry Cyprus climate, the straightforward and practical approach would be to effect improvement in the use of the remaining 12½% (2½ in.) of the rainfall at present collected or wasted to sea. This of course did not mean that subsidiary efforts should be neglected to reduce unprofitable evapo-transpiration elsewhere, particularly with regard to useless vegetation.

119. The Authors could not agree with Mr Rowntree's low estimate of the importance of real losses to sea as compared with evaporation in all its aspects as implied in the first sentence of § 87, which was understood to indicate a ratio of 2.25 in. to 24.5 in., or 9% approximately. First, the Authors did not consider that the 87.5% (17 in.) evapo-transpiration losses should be averaged over the arable and forest lands for the purposes of comparison. Secondly, even if this procedure were adopted, the loss of 17 in. would become equivalent to 21.5 in., not 24.5 in. Thirdly, the majority of this 21.5 in., possibly about 15 in., would remain unusable, however much progress was made in eradicating useless vegetation or in collecting surface run-off. The relative importance of losses to the sea as compared with controllable evapo-transpiration losses was therefore on this basis of comparison much more than indicated by Mr Rowntree and was probably of the order of 2.25:6.5 in. or 35%. The losses to the sea were tangible and could be prevented by immediate and direct engineering effort and were therefore the logical starting point of a programme of development.

120. Mr Rowntree had touched upon the significant subject of wasteful irrigation and cropping. The Authors considered that the knowledge required to avoid this type of loss could be provided only by the establishment of the research organization envisaged in § 50. Proposals had been put forward in Cyprus for a central water-use research station which would collect and analyse data provided by numerous experimental plots throughout the island. It was thought that until such an organization was working it would not be possible to obtain reliable figures for the water requirements of different crops. The Authors doubted if methods based on the absorption of solar energy at different efficiencies could be satisfactorily applied in Cyprus, chiefly because it seldom happened that the ground was continuously covered with green vegetation and because different soil textures and water-holding capacities in different places caused unequal drying-out of the soil in the hot sun. Current experience indicated that water requirements varied widely between different crops in the same parts of the island, and between the same crops in different parts of the island. They also varied according to the particular irrigation practice adopted. The range was roughly between 2,000 and 8,000 gal/acre/day.

121. In reply to Mr Underhills' inquiry regarding evaporation in § 95, the Authors had obtained the following information from the Government Meteorological Office. The evaporation losses at Nicosia, which was a typical medial plains station, 536 ft above mean sea level, averaged over the four years 1954-57, and obtained from an 8-in.-dia. pan were as follows:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
2.3	2.7	4.7	7.7	10.5	14.4	16.1	13.6	10.3	6.6	3.3	2.3	94.5

122. Evaporation losses from a free water surface at Nicosia, calculated by the Penman method and averaged over the same years, were as follows:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1.5	2.0	3.4	4.9	7.0	8.7	9.3	8.2	6.3	4.1	1.9	1.2	58.5

123. The potential evapo-transpiration at Nicosia, averaged over 1954-57 and calculated by the Penman method and the Thornthwaite method, were as follows (Penman first):—

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
0.9	1.3	2.4	3.5	5.3	6.5	7.1	6.3	4.4	2.8	1.3	0.8	42.6
0.5	0.7	1.1	2.1	3.9	6.6	7.6	7.0	5.2	3.4	1.5	0.7	40.3

124. The potential evapo-transpiration for other places in Cyprus, averaged over 1954-57 and calculated by the Thornthwaite method, were as follows:—

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Amiandos (in Troodos mountains—4,250 ft above M.S.L.)												
0.3	0.4	0.8	1.5	3.0	4.5	5.5	5.2	3.6	2.5	1.3	0.5	29.1
Larnaca (on south coast—10 ft above M.S.L.)												
0.9	1.0	1.5	2.3	3.5	5.7	6.9	6.5	4.8	3.4	1.9	1.2	39.6
Famagusta (on east coast—75 ft above M.S.L.)												
0.8	0.9	1.3	2.1	3.5	6.0	7.1	6.7	5.0	3.3	1.7	1.1	39.5

All the above measurements are expressed in inches.

125. Regarding the reduction of evaporation from open water surfaces, mentioned by Messrs Dixon and Underhill, the Authors had considered the use of cetyl alcohol. The total area of water surface in Cyprus was, however, relatively small. The reservoirs, being mostly in mountain valleys, were long and narrow and there was a flow of water over the spillways for most of the year. This indicated, they thought, that a film on the top of the water surface would be carried away. A calculation of the total saving that was probable from the use of cetyl alcohol under current Cyprus conditions showed that it was equivalent only to the output of one ordinarily good borehole, namely about 40 million gallons per year. They had concluded that field experiments were not worth while at present.

126. In reply to § 98 the Authors stated that the pools behind all measuring weirs under Cyprus conditions inevitably silted up with the first spates and thereafter maintenance work was solely concerned with obtaining an even flow over the weir crest from end to end. A correction was then applied for the velocity of approach where necessary. Scouring had so far not been encountered on the up-stream sides of any of the measuring weirs constructed. Flash floods in Cyprus were of such short duration that observations of peak velocities were extremely rare. Current meters had not been used because float measurements were more suitable under the conditions. Maximum velocities at flood-measuring sites were generally reasonably well defined by extrapolating the rating curves and, on the few occasions when direct observation had been possible, showed a reasonable degree of accuracy.

127. The effect of transpiration and afforestation upon water resources had been mentioned by Messrs Dixon, Underhill, McConnell, and Noble. Areas with vegetation drawing on the ground-water at all seasons of the year had not been systematically mapped but their occurrence was known in many well defined places, including river-beds throughout the island and the coastal ground-water zones near Morphou, Famagusta, and Limassol, where deep-rooted trees and shrubs could draw continuously on the ground-water. It had been established that the roots of some trees could penetrate to great depths. For instance, part of the Arab Ahmed infiltration gallery, which had

formerly supplied some of Nicosia town with water, was completely blocked with eucalyptus roots at a depth of between 55 and 60 ft below ground and eventually had had to be abandoned. At Famagusta eucalyptus roots had been found in wells at 80 ft and more below ground surface. The forests of Cyprus occupied 19% of the total area of the island and the total water consumed by them in transpiration must represent a very large proportion of the total water resources. If annual interception losses plus transpiration were assumed, conservatively, to amount to 10 in. over the forest areas, which were mostly in the high-rainfall zones, then the total consumption would represent about 10% of the total rainfall of the island. This was double the quantity now used for irrigation in the whole of Cyprus.

128. The effect of forests upon run-off required much study, and large-scale experiments were needed to determine to what extent stream-flow could be increased by the removal of forest trees and uncultivated vegetation both from stream-beds and catchment areas. It was to be noted in this respect that in the paper quoted by Mr Dixon, Dr Rutter had written, after describing experiments in the U.S.A. and elsewhere: "the foregoing results obtained from studies of entire waters show that the water yield from forests may be 5 to 15 per cent, or several inches less than from adjacent areas of grass or herbaceous vegetation or farmland". The Authors would expect similar results if experiments of this type were carried out in Cyprus.