Report on *DEPUTATION* to *AUSTRALIA* to Study the Latest Scientific and Technological Developments on Reducing Water Losses due to Evaporation, Seepage, Water Conservation and Irrigation

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GOVERNMENT OF INDIA

MINISTRY OF IRRIGATION AND POWER

NTRAL WATER AND POWER COMMISSION

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Report on *DEPUTATION* to *AUSTRALIA* to Study the Latest Scientific and Technological Developments on Reducing Water Losses due to Evaporation, Seepage, Water Conservation and Irrigation

by

Dr. R. C. Hoon, Director, C.W. & P. C.

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FOREWORD

Mr. Jack G. Beale, a Member of New South Wales Parliament and Chairman, Water Research Foundation Board of Australia, who visited this country in May 1956, described to the Prime Minister, Union Ministers of Irrigation and Power and Food and Agriculture, Chairman, Central Water and Power Commission, Director General, Council of Scientific and Industrial Research and several other officers some of the recent researches carried out in his country on restriction of losses due to evaporation and seepage from water storages in particular and several aspects of water conservation in general. That work was considered of immense importance to this country and, therefore, the Government of India sponsored a delegation to visit Australia and study the latest scientific and technological development bearing on those subjects.

The Indian delegation included the following:—

(1) Prof. M. S. Thacker, Director General, CSIR.

(2) Shri U. N. Mahida, ISE, Chief Engineer, Irrigation, Bombay. } Ministry of Irrigation and Power.

(3) Dr. R. C. Hoon, Director, C W & P C. } Ministry of Irrigation and Power.

(4) Shri C. K. Ashdhir, Assistant Irrigation Adviser, Ministry of Food and Agriculture.

On account of the inability to secure the air passages for all the members of the delegation to enable them to travel together, while Prof. Thacker and Shri Ashdhir reached Australia on the 25th September, 1956, Shri Mahida and Dr. Hoon reached there about a fortnight later. The joint programme of the members of the delegation in Australia had, therefore, to be somewhat altered for that reason.

The present report is based on the observations, notes, etc. recorded by the delegation in general and the writer in particular during their stay in Australia. Relevant quotations, plates, figures, etc. from some publications, draft bulletins and experimental data and certain facts emerging out of the several discussions held during that period in Australia are also included in the report.

It is hoped that the report will serve a useful purpose in initiating laboratory and field experiments on somewhat similar lines on those subjects in India.

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TABLE OF CONTENTS

INTRODUCTORY

The itinerary of the deputation period spent in Australia *i.e.*, 7th to 27th October, 1956 is given in the appendix.

The salient features and details of the scientific and technological development in Australia with regard to reducing evaporation and seepage losses from water storages and some aspects of water conservation, irrigation and water supply are described in the Report. The Report also includes interesting features of some of the dams, and water supply schemes and work in some of the research institutions and testing laboratories of that country so visited, for convenience the Report has been prepared under the following nine heads:—

1. Experiments conducted by the Commonwealth Scientific and Industrial Research Organisation on the use of Cetyl alcohol to restrict evaporation from open water storages.

2. Plastic membrane lining of a water storage.

3. Experiments on artificial stimulation of precipitation in the Snowy Mountain region.

4. Some aspects relating to irrigation and soil conservation practices: '*Water Harvesting*'; '*Key-line Farming*'; Sprinkler Irrigation Practice; Soil Conservation Practice near Broken Hill; Soil reclamation near Carwarp (Mildura).

5. *In situ* lining of cast iron water mains.

6. Discussions on problems relating to irrigation, water supply, floods, etc.

7. Visits to some dams and water supply schemes.

8. Visits to research stations, hydraulic and material testing laboratories.

9. Miscellaneous:—(1) Water de-salting by ion exchange membrane; (2) Ultravision projection screen, (3) Film on *in situ* lining of water mains; (4) Works of Messrs. Le Tourneau Westinghouse Pty. Ltd.: (5) Guthega Power Station.

An abstract of the Report is also included.

Acknowledgement

The author is extremely grateful to the Central Water and Power Commission and the Ministry of Irrigation and Power, Government of India for deputing him to Australia to report on some of the latest scientific and technological developments relating to water conservation and allied activities in that country.

He thankfully acknowledges the inclusion in this Report of relevant quotations, plates and figures, from publications, draft bulletins, experimental data, etc. so kindly made available to him and of certain facts emerging out of discussions held during his stay in Australia and quoted therein.

Further he takes this opportunity of expressing his sincere thanks to all the friends in Australia, whom he had the privilege to meet during the brief stay in that country, for their valuable assistance, frank discussions and courtesy. He is particularly grateful to Mr. Jack G. Beale, M.L.A.; Member of Parliament, N.S.W. and Mr. N. S. Panton and Mr. F. R. Pearce of the Ames Irrigation Pty. Ltd., Sydney for the trouble they so kindly took to arrange the details of the visits to various works, institutions, etc. But for their help it would not have been possible to cover so much ground in that short time.

Dated 26th Feb. 1957. R. C. Hoon

ABSTRACT

1.0. The Use of Cetyl Alcohol to Restrict Evaporation from Open Water Storages

1.1. The Division of Industrial Chemistry, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia has been engaged on a coordinated programme of research, both in the laboratory and field, on the possibilities of employing the monolayer formed from Cetyl alcohol to cut down evaporation losses from open water storages. For their field trials they have attempted to include storage reservoirs of varying sizes; one of the full-scale field experiments is being conducted since December 1955 on the Stephens Creek Reservoir, with a waterspread of about 2 thousand acres, by the Broken Hill Water Board in conjunction with the CSIRO.

The salient features of that laboratory and field work carried out so far by the Division of Industrial Chemistry, CSIRO and the Broken Hill Water Board are described in the Report.

1.2. Unfortunately, the unseasonably heavy rainfall at practically all field sites during the experimental period to date has curtailed the continuous performance record at those sites. The experiments still remained in an early stage and the results, though promising, are considered somewhat meagre and it may be some time before a firm statement on the results achieved is issued by the CSIRO. They have, however, helped to derive the conclusion that some reduction in evaporation can be accomplished on water storages of the size up to 10 acres. On the basis of their experience to date they recommended confidently the Cetyl alcohol technique for small-sized reservoirs with a waterspread of one or two acres only.

1.3. It seemed too early to expect information with regard to the overall economics of the application of monolayer to a storage reservoir of a reasonable size; the results of the experiment in progress at the Stephens Creek Reservoir at present, as and when available, should yield valuable information on that aspect.*

**Postscript.*—The report since received of trials at that reservoir is quite encouraging and indicates that the technique can be applicable to storages of bigger sizes as well.

1.4. The progressive development of some of the features of the CSIRO investigations *e.g.*, the dispensation of Cetyl alcohol in solution form, the design of the floating rafts, the shore-based units and the more recently evolved dispensing unit where the regulation of solution supply was controlled by a sensitively-balanced wind vane operating the outlet valve, etc. should go a long way to even out the inequalities in dispensing monolayer on the waterspread in storage reservoirs and be of great help in conducting of similar experimental work elsewhere.

1.5. Information was still not definite on such aspects of the monolayer as its continuity, ageing, etc. when exposed to high atmospheric temperatures that are expected to prevail during summer in tropical conditions and due to its contact with algae growth which develops on water surface in some reservoirs. It is hoped that further work with particular reference to these aspects shall help to clear these issues.

2.0. Plastic Lining of Water Storages to Reduce Seepage Losses

2.1. The lining of the Charlton Reservoir, having a waterspread of about 1½ acres with a maximum depth of about 15 ft. of water, was the solitary example in Australia of the use of plastic (Polythene) membrane lining to reduce seepage losses from a water storage reservoir. The membrane was embedded below a few inches of soil cover; the latter was simply dumped and not consolidated except by treading over it by workers. Although a considerable lowering of the rate of seepage from the reservoir as a result of the lining had been reported but no experimental data could be obtained.

2.2. The membrane, normally employed for lining of water storages is recommended to be 0·006-0·008 inch thick to be economical. The plastic material is a wax of high molecular weight and is available in form of thin sheets. The membrane is fairly resistant to being torn or punctured and is reported to defy attack by soil micro-organisms.

2.3. Further work on lining with plastic membrane was abandoned in that country due to the imposition of import restrictions but they were hopeful of resuming that work as soon as they started manufacturing it there in about a year's time.

3.0. Experiments on Artificial Stimulation of Precipitation in the Snowy Mountains Region of Australia

3.1. A long-term experiment on the artificial stimulation of precipitation in the snowy mountains had been in progress jointly by the Snowy Mountains Hydro-electric Authority and the CSIRO from June 1955. The tests are based on the employment of aerial seeding with Silver Iodide vapours and incorporation of some novel features both in the experimental technique and methods used to assess results.

3.2. From the operational point of view the dissemination of Silver Iodide by an aircraft for modifying the rainfall in a given area has proved to be quite successful. Although the results so far indicate that the ratio of target to control area precipitation has been greater during the seeded periods but it is proposed to continue the experiment using the same technique of seeding for several years to afford a firm answer to the question whether the increased precipitation during seeded periods is a natural effect or is due to the seeding programme.

3.3. The procedures used have the following advantages to those used in the past:

(a) No extrapolation of the historical data is necessary so that any sudden or long-term climatic change which may take place, is automatically accounted for.

(b) The use of random on-off seeding permits full use of the raingauge coverage. If past data were only used as a control one would make use only of readings from those gauges for which sufficient past data were available; data from recently installed gauges could not be used in the analysis.

(c) The use of periods determined by the passage of high pressure systems, instead of weekly readings on a calendar basis, affords an unexpectedly higher correlation between target and control area precipitations.

(d) Better estimates of the precipitation in the areas concerned are given by the method of isohyet integration than by using individual gauge readings.

(e) The use of ratio precipitation in target and control areas as the test variable for statistical tests makes use of the high correlation between the precipitations in the two areas without having to make the assumptions necessary in normal regression analysis. In addition, the confidence levels of the regression method are appropriate only to individual values and not to the overall effects of the operation and the use of ratios also appears to eliminate any seasonal effect.

(f) Two other methods of analysis used, *viz.*, the cumulative sum ratio of precipitations in target and control areas and the distribution free method, afford an automatic weighting to results according to the amount of precipitation and make fewer *a priori* assumptions than any other method of analysis.

4.0. Some Aspects relating to Irrigation and Soil Conservation Practices

4.1. The Australian farmer has developed the aptitude and mastery of dry farming methods. Rainfall is limited in quantity and in reliability as only 32 per cent. of the Continent receives an average annual precipitation of greater than 20 inches and its seasonal distribution is generally erratic and impredictable. Under these conditions increased production is dependent on extraction of the utmost benefit from available water and on some methods of making this water readily available as and when required.

In New South Wales, the Water Conservation and Irrigation Commission through their Organisation dealing with Farm Supplies, advise farmers and graziers with regard to installing of tubewells for irrigation and encourage them to arrange for surface storage of water on farms and properties. The Soil Conservation Service has most successfully disseminated technique of control of soil erosion by such means as bring about the absorption of water into the soil.

4.2. Details are presented in the fuller Report of the two unconventional but successful solutions of the farm irrigation, *viz.*, *Water Harvesting* by Mr. H. J. Geddes of the Sydney University and *Key-Line Farming* by Mr. P. A. Yeoman, a Sydney Mining Contractor which have aroused considerable interest in Australia. *Water Harvesting* is essentially a system in which a part of the farm is kept in a relatively underdeveloped state to conserve all available run-off in surface storages for intensive irrigated cultivation on the remaining areas. *Key-Line Farming* is based on the principle of absorbing as much rainfall as possible directly into the soil by working and treating the land to improve its infiltration capacity and promoting an even water distribution. A comparison of the water harvesting and key-line farming practices is presented in the fuller Report.

4.3. *Sprinkler Irrigation Practice.*—The practice of spray irrigation has greatly increased in Australia during the past few years due to the fact that, firstly, irrigation by spray equipment can be applied to lands which cannot otherwise be irrigated and, secondly, due to necessity for increased productivity methods of farming, the practice permits greater control cver the quantity and distribution of water applied. The various aspects of sprinkler irrigation plants and comparison of the cost figures are presented in the fuller Report. The working of the Mulyan Farm, Cowra, which served as an example where sprinkler irrigation was introduced a few years ago. is briefly described in the fuller Report.

4.4. *Soil Conservation.*—The city of Broken Hill which affords a typical example of the area of semi-arid climate where soil conservation has been achieved with success by growing different varieties of vegetation. A scheme in progress for reclaiming about 20 thousand acres of mildly undulated land representative of Mallee soil—texture from sand to sandy—by cultivating rye on the mounds and wheat in the depressions is described.

5.0. In Situ Lining of Cast Iron Water Mains

5.1. Cast iron pipes comprising water mains which are originally smooth in bore become rough and reduced in capacity due to the formation of nodular incrustation which if allowed to continue will rapidly cause complete blockage of the pipeline. The damage is caused by iron bacteria, chemical action between oxygen in water and iron of pipes and also by anaerobic organisms.

5.2. Scrapping and cleaning of corrosion on the inside of pipe are temporary palliatives and are in the long run costly processes requiring constant repetitions. The real remedy lies in coating the interior of pipes with some substance which would prevent corrosion. The Concrete Industries Pty. Ltd., Australia have developed a process of *in situ* lining of water mains with a rich cement-sand mortar by employing a special liner tool; the latter leaves an even coating, an eighth to a quarter inch in thickness, around the inner periphery of the pipeline.

5.3. The details of the process of *in situ* lining, as actually demonstrated by the Company at one of the jobs in hand at Adamstown, New Castle, and the cost figures and improvement in working of the *in situ* lined pipes based on Australian experience and conditions are described in the fuller Report.

5.4. The Concrete Industries Pty. Ltd., Australia are the patentees of the process. The method of *in situ* lining of corroded water pipes can usefully be tried in this country.

6.0. Irrigation, Water Supply, Floods, etc.

6.1. A number of eminent engineers particularly of the States of New South Wales, South Australia, Victoria and the Snowy Mountains Hydro-electric Authority were contacted and problems relating to irrigation, floods, etc. discussed. Some information about the work done by the Organisation dealing with Farm Water Supplies in New South Wales was also obtained. The University of Technology of Sydney, N.S.W. has a Civil Engineering Wing which is engaged on the various aspects of research relating to irrigation, hydrology, hydraulics, materials of construction, etc.

6.2. During the flights and tours, more particularly those of Canberra-Broken Hill-Mildura with the delegates of the UNESCO Symposium on Arid-zone climatology, opportunities were afforded to see from the air the flooded areas along the Murrambidgee, Lachlan, Darling and Murray rivers and their tributaries. The destructive effect differed from valley to valley. The floods were due to unusual rains supplemented by the thawing of snow on the mountain ranges. The peculiar feature along most of the rivers in floods was the very slight gradient of the land along the river course so that the spill of flood flow took a very long time to clear off and find its way out to sea. The Hunter valley stands out as the most significant area in Australia for flood drainage as in the last 47 years that valley has experienced a major flood nearly every other year.

The following are the main methods adopted to mitigate floods:—

(i) Reduce and delay run-off by soil conservation and afforestation.

(ii) Hold the flood water or part of flood in dams.

(iii) Levee banks, bank protection, dredging, strengthening of streams, use of flood by-pass channels.

(iv) Shift towns and industries to flood-free ground.

Australian authorities are at a disadvantage in initiating effective flood regulation measures because of the lack of adequate records concerning river behaviour and related data.

6.3. Although there are differences of opinion on the utility of levees for flood protection, the levees are generally built as protection from floods. The levees are built somewhat distant apart to permit rise in the river without building high velocity. Planting of willows on the river-side of the levees, and horizontal at times, is advocated to avoid their damage by erosion. Measures for protection of levees and river banks against damage include use of sand bags, stone and wooden walls or groynes to deflect strong currents away from bank.

7.0. Visits to Dams and Water Supply Schemes

7.1. *Adaminaby Dam.*—The Adaminaby Dam, one of the highest earth and rockfill dams in the world, and under construction for the Snowy Mountains Authority across Eucumbene river by the American contractors combine, was visited. The Project is one of the several major dams included in the Snowy Mountains Scheme to divert rivers at present flowing into the sea to irrigate the rich western plains of South-East Australia. The dam is about 2,300 ft. thick at the base and is to be 380 ft. high when completed. The gross storage capacity of the reservoir so formed will be 3·86 million acre feet. From Adaminaby reservoir water will be released through the 14-mile, 21-ft. diameter Eucumbene-Tumut Tunnel through the Great Dividing Range to the Tumut river.

7.2. *Burrinjuck Dam.*—This Dam on the Murrambidgee river is of concrete and some alterations and additions had been carried out recently with the object of strengthening and raising the height of the earlier built structure. Those additional features comprise:—

(a) Elimination of seepage.

(b) Provision of drainage and inspection galleries within the dam.

(c) Provision of buttresses and increasing height of dam.

(d) Enlargement of the spillway and capacity of the dam.

7.3. *Glenbawn Dam.*—This Dam, another example of a zoned earth dam, was under construction on the Hunter river to affect maximum control of the flow of that river and to substantially mitigate the intensity of floods and insure ample supply of water during drought period for the normal requirement of agriculture, stock and domestic purposes in the valley.

7.4. *Tomago Sand-beds Water Supply Works.*—This water supply scheme has been developed by tapping ground water stored in extensive area of sand beds existing northerly along the coast from the Hunter river estuary. The water-bearing sands cover an area of about 50 sq miles and vary in depth, to an impervious bottom, of approximately 60 ft. in the portion developed. The source of water is the rainfall on the surface.

Each of the original 15 pumping stations is estimated to have an average capacity of a million gallons a day normally and capable of delivering up to nearly 2 million gallons per day for a short period under favourable conditions. The pumps and pipelines have been designed to accommodate a maximum delivery of 25 million gallons a day. The original scheme is capable of delivering 5,500 million gallons per year; the full development of the scheme shall increase that capacity to 7,300 million gallons per year.

8.0. Research Stations and Hydraulic and Material Testing Laboratories Visited

8.1. The following Research Stations and Hydraulic and Material Testing Laboratories were visited:—

1. Materials Laboratory (Water Conservation and Irrigation Commission), N.S.W., Sydney.
2. Laboratories of the Civil Engineering Department, University of Technology, Sydney.
3. Group of Hydraulic Laboratories at Manly, N.S.W. attached to each of:—
   - (i) Civil Engineering Deptt., University of Technology.
   - (ii) Public Works Department, N.S.W.
   - (iii) Water Conservation and Irrigation Commission, N.S.W.
   - (iv) Metropolitan Water and Sewage Board.
4. Central Laboratories, Snowy Mountains Hydro-electric Authority, Cooma.
5. Waite Research Institute (CSIRO), Adelaide.
6. Research Laboratories, Civil Engineering Deptt., University of Adelaide.
7. Cement and Ceramic Section, Technological Laboratories, CSIRO, Melbourne.
8. Horticultural Research Station, CSIRO, Merbein (Mildura).
9. Field Test Laboratory, Glenbawn Dam.
10. Field Test Laboratory, Adaminaby Dam.

The salient features of the special testing equipments and of testing and research programme at each of the above-mentioned stations and Laboratories are described in the Report.

9.0. Miscellaneous

The demonstration of the "Ultravision" projection screen was seen. The screen seemed to have the advantage that it made projection possible under conditions where complete dark room facilities could not be arranged, as reasonable day light did not interfere with projection. Moreover, more than one film could be projected simultaneously.

Besides the places covered by the earlier sections of the Report, visits were paid to (a) the works of M/s. Le Tourneau Westing House Pty. Ltd., Ryaldmere, N.S.W.; (b) Guthega Power Station (Snowy Mountains Hydro-electric Authority); (c) Winery and Workman's Club, Mildura and (d) Storage Water Reservoirs for town supply at Broken Hill.

2—3 C.W P.C./57

DETAILED REPORT

1. The Use of Cetyl Alcohol to Restrict Evaporation from Open Water Storages

1.0. INTRODUCTORY

1.1. Rigid films such as monolayers of long chain fatty acids or oils are damaged by wind and dust. As the rigidity of such film also hinders repairs the ability to retard evaporation is lost rapidly. Likewise, the more fluid oil films decay rapidly under natural conditions. The straight chain alcohols generate monolayers providing greater retardation than those formed from alcohols containing branched chains or ring skeletons within the molecules. Among the straight chain alcohols, Cetyl alcohol is known to afford the most efficient restriction of evaporation. Provided excess crystals of the solid, from which it is derived, are available the efficiency of a liquid monolayer, such as that formed by a straight chain alcohol, is considered to be unimpaired by the action of wind or bombardment with dust.

1.2. Small-scale experiments had been carried out in this country at the Irrigation and Allied Research Station, Poona (Bombay State) and indicated a reduction in the rate of evaporation to an extent of 34-36 per cent by use of Cetyl alcohol monolayer.

1.3. The Commonwealth Scientific and Industrial Research Organisation, Australia (CSIRO) has been engaged on a coordinated programme of research, both in the laboratory and field on investigating the possibilities of use of Cetyl alcohol monolayer to effectively reduce evaporation from open water storages. Some of that Australian work was seen by the members of the delegation sponsored by the Government of India to assess how far the Australian experience in that connection could be utilized with advantage in this country.

The salient features of that Australian work, as described in some of the recent reports of the CSIRO along with such information as was collected during personal on-the-spot discussions on that aspect with several officers, are presented briefly in the following sections.

2.0. EXPERIMENTAL WORK DONE BY THE COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATIONS, AUSTRALIA

2.1. 1954-55 Experiments

2.1.1. Laboratory experiments and small-scale field tests with evaporator tanks of 3 ft. dia. done in 1954 at Melbourne indicated that for economic use the Cetyl alcohol must be sufficiently finely divided for the ratio of perimeter of the floating particles to the area of water to be 10^{-3} cm. However, very finely divided alcohol though immediately available to the surface could not be constrained and so tended to be driven ashore.

2.1.2. During the summer of 1954-55 in South Australia and during the dry season in North Australia it was proposed to conduct actual tests on some of the reservoirs with Cetyl alcohol. The tanks so selected varied in size as below:—

State	No. of tanks selected	Range of size of tanks (acres)
Western Australia	1	0·14
Victoria	8	2·31
N. S. Wales	1	3·20
Queensland	3	—

2.1.3. The period chosen unfortunately coincided with exceptionally heavy and unseasonal rainfall throughout Australia and the tests were vitiated either by the reservoirs overflowing, excessive intake and unpredictable seepage losses or could not be started due to the water in the reservoir not falling below the top of the excavated portion of the tank during the dry season. Unseasonably heavy rainfall was received on all sites during late January and in February 1955. Much of the Cetyl alcohol in flaky form used in those experiments was broken into small fragments during transport and there was further disintegration within the gauze containers while on the water surface. The finer solid particles of alcohol passed through the meshes of the container and were soon washed on to the banks and lost.

2.2. Conclusions of 1954-55 Experiments

2.2.1. The period of treatment in tests thus far was too short and the results meagre. The treatment with Cetvl alcohol proved successful for periods up to 6—8 weeks but then failed because the flaky Cetyl alcohol proved too fragile under practical conditions. Very little practical results could be obtained as majority of experiments were spoilt.

2.2.2. These tests brought out firstly, that flaky Cetyl alcohol was unsuitable and needed replacement by the same in the form of beads and secondly, that it was necessary to administer a higher initial dosage of say 3-5 lbs. of Cetyl alcohol per acre.

2.2.3. On the basis of these earlier experiments, the process could not be recommended and it was thought that tests might well be required to continue for some time more, before accurate information could be gathered on the cost of the process and its efficiency at different dose levels. However, in general, it was indicated that some reduction in evaporation could be obtained on areas of water up to 10 acres.

2.3. Field Trials on different-sized Water Storage Reservoirs (September 1955—August 1956)

2.3.1. The seven small tanks included for field trials during the period were Charlton (Victoria), Round Hill (W. Australia), Badgery Creek (N. S. Wales), Terrick (Queensland), Granada (Queensland), Tennant Creek (Northern territory) and Moora (W. Australia); those of larger size included Umberumberka and Stephens Creek Reservoirs (Broken Hill). However, while for none of these sites, the data were considered worth presenting, those experiments resulted in the development of some types of floating rafts for dispensing Cetyl alcohol monolayer (Plates 1 and 2). Moreover, they led to the conclusion that the best way to dispense Cetyl alcohol would be in the form of its solution in a suitable solvent.

2.3.2. The experimental work done at the Stephens Creek Reservoir, which comprises somewhat different approach. is described in Section 2.5.

2.4. Manufacture and Designing of Rafts

2.4.1. The gauze containers were floated on rafts and the latter moored by line and anchor. The earlier design incorporated a raft of light pinewood treated with paraffin wax to minimize water absorption by wood. The gauze cabin on float confined about a lb. of floating solid particles of Cetyl alcohol but allowed the monolayer to spread over the water surface. Plates 1 and 2 are photographs of commercial rafts designed for use on sites. The small one

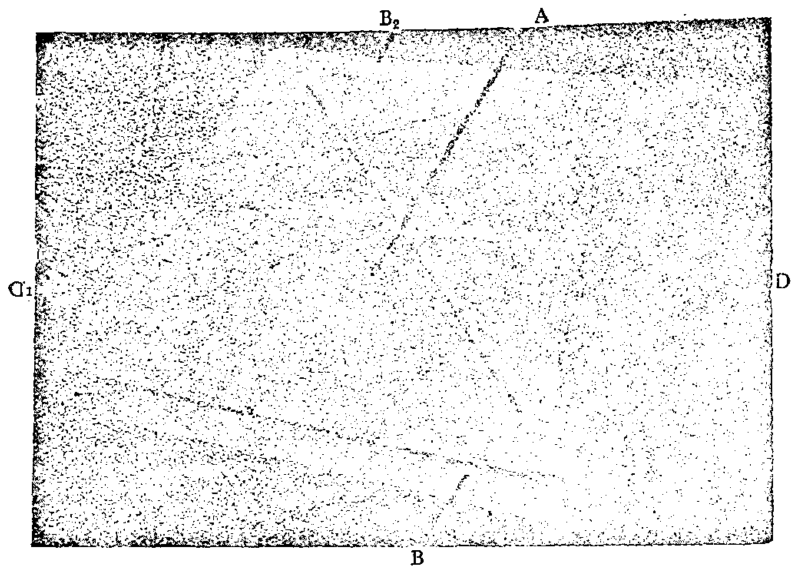


Plate 1—Small-sized Raft.

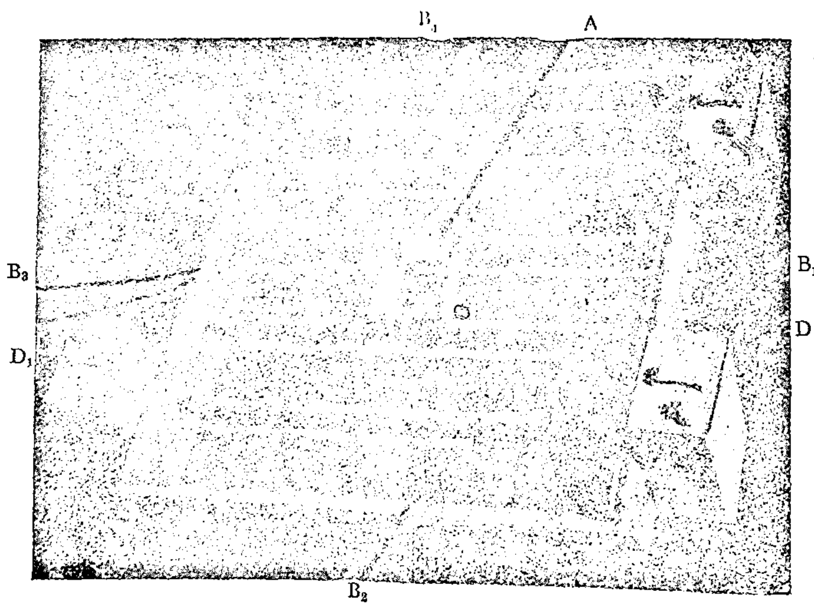


Plate 2—Another form of Raft.

('A' is trap door or filling plug. B_1 to B_1 are gauze sides, 'C' top and bottom Screens and D, D_1 are anchoring bolts.)

30313

is intended for use at site of one acre in area and is the smallest unit which should be used. The area of water lying inside the gauze basket of the raft should be 9 sq. ft. and 2 to 2½ lbs. of alcohol introduced through a trap door or filling plug (Marked 'A' in the Plate). When raft is floated in water the charge of alcohol should completely cover the water surface inside the basket and be replenished at regular intervals to maintain the complete layer of beads.

2.4.2. Along two or more sides of the raft the gauze windows of the basket (B_1, B_2, B_3 and B_4) are freely exposed. Through these windows the monolayer escapes to cover the water surface, the beads being retained. It is essential that the combined lengths of windows should total at least six feet and that the gauze should be of bronze or of light resistant plastic as substitute of bronze and of 16 meshes to an inch. The gauze basket may have a gauze top and bottom forming the container from which the solid Cetyl alcohol cannot escape. Close inspection is needed to ensure that there is no hole anywhere in the gauze from which beads can escape otherwise the whole charge will be lost as the raft is tossed about by wavelets.

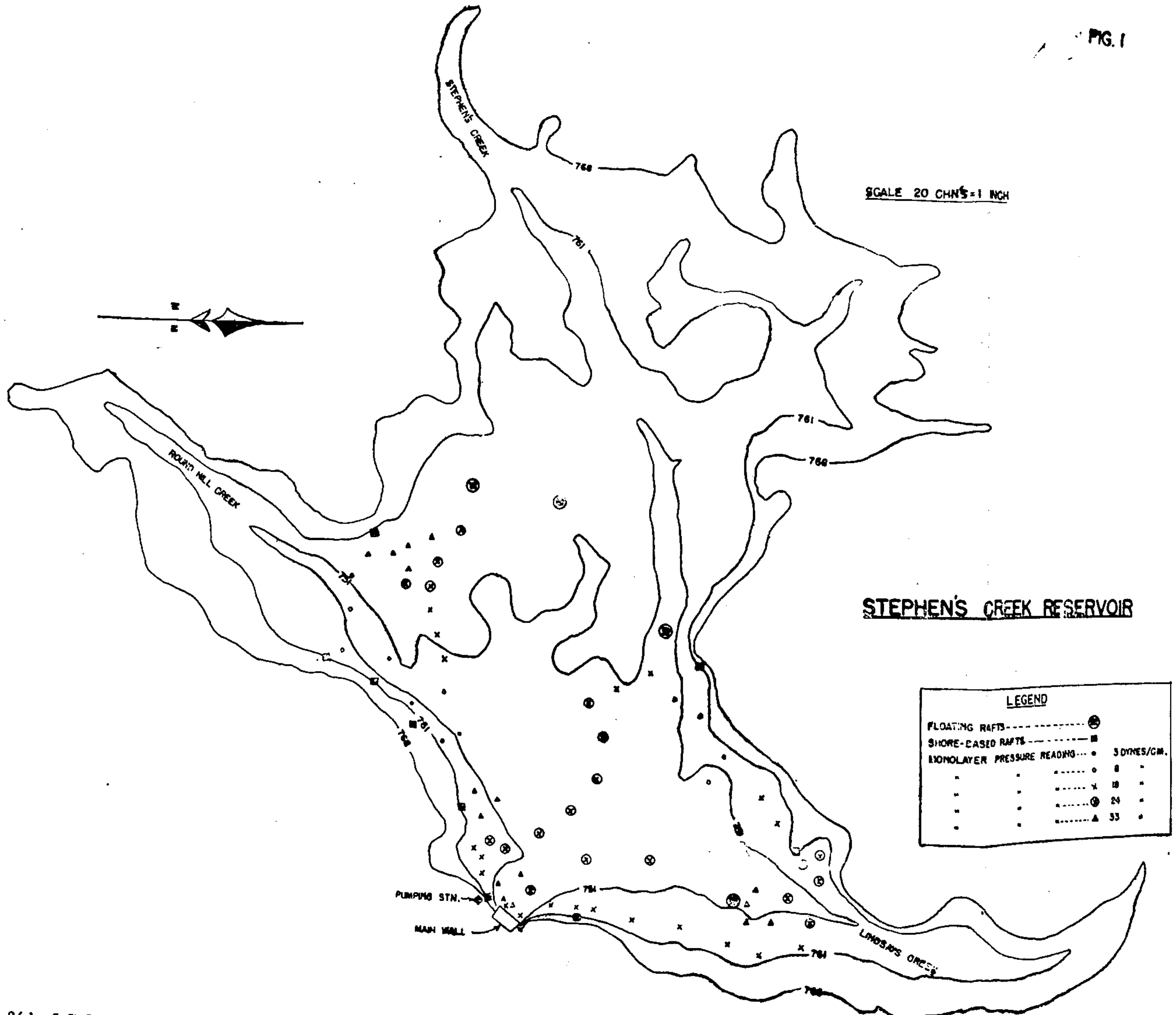
2.4.3. The top screen C closing the top of the basket must be at least 3 inches above the surface of the water and the bottom screen C closing the bottom of the basket at least 2 inches below the water surface. If the raft sinks low into the water, even if it is still floating, the waves will rub the beads against the upper screen and within a short time they will disintegrate and escape far more rapidly than is required.

2.4.4. Rafts relying entirely on the buoyancy of wood have proved unsatisfactory for, whatever the treatment given to wood, it becomes water-logged and as the raft sinks lower abrasion increases by beads rubbing against the upper screen.

2.4.5. After loading with beads the raft is floated and the height of the upper screen above the water surface is adjusted to three inches. Check should be made monthly to ensure that there is sufficient alcohol and that upper screen is about 3 inches above the water surface.

2.4.6. It is easy to anchor a raft in the centre of a tank by means of wire from two bolts (D, D_1) on each side of the raft to the shore. This arrangement makes it easy to pull the raft to the shore for monthly inspections. Rafts may, of course, be secured at the centre of the tank by means of any suitably dropped anchor.

FIG. 1


SCALE 20 CHNS = 1 INCH
STEPHEN'S CREEK RESERVOIR
STEPHEN'S CREEK
ROUND HILL CREEK
LINDSAYS CREEK
768
761
PUMPING STN.
MAIN WALL
LEGEND
FLOATING RAFTS
SHORE-BASED RAFTS
MONOLAYER PRESSURE READING 3 DYNES/CM.
8
18
24
33

2.4.7. On sites of one acre or less one raft is used. For sites between one and two acres two rafts must be used.

2.4.8. There is some difference of opinion as to whether the rafts should be designed to be of long life, and therefore probably of high initial cost, or whether they should be made from materials readily available. There have been quite good simple suggestions for rafts which farmers could make themselves.

2.5. Experiments on the Control of Evaporation at the Stephens Creek Reservoir—Broken Hill (N.S.W.)

2.5.1. The Stephens Creek Reservoir, which is one of the two large local storages from which the Broken Hill Water Board draws its supply of water, has a surface area of 2,000 acres at the top water level of R.L. 766 ft.*, its maximum depth is 16 ft. and, when full contains 4,500 million gallons of water. The reservoir is illustrated by Plate 3 and its contour details shown in Fig. 1. The reservoir has a catchment area of about 200 sq. miles. A 60-mile pipeline leads water from the Darling river to the reservoir when so required.

With the reservoir at its present level of R. L. 760, the Board loses in each of the summer months from November to March, 4 gallons through evaporation for every gallon pumped. In some months as much as 13 inches are lost through evaporation, and peak week could record an evaporation loss upto 4½ inches. A comparison with the evaporation record from the evaporimeter installed at the site accounts for about 95 per cent of the losses due to evaporation from the reservoir and, therefore, the loss due to seepage from the reservoir is taken as more or less negligible.

The CSIRO commenced the test at the Stephens Creek Reservoir on the 6th December, 1955. One marked feature of that test was that Cetyl alcohol was dispensed in the form of solution in a highly vaporising solvent. It was found that within 6 days from commencement, a satisfactory film had spread over the greater part of the water surface.

2.5.2. *Operating Details*

(a) *Description of treatment.*—Four rafts have been moored over the channel comprising the deepest section of the reservoir. The rafts are 8 ft. by 8 ft. in dimensions and are supported by six 44-gallon drums with a seventh drum fixed to the platform of the raft, the

---

**Postscript*—According to a recent report the waterspread of that reservoir has been given as 1,000 acres.

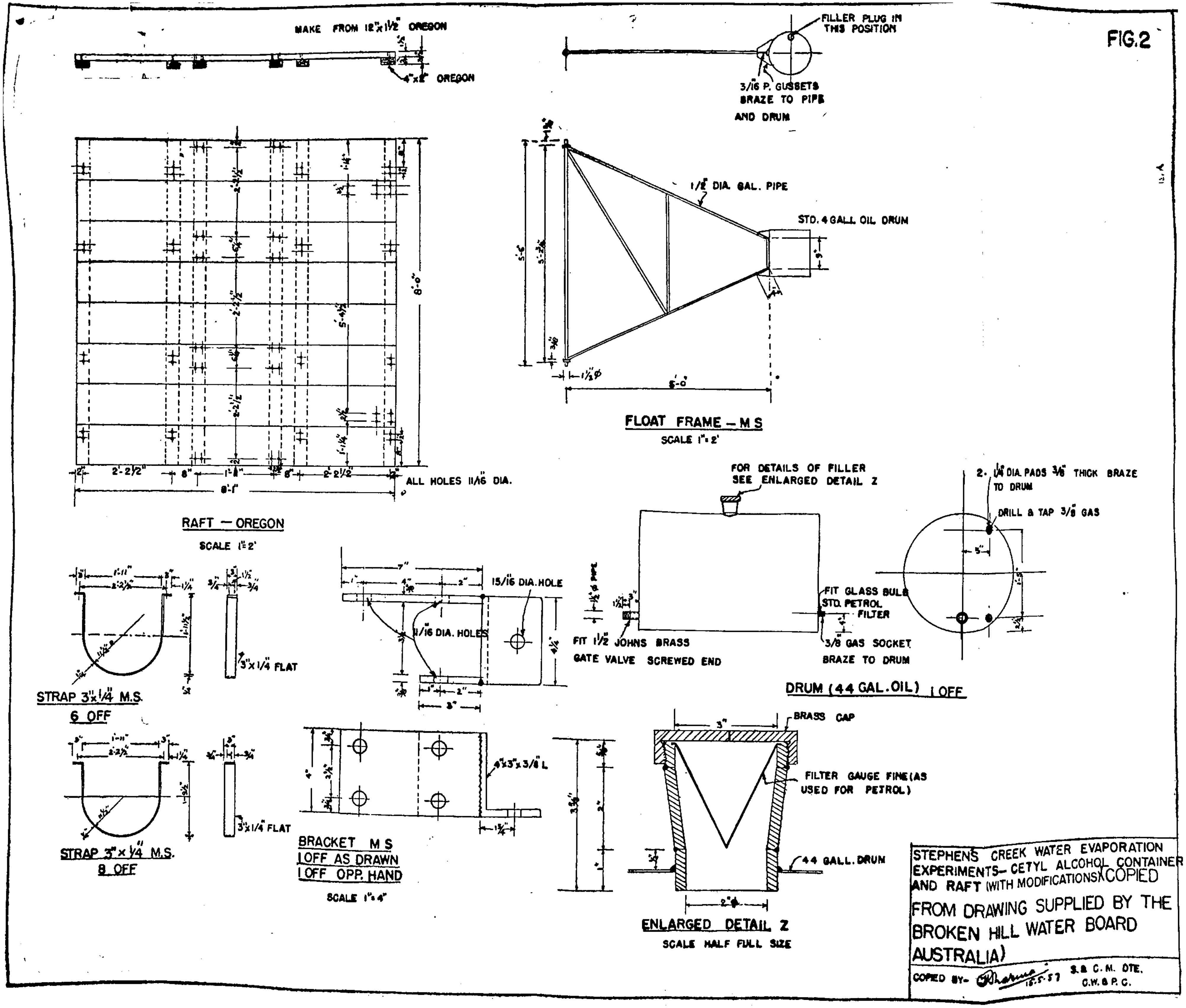


FIG.2
MAKE FROM 12"x1½" OREGON
4"x2" OREGON
FILLER PLUG IN THIS POSITION
3/16 P. GUSSETS BRAZE TO PIPE AND DRUM
1/2" DIA. GAL. PIPE
STD. 4 GALL OIL DRUM
FLOAT FRAME — M S
SCALE 1"=2'
ALL HOLES 11/16 DIA.
RAFT — OREGON
SCALE 1"=2'
FOR DETAILS OF FILLER SEE ENLARGED DETAIL Z
2. 1¼ DIA. PADS 3/8" THICK BRAZE TO DRUM
DRILL & TAP 3/8 GAS
15/16 DIA. HOLE
11/16 DIA. HOLES
3"x1/4 FLAT
STRAP 3"x1/4 M.S.
6 OFF
FIT GLASS BULB STD. PETROL FILTER
FIT 1½ JOHNS BRASS GATE VALVE SCREWED END
3/8 GAS SOCKET BRAZE TO DRUM
DRUM (44 GAL. OIL) 1 OFF
BRASS CAP
4"x3"x3/8 L
FILTER GAUGE FINE (AS USED FOR PETROL)
44 GALL. DRUM
STRAP 3"x1/4 M.S.
8 OFF
BRACKET M S
1 OFF AS DRAWN
1 OFF OPP. HAND
SCALE 1"=4"
ENLARGED DETAIL Z
SCALE HALF FULL SIZE
STEPHENS CREEK WATER EVAPORATION EXPERIMENTS— CETYL ALCOHOL CONTAINER AND RAFT (WITH MODIFICATIONS) (COPIED FROM DRAWING SUPPLIED BY THE BROKEN HILL WATER BOARD AUSTRALIA)
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C.W. & P. C.

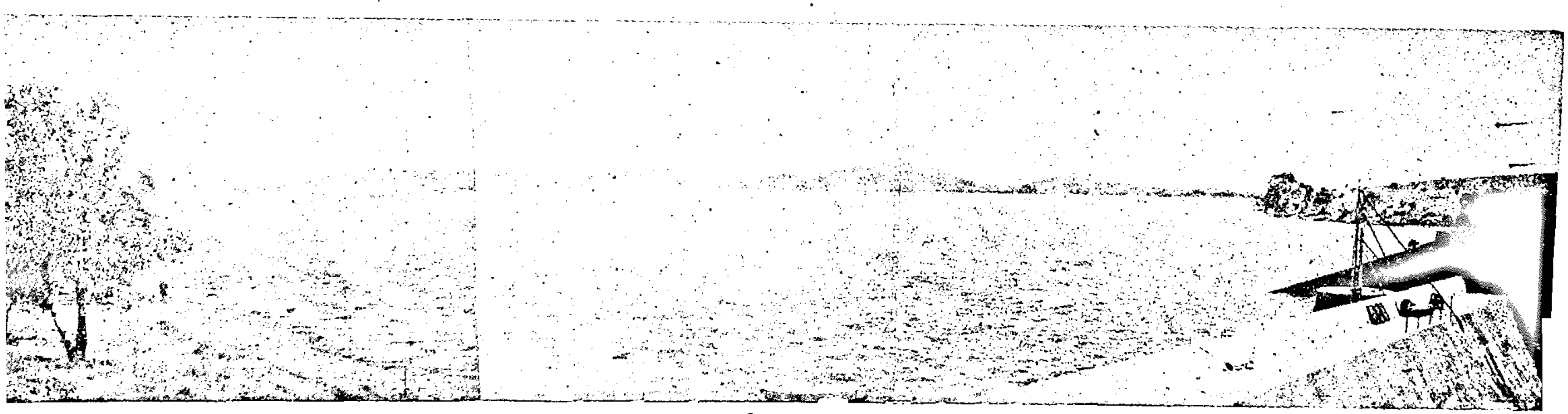


Plate 3—General view of the Stephens Creek Reservoir, Broken Hill.

latter to contain Cetyl alcohol*, reduced to a liquid by special solvent and fitted with a delivery unit comprising a filter, a length of plastic tubing and a glass capillary delivery tip. The design details of the floating raft are given in Figs. 2 and 3.

It was soon noticed that with a following wind the trail of film spread rapidly to the windward of the rafts but did not appear to fan out on either side, *i.e.*, at right angles to the wind as satisfactorily as was expected. So a further modification of augmenting the supply from the anchored rafts by feeding the Cetyl alcohol solution into water from shore-based units was introduced. For the shore units, of which at the moment they had 9 operating, each had a plastic tube fitted at the end which was passed through a conduit, the latter led the capillary delivery tip a little away from the shore.

(b) *Preparation of Cetyl Alcohol Solution.*—The contents of the 44-gallon reservoir drum of each raft are approximately as follows:—

18 lbs. Hexadecanol.

36½ gallons of Shell-X 95 solvent.

3 gallons of methylated spirit (cut out in summer when high temperature prevailed generally).

(c) *Delivery Rate of Solution.*—The solution is fed into the reservoir at the rate of 3 to 3½ gallons per day per raft, such being the approximate quantity lost each day through the film being washed ashore.

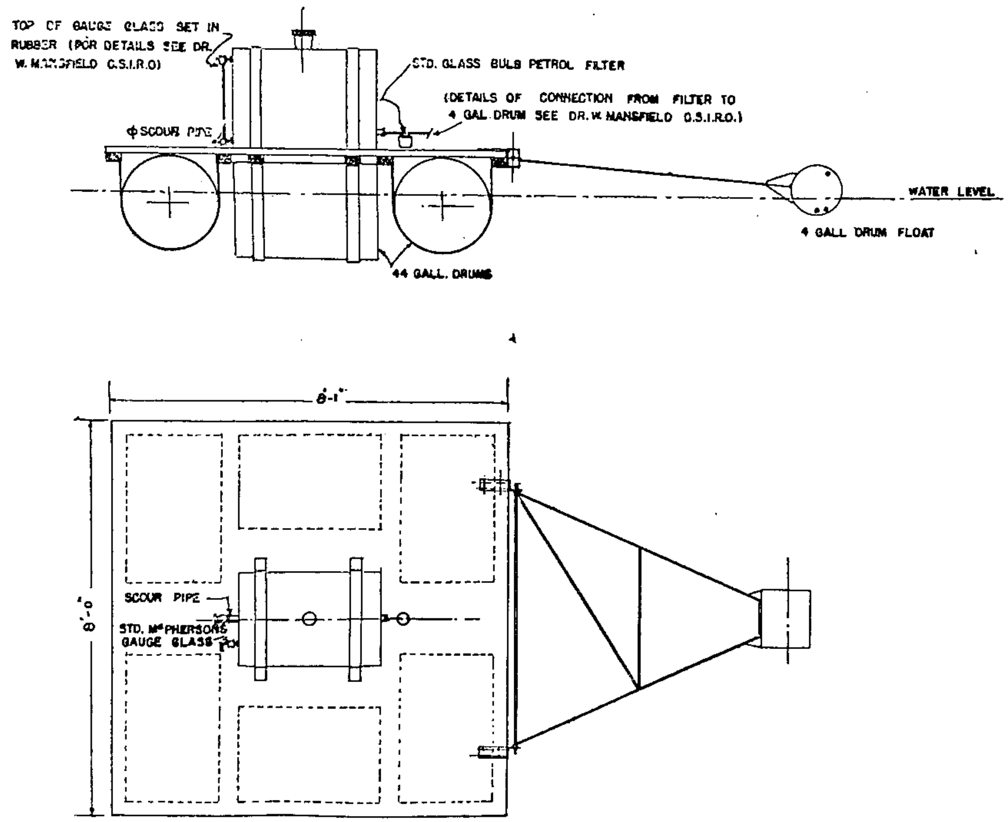
The allowable tolerances in delivery rates are given below:—

	Recommended
Per raft per day 2½ to 4½ gallons.	3½ gallons.
Total per day 10 to 18 gallons.	14 gallons.
Per raft per week 17½ to 31½ gallons.	24½ gallons.
Total per week 70 to 126 gallons.	98 gallons.

2.5.3. *Replenishing and Maintenance of Rafts.*—The floating containers need replenishing weekly to contain 34 to 40 gallons thereby avoiding overfilling and leaking at top. Apart from the repairs necessitated by accidents, the maintenance required comprised ensuring that each delivery unit is dispensing solution at the required rate.

*According to that recent report a mixture of Cetyl alcohol and Stearyl alcohol was used instead of forming monolayer.

FIG.3.



SCALE 1"=2'

STEPHEN'S CREEK WATER EVAPORATION EXPERIMENTS – DRUM POSITIONS ON OREGON RAFT (COPIED FROM DRAWING SUPPLIED BY THE BROKEN HILL WATER BOARD AUSTRALIA)

COPIED BY– [signature] S.&C.M.DTE C.W.& P.C.

2.5.4. *Improvement in Dispensers for Solution.*—One difficulty which presented itself respecting the shore-based units was that the solution discharged from the drum would be washed ashore if the prevailing wind came from across the water. Thus it was considered necessary to design a unit which would permit the full discharge of liquid from the drum when the wind was from the shore and would cut off supply when the wind was from across the water. The Board had recently developed in their workshop such a dispenser wherein the regulation of supply of liquid was automatically controlled by a sensitively-balanced wind-vane mounted on the top of the unit (Plate 4), which operated the outlet valve. (For details *see* Fig. 4.)

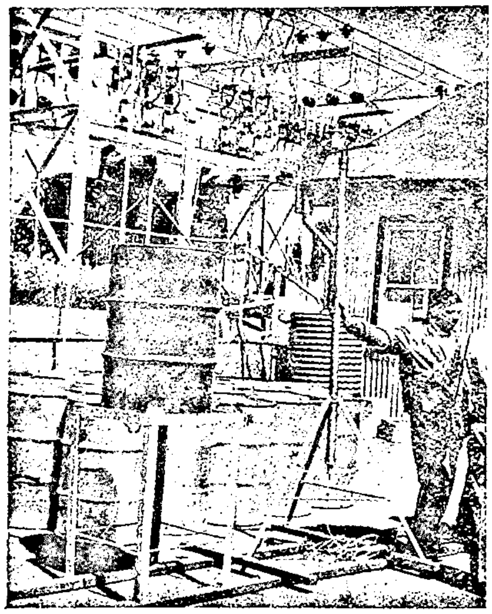
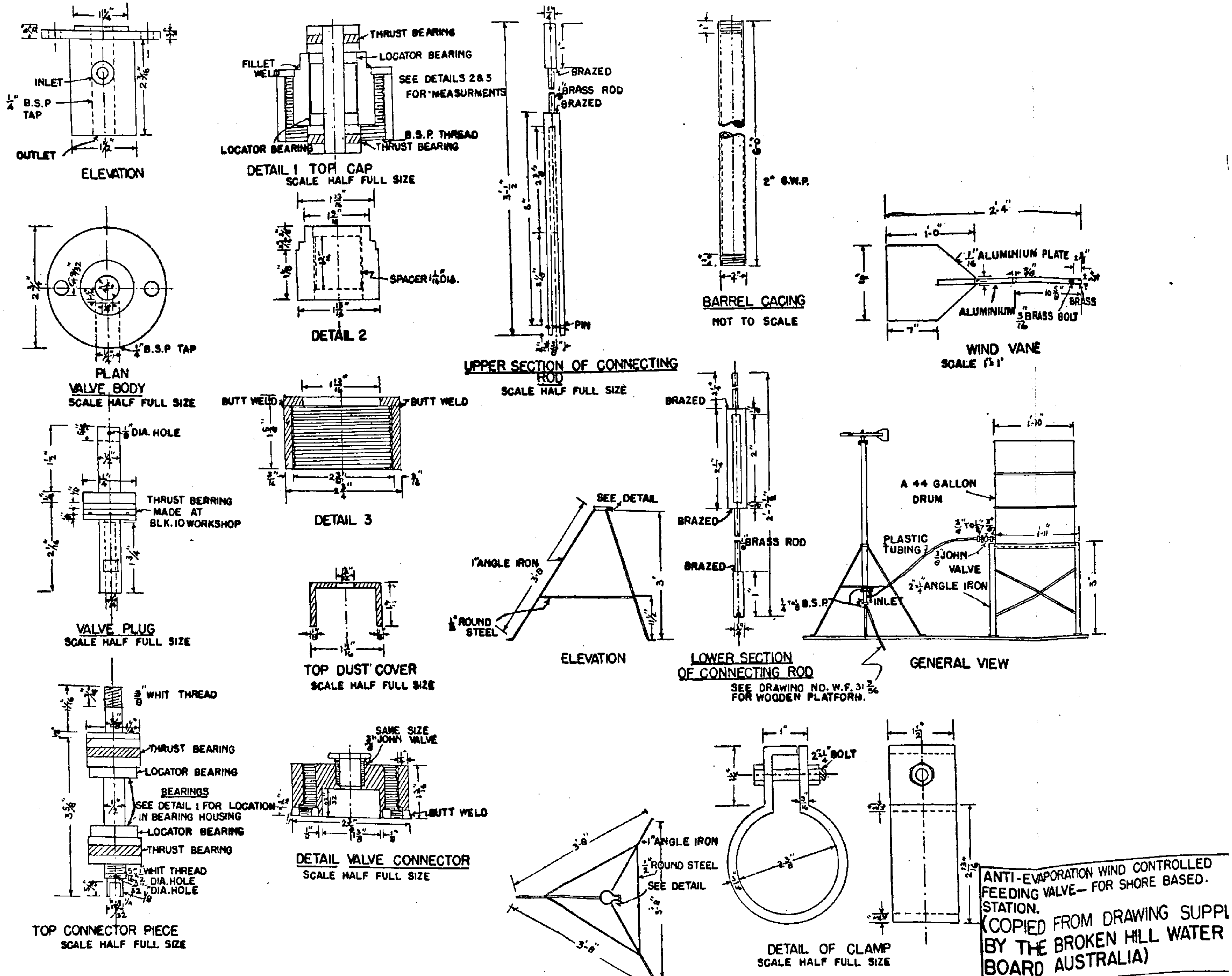


Plate 4—The newly designed Dispenser with a sensitively balanced wind-vane mounted on the top of the unit to control the outlet valve supplying Cetyl alcohol solution.

2.5.5. *Testing of Monomolecular Film.*—The strength of the film is most easily indicated by the surface pressure built up on the water surface; this pressure is measured generally as dynes per centimeter. A number of samples of oils which spread on water are provided. These oils are graded and numbered depending on the surface pressure they generate on water; the first *i.e.*, No. 3 generates a surface pressure of 3 dynes/cm. and the last *i.e.*, No. 33 that of 33 dynes/cm. If the surface pressure on a water surface should happen to be, say, 17 dynes/cm. then oils Nos. 3, 8 and 12 will not spread, oil No. 18 will just spread and the oils of higher numbers will spread easily. It will be recorded as greater than 12 and just less than 18. Surface pressure measurements are taken regularly once a week for points near each of the rafts and about 100 yards from each raft into



ANTI-EVAPORATION WIND CONTROLLED FEEDING VALVE— FOR SHORE BASED. STATION.
(COPIED FROM DRAWING SUPPL BY THE BROKEN HILL WATER BOARD AUSTRALIA)

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N.B. THRUST BEARINGS ARE OF THE HOFFMAN W½ TYPE (2 OFF) S.K.E 04

LOCATOR BEARINGS ARE OF THE F.A.G. EE4 TYPE (2 OFF) S.K.F. EE4 the direction of the wind. Should time permit, other readings can be taken. In rough weather should measurement prove difficult or impossible, this fact should be recorded. An illustration of the recording done at the Stephens Creek Reservoir is shown in Statement I.

2.5.6. *Conclusions.*—The work at the Stephens Creek Reservoir represents an organised attempt at assessing the utility of the film forming qualities of Cetyl alcohol for prevention of evaporation from reservoirs. However, that experiment is also in an early stage and it may be some time before a firm statement on the results achieved is issued but to date they look extremely promising*. It was reported by the officers at the Stephens Creek Reservoir that the monolayer of Cetyl alcohol at the water surface in the reservoir toned down the wave action considerably.

3.0. MANSFIELD HEXADECANOL (SIROSEAL) PROCESS

3.1. Mansfield had laid down specifications to which Cetyl alcohol (Hexadecanol), an insoluble chemical, should conform for use to restrict evaporation. Hexadecanol is a white waxy solid which is lighter than water. The specifications require that the Hexadecanol (Siroseal) shall be in the form of beads whose diameters lie between 2 mm. (0·08″) and 4 mm. (0·16″), the preferred size being between 2·5 and 3·0 mm. (approx. 1/10″ and 1/8″). The sample shall contain:

Hexadecanol	Not less than 80%
Octadecanol	Not more than 10%
Tetradecanol & Dodecanol	Not more than 10%
Alcohols of chain length less than 10	Absent
Unsaturated alcohols	Not more than 4%
Iodine value	Less than 3·0
Acid value	Less than 0·3
Saponification value	Less than 0·5
Hydroxyl value	225 to 230
Melting point	47-50°C

**Postscript*—According to latest reports about the trials at the Stephens Creek Reservoir over a 3-month period more than 200 million gallons of water were saved *i.e.*, an average reduction of 37 per cent at a cost of about a penny (less than 1/16 rupee) per thousand gallons.

4.0. METHOD OF ESTIMATING PERFORMANCE

4.1. The records of the various water storages were examined for periods of upto 15 years prior to treatment. From the records of levels, intakes and withdrawals, the losses by seepage and evaporation for known weekly or monthly periods were calculated; for the same periods the evaporation from a standard evaporimeter either at the site of the experiment or nearby were obtained from meteorological records. It was found that the measure of evaporation (*E* inches) and the combined loss due to evaporation and seepage from the site (*f* inches) were related as below :—

$$f = S + KEs$$

when *K* represents an empirical relation between evaporation from the evaporimeter and from the test reservoir and *S* the seepage. To obtain a linear relation between *f* and *E* it was necessary to work within specified limits which involved excluding data:—

(i) When the reservoir level was above a specified height or below a second specified height;

(ii) When the recorded rainfall or direct intake exceeded a small fraction of the daily drop in level; or

(iii) When the withdrawal exceeded a small fraction of the daily drop in level.

Condition (i) arises because seepage losses vary considerably with reservoir level so that *S* in the above equation is constant only over a limited range. Conditions (ii) and (iii) are related to the level of the watertable external to the reservoir; when there is a rapid change in reservoir level then seepage losses vary from the almost steady losses of a slowly falling level. Further, the measurement of the withdrawn water or the area of water in the reservoir cannot be measured with sufficient accuracy to allow the relation between *E* and *f* to be determined precisely.

After treatment of the surface with the alcohol a relation similar to that given above was obtained and any reduction in evaporation could be estimated directly from the fall in the value of *K* which value lies between 0.8 and 1.2 in the absence of a protective film.

5.0. COST AND SAVINGS

5.1. The major capital cost is that of the raft. A satisfactory raft probably costs about £15 (Rs. 159) and it should have a useful life of three years. Hexadecanol to the specification of Siroseal costs between shillings 6 to 7 (Rs. 3 to 4) per lb. from the importer. If a maximum consumption of 12 lbs. of hexadecanol [at shillings 6/6 (Rs. 3-7-0) per lb.] per annum for each acre treated is assumed and allow £5 (Rs. 53) per annum per raft for depreciation then the cost is approximately £9 (Rs. 95) per annum, no allowance being made for labour. On the basis of the annual evaporation in a given area as reported by the Commonwealth Meteorological Bureau, these experiments indicate the possibility of saving at least 25 per cent of this figure. In giving this figure of 25 per cent, the Organisation had made allowance for the difference in evaporation from the tank. On this basis, cost per 1,000 gallons of water saved in regions of different evaporation rates (annual evaporation varying from 2 ft. to 10 ft.) is expected to range from 16 d. (Re. 0-11-0) to 4 d. (Re. 0-3-0), calculated on the basis of saving of water to the extent of 0.5 acre ft., for an annual evaporation rate of 2 ft., to 2.5 acre ft. for an annual evaporation rate of 10 ft. respectively. If a raft costing £14 (Rs. 148) has to be replaced every year then the cost of water saved is doubled. In areas of high evaporation (6 ft. or more) the water thus saved from evaporation will still be cheap.

For the Stephens Creek Reservoir the present cost of the Cetyl alcohol had been given as shillings 3-11 per lb. and the cost of material used per week per raft as £ 9-3-9 (about Rs. 97).

6.0. CONCLUSIONS

6.1. It is seen from the above that, besides the general conclusion that some reduction in evaporation can be accomplished on water storages of the size of about 10 acres, the experiments still were in an early stage and although the results seemed promising it might be some time before a firm statement on the results achieved would become possible. Those experiments have, however, resulted in the development of suitable forms of floating rafts, shore-based units and unit with Wind-Vane device for regulation for dispensation of monolayer of Cetyl alcohol with the object of removing the inequalities in monolayer on the waterspread in storage reservoirs. These improvements in the technique should be of great help in conducting of similar experimental work elsewhere. Although the results of 1954-55 field experiments indicated that some reduction in evaporation can be obtained on areas of water up to 10 acres by dispensing monolayers of Cetyl alcohol on the water surface but on the basis of their experience to date, they recommended for the present the Cetyl alcohol technique for small-sized reservoirs covering one or two acres only.*

*Please refer to footnote to para 2.5.6.

STATEMENT 1

THE BROKEN HILL WATER BOARD

Anti-evaporation Experiment

Return No. ——————————

Reservoir ——————————

Period ended ——————————

Date of last return ——————————

Prevailing wind past 24 hours ——————————

Condition of Water Surface ——————————

Prevailing wind at time of test ——————————

Date of test ——————————

Materials Stock Return

Date	Cetyl alcohol (lbs.)	Solvent (Gallons)	Methylated Spirit (Gallons)
On Hand			
Received			
Total			
Consumed			
Remaining			

Explanatory Notes and Key to Plan

Decimal square on graph = 2 inches

Outer contour R. L. = 768

Inner contour R. L. = 75

Reservoir T. W. L. = 766

Raft No. and position shown thus —————— Shore stations

3 8 18 24 33 dynes

Pressure reading and location shown thus ——————————

Level of reservoir at beginning of intervals dated —————— ft. in.

Level of reservoir at end of interval dated —————— ft. in.

Quantity pumped during interval (000's of gallons) ——————————

Rainfall during interval —————— (o)

Evaporation measured at evaporimeter during interval —————— (to)

Remarks

2. Experiments carried out in Australia on Plastic Membrane Lining of Water Storage Reservoirs

It was suggested that we should contact the Imperial Chemical Industries Ltd., Melbourne, to obtain information regarding the experiments carried out by them on the plastic lining of water storages. Accordingly Mr. K. Keith of the Technical Sales Department, Imperial Chemical Industries Ltd., Melbourne was contacted for that purpose.

Mr. Keith described how the Charlton Reservoir was lined with plastic membrane. That reservoir had a waterspread of about 1½ acres with a maximum depth of about 15 ft. of water. The seepage rate at that reservoir was very excessive so that within a very short period it got emptied out. The plastic membrane was imbeded below a few inches of soil cover, the latter was simply dumped and not consolidated and treading by workers on the layer during dumping of soil, though reduced to the minimum, was not completely excluded.

There was a considerable lowering of the rate of seepage after the reservoir had been lined with plastic membrane. However, neither the experimental data to bear out the improvement in the seepage rate at that reservoir and the subsequent behaviour of the lining during the period since elapsed nor figures of the economics of that type of lining, could be obtained. The polythene membrane had to be 0·006 inch thick to be economical. It cost about 3 Aust. shillings (about Rs. 1-10-0) per sq. yard. That plastic was a wax of high molecular weight and available in the form of sheets of 12 ft. width. The membrane was fairly resistant to being torn or punctured. It was stated that there had been no single recorded instance of polythene membrane having been attacked by soil micro-organisms.

Unfortunately that was the solitary example on use of plastic membrane for purposes of lining water storages. One reason for their not proceeding with the work had been that the Government of Australia had withdrawn the licence for importing plastic membrane in the country. It was hoped that it might become possible to resume the experiments when they started manufacturing that material in Australia in about a year's time.

Mr. Keith suggested that several improvements could be effected in carrying out plastic lining experiment in future. Some of those were:

(1) The use of black polythene membrane, instead of the whitish one as the latter deteriorated quickly, especially when exposed to light.

(2) For the purpose of joining the ends of polythene sheets while laying, he intended to provide a double overlap at edges and then cement them.

It was stated that the plastic membrane could be put to several other uses, *e.g.*, laying concrete over earth surface preventing growth of weeds during cultivation of regular agricultural cropping, protection of protein in sullage water, etc.

3. Experiments on Artificial Stimulation of Precipitation in the Snowy Mountains Region of Australia

1.0. Introductory

A long-term experiment on the artificial stimulation of rain over an area in the Snowy Mountains region of South-East Australia has been in progress jointly by the Snowy Mountains Hydro-electric Authority and the CSIRO since June 1955. The tests incorporate the exclusive employment of aerial seeding and some novel features both in the general design and in methods used to assess the results and which have definite advantages to those used in the past, are briefly described.*

2.0. Design of the Experiment

2.1. *Method of Control.*—To improve the reliability with which the precipitation in the absence of seeding can be inferred instead of the commonly applied historical method, the alternative approach relies on seeding being confined to random periods so that the intervening unseeded periods are available to provide the essential control data. The latter is not dependent upon the existence of long series of records from a closely spaced network of stations and any desired cover of gauge stations may be specially installed for the purpose of the tests.

2.2. *Length of Period.*—The selection of the convenient natural period for seeded 'on' and unseeded 'off' periods, corresponding to the passage across the area of anti-cyclone centres, adopted for the present experiment provides a two-fold advantage. The measurements of precipitation can be made more expeditiously in the favourable weather usually accompanying anti-cyclones and incorporates the measurements at null points which is the next best thing to reading all gauges simultaneously. The division into the on and off periods is made on the basis of random numbers during the regular procession of high pressure and frontal systems across S. E. Australia from March to December.

*Extracted from the literature made available during the visit which fact is gratefully acknowledged.

2.3. *Estimation of Precipitation.*—The raingauge cover in the Snowy Mountains area has been greatly increased since the beginning of this experiment where the total precipitation, *i.e.*, both rain and snow is measured. At the conclusion of each period isohyetal patterns are plotted for that period and the total precipitation in acre feet calculated by integration of the isohyets. This furnishes a better estimate of the true total than that given by individual gauges.

2.4. *The Area of Operations.*—The orography and climatology of the region of the general area in Snowy Mountains, shown in Fig. 5, selected for an operation of that kind is very suitable. Its division into, more or less, actual 'control' and 'target' areas is shown in Fig. 6. The prevailing winds are from the north-west to south-west and precipitation and deep clouds are most frequently associated with winds in conjunction with frontal and post-frontal synoptic situations. The clouds seeded to date have been cumuli or stratocumuli.

3.0. Equipment

An Avro Anson Aircraft is used for seeding (Plate 5). The silver iodide smoke generator is attached to each wing-tip (Plate 6) and its design is detailed in Fig. 7. A pump within the cabin of the aircraft pumps the solution containing silver iodide and sodium iodide in acetone from a tank in the fuselage (Plate 7) to the wing-tip generator units. The latter atomize the inflammable solution to a fine spray to be ignited by a *glow-type* spark plug at the rate of 500-800 gms. of silver iodide per hour. Thermocouples measure the temperature of each burner and serve to indicate that the burners are operating correctly. For reasons of safety the incandescent vapour is cooled by radial introduction of air so that the flames are confined to the interior of the burner tube. The aircraft is equipped with complete navigational aids so that accurate position finding is possible in all circumstances. The interior of the aircraft cabin is shown in Plate 8. The crew who carried the delegation members on demonstration flight on the plane is shown in Plate 9.

4.0. Operational Procedure

The earlier experiment had indicated that seeding was likely to induce precipitation provided that (i) the temperature of the top of the cloud was $-6°C$ or colder and (ii) the cloud was compact and at least several thousand feet in vertical height. The routine seedings in the present experiment are conducted with the above considerations. The prevailing meteorological situation at the base station indicates suitable cloud conditions. The most suitable level

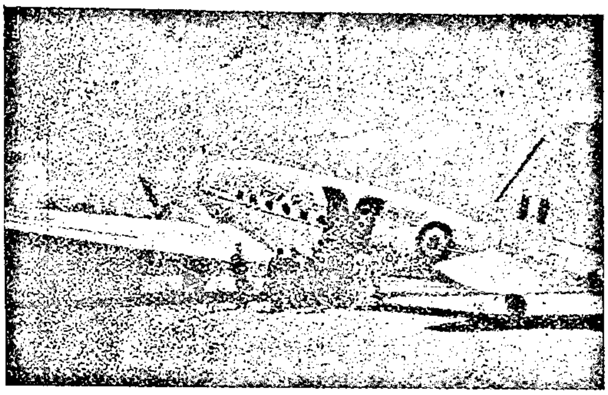

Plate 5—The party about to enplane the R. A. A. F. aircraft to watch the demonstration of seeding of the clouds over the Snowy Mountains.

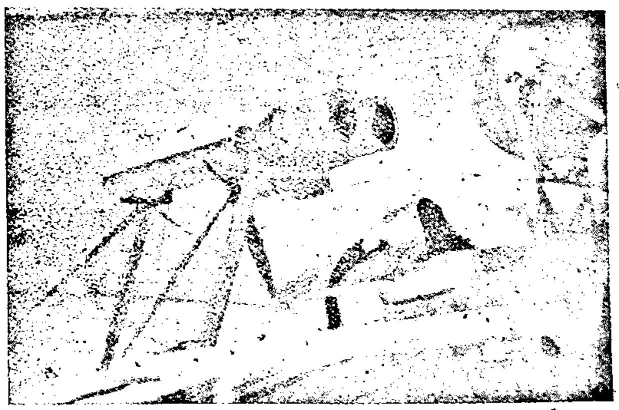

Plate 6—The burner mechanism fitted on the outside below the wings of the aircraft to produce Silver iodide vapour trail during cloud seeding operations.

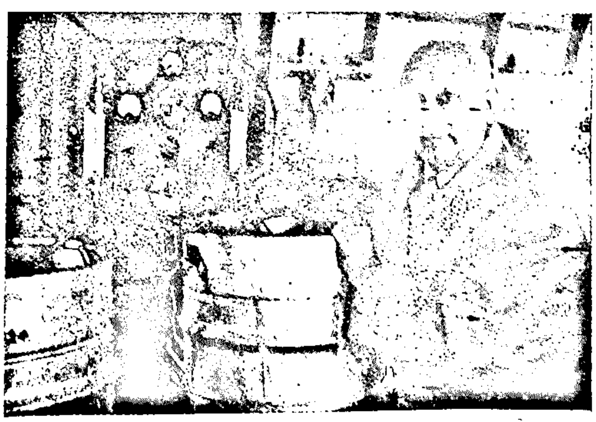

Plate 7--A closer view of the drum and control panel part of equipment in the aircraft cabin.

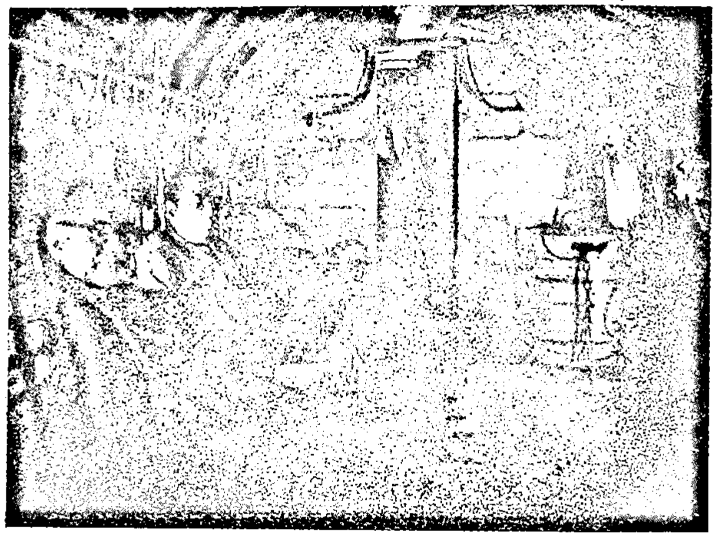

Plate 8—Interior of the aircraft cabin; the drums containing the Silver iodide solution are on the right of the photograph.

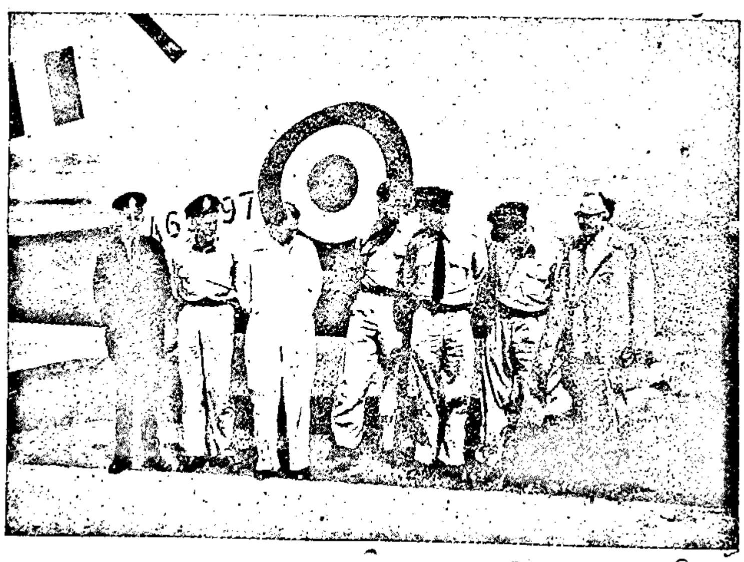

Plate 9—Prof. Thacker with the crew members of the R. A. A. F. plane at the end of the demonstration flight.

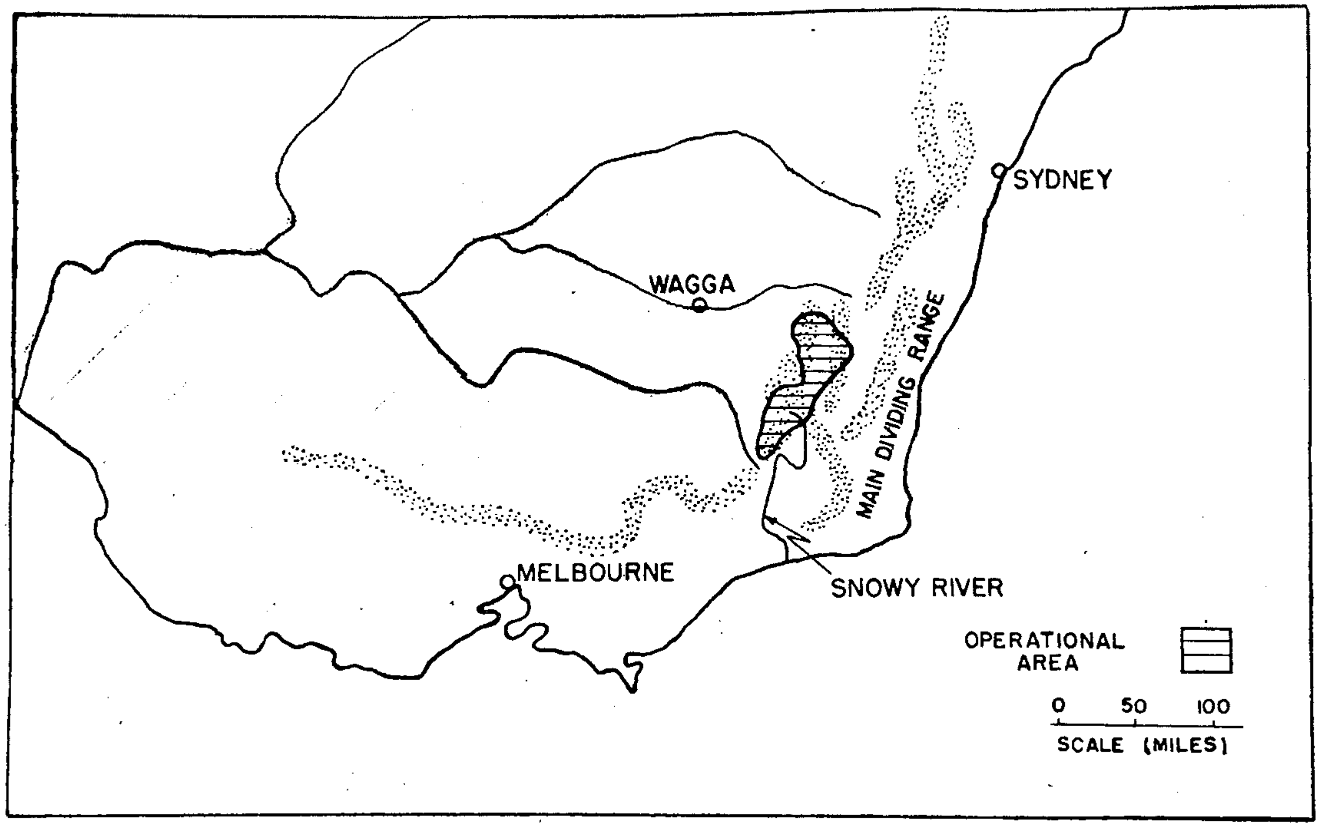

FIG: 5 MAP SHOWING SNOWY MOUNTAINS AREA IN RELATION TO SOUTH EAST AUSTRALIA

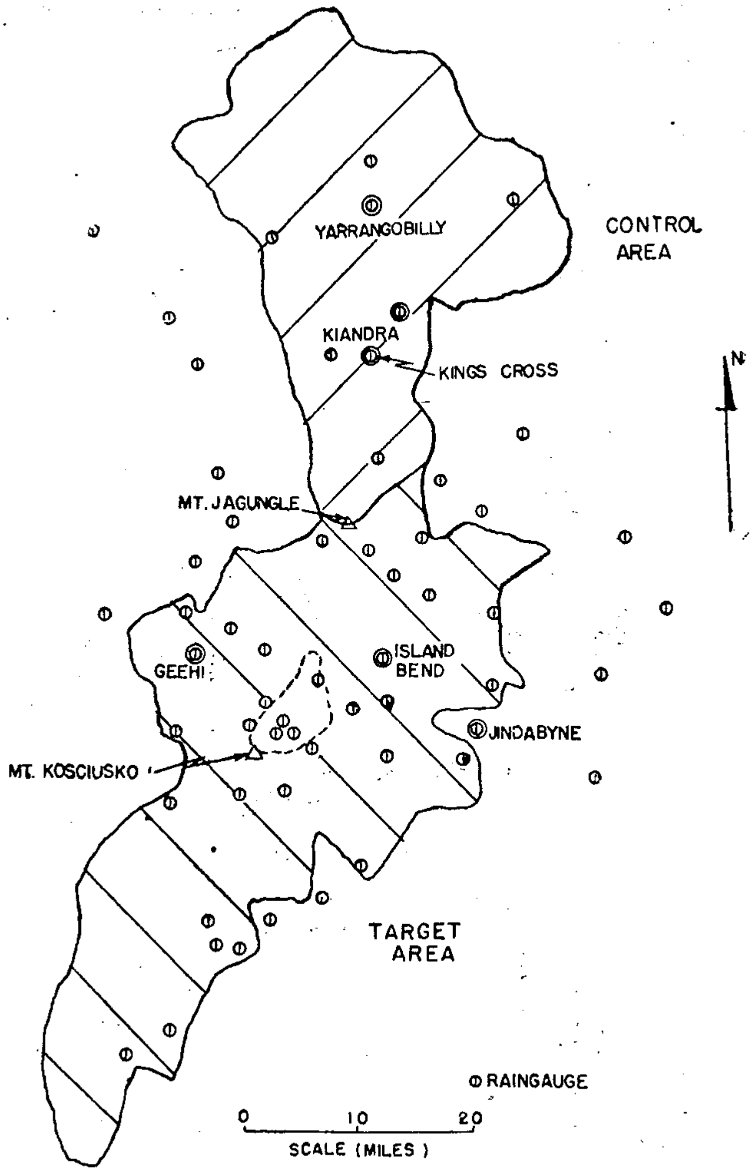

FIG: NO.6 SNOWY MOUNTAINS CATCHMENT AREA, SHOWING THE TARGET AND CONTROL AREAS' RAIN GAUGE STATIONS AND OTHER SALIENT FEATURES

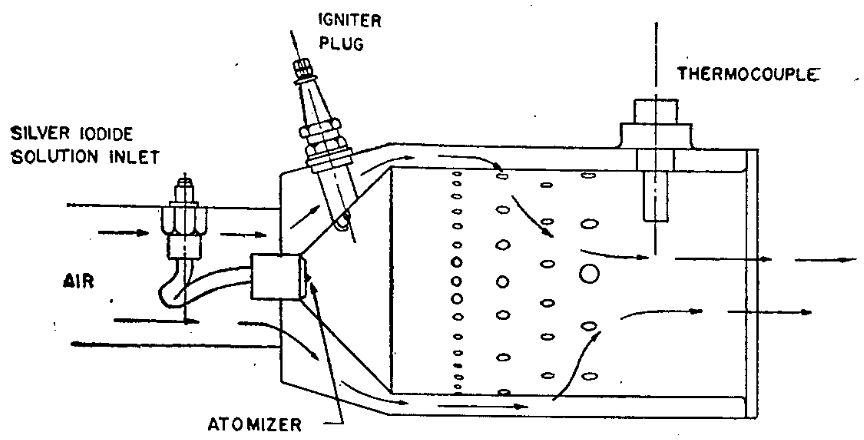

FIG: 7 SILVER IODIDE BURNER.

for seeding is decided; the track of seeding flight is plotted and the distance upwind of the seeding track in the direction of the wind at the seeding level is designed to allow for the expected time interval between a successful seeding and the arrival of precipitation at the ground. The distance referred to is obtained by multiplying the wind velocity at the seeding level by 30 minutes in the case of cumulus clouds with bases at or below 6,000 ft. or by 60 metres in the case of layer-type clouds; when the cloud base exceeds 6,000 ft. 1½ metres are added for each 1,000 ft. by which the base exceeds that height. The best seeding level is considered to be the −6°C isotherm and seeding is usually carried out at cloud base. A number of passes is then made following the predetermined track. Precipitation has often been observed over the target area following seeding. At present daytime operations are only conducted. It is planned to increase the duration of seeding during the daylight hours and to introduce night seeding at some date in the future.

5.0. Analysis of Results

From the data collected during the operational periods the precipitation figures are obtained by integration of the isohyetal patterns. The prediction of what precipitation would have fallen in the target area in the absence of seeding is usually done by using a straight line regression equation of target area precipitation on control area precipitation computed from unseeded data. The natural spread of the precipitation about this idealized relationship is expressed by two lines drawn on either side of the regression line within which

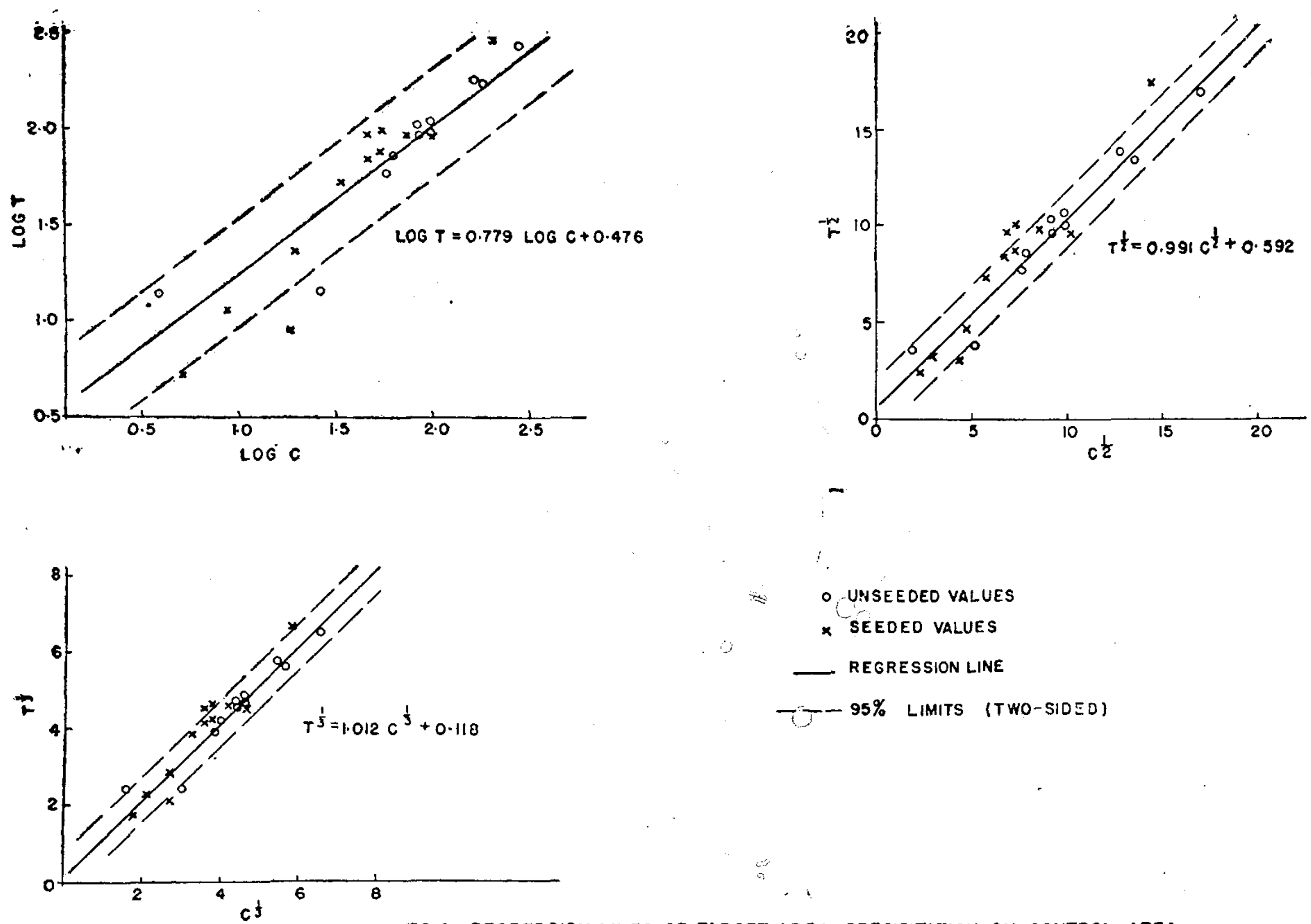

FIG: 8 REGRESSION LINES OF TARGET AREA PRECIPITATION ON CONTROL AREA PRECIPITATION USING THREE DIFFERENT TRANSFORMATIONS.

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a given percentage (usually 95%) of the points might be expected to fall. The regression lines of target area precipitation (T) on control area precipitation (C) are given in Fig. 8 using all three transformations. The ratios of target to control area precipitation (T/C) have very small dispersion and will be sensitive to changes in the target area precipitation. The use of such ratios also appears to remove the seasonal effects. The difference between the seeded and unseeded mean values of log T/C is at a confidence level of 45%.

The ratio of the cumulative sums of two series of numbers is adopted to show the difference between the seeded and unseeded period precipitations and are plotted in Fig. 9.

6.0. From the operational point of view the dissemination of silver iodide by an aircraft for modifying the rainfall in a given area has proved to be quite successful.

The procedures used have the following advantages to those used in the past:

(a) No extrapolation of the historical data is necessary so that any sudden or long term climatic change which may take place, is automatically accounted for.

(b) The use of random on-off seeding permits full use of the raingauge coverage. If past data were only used as a control, one would make use only of readings from those gauges for which sufficient past data were available; data from recently installed gauges could not be used in the analysis.

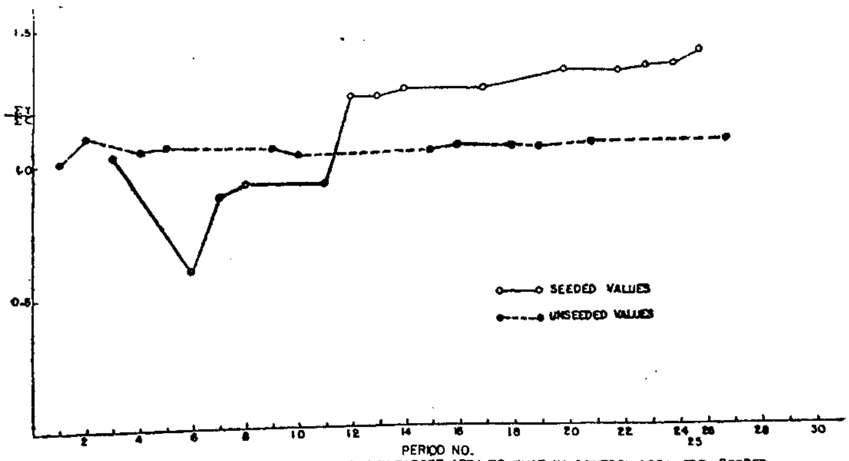

FIG. NO. 9 CUMULATIVE RATIOS OF PRECIPITATION IN TARGET AREA TO THAT IN CONTROL AREA, FOR SEEDED AND UNSEEDED PERIODS.

(c) The use of periods determined by the passage of high pressure systems, instead of weekly readings on a calendar basis, affords an unexpectedly higher correlation between target and control area precipitations.

(d) Better estimates of the precipitations in the areas concerned are given by the method of isohyet integration than by using individual gauge readings.

(e) The use of ratio precipitation in target and control areas as the test variable for statistical tests makes use of the high correlation between the precipitations in the two areas without having to make the assumptions necessary in normal regression analysis. In addition the confidence levels of the regression method are appropriate only to individual values and not to the overall effects of the operation and the use of ratios also appears to eliminate any seasonal effect.

(f) Two other methods of analysis used, *viz.*, the cumulative sum ratio of precipitations in target and control areas and the distribution free method, afford an automatic weighting to results according to the amount of precipitation and make few *a priori* assumptions than any other method of analysis.

Although the results so far indicate that the ratio of target to control area precipitation has been greater during the seeded periods but it is proposed to continue the experiment using the same techniques of seeding for several years to afford a firm answer to the question whether the increased precipitation during seeded periods is the natural effect or is due to the seeding programme.

4. Some Aspects relating to Irrigation and Soil Conservation Practices

Australia is an arid continent handicapped by a sparse and erratic rainfall and limited in the area suitable for pastoral and agricultural development. The development of water resources and techniques of land use are, therefore, receiving very serious attention in that country. Water from streams and reservoirs for irrigation is limited both in quantity and in the area to which it can be delivered economically. In consequence, the crops in that country depend mostly on rainfall for their growth and Australian farmer has developed the aptitude and mastery of dry farming methods. Rainfall, however, is itself limited in quantity and in reliability for only 32 per cent of the continent receives an average annual precipitation of greater than 20 inches and its seasonal distribution is generally erratic and unpredictable. Under these prevailing conditions of rainfall, increased production is dependent on extraction of the utmost benefit from available water and on some methods of making this water readily available as and when required.

There is an increasing realisation that a greater overall benefit may result from the use of improved techniques on individual farms and properties. In New South Wales the Water Conservation and Irrigation Commission are engaged, besides bigger irrigation projects, on advising farmers and graziers on conventional techniques and encouraging the surface storage of water on farms and properties through their Department of Farm Supplies. The soil conservation service has most successfully disseminated techniques of erosion control which, depending for their success on the absorption of water into the soil, may have valuable effects on the secondary aspect of water conservation.

Two experimenters, Mr. H. J. Geddes of the Sydney University and Mr. P. A. Yeomans, a Sydney mining contractor have developed unconventional solutions of the farm irrigation, *viz.*, *Water Harvesting* by the former and *Key-line Farming* by the latter, which have aroused great interest. These two techniques are briefly described.*

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*The author is particularly grateful to Prof. C. H. Munro, Head of the Civil Engineering, University of Technology, N. S. W. and Mr. John R. Burton, Lecturer in Civil Engineering for lending Bulletin No. 7, which is extensively quoted.

(A) Water Harvesting

Water Harvesting is essentially a system in which a part of the farm is kept in a relatively undeveloped state to store water for intensive irrigated cultivation on the remaining area. This practice is known as supplemental irrigation, the water so stored being used to supplement natural rainfall and to even out fluctuations in the seasonal rainfall pattern. The success of a supplemental irrigation or water harvesting project is determined principally by economic considerations.

Planning of a water harvesting project involves consideration of a number of hydrologic and economic factors and the ratio of the relative areas of the property used for watersheds, water storage and irrigation may vary widely, the determination of the optimum relationship between these factors is one of the principal considerations in the planning of a water harvesting development.

Water Harvesting is based on the principle of conserving all available run-off in surface storages which is used for intensive production of crops and pastures under irrigation. The Officer-in-Charge of the Farm at the Badgery Creek, Mr. H. J. Geddes, has worked, since 1952, on the establishment of the Water Harvesting Project whereby the property has been developed progressively into an economic and self-contained irrigation system using run-off and storm water drainage collected in surface reservoirs (Plate 10). Some 13 dams with a total capacity of over 45 million gallons provide for the water requirement of the project. Geddes has as objective the development of three-fourth of the farm as a watershed to furnish water for the development of the remaining one-fourth. The watershed portion is not wasted but put to native grass to afford as much grazing as possible. The irrigated area is giving yields that are in the neighbourhood of 15 to 20 times as great as it formerly did. At present some 90 per cent. of the property contributes run-off to 13 storage dams through a system of contour drains and in flood period, water is pumped from a storm water channel into two *Turkey nest* reservoirs. The improved pastures are irrigated through a diesel-operated medium-pressure spray system and with the application of carefully managed strip and rotational grazing methods a sustained high rate of milk production has been achieved without any need for supplemental hand feeding. Indications are that a high margin of profit can be maintained with yields of the order of 500 per cent of operating costs. The irrigated pastures totalling 132 acres have been sown with rye grass, red clover, subterranean clover, white clover and strawberry clover, *i.e.*, crops known to have a heavy water requirement but give the greatest milk yield. Careful grazing management is a feature at the farm. Strip grazing is practised. The cattle are

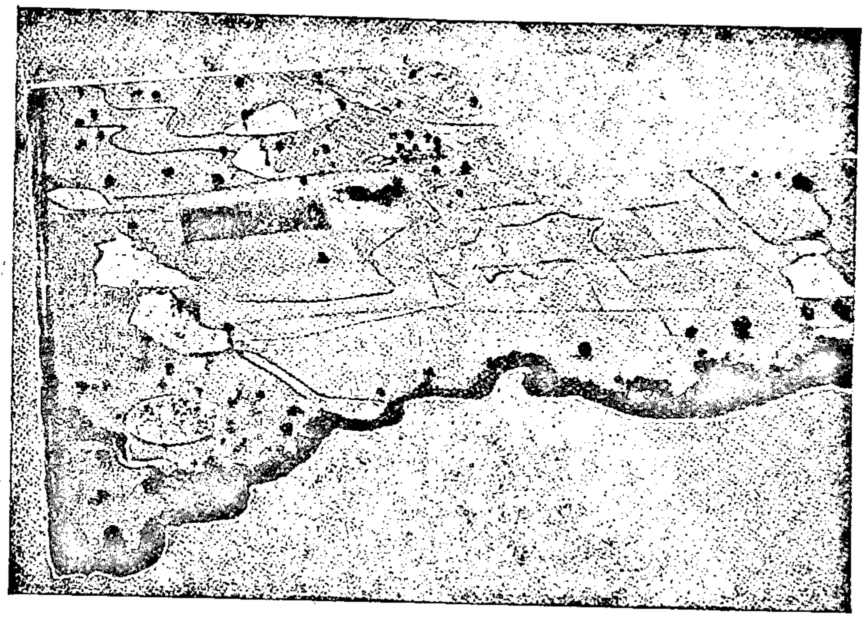

Plate 10.—AN AERIAL VIEW of the McGarvie Smith Animal Husbandry Farm, Badgery Creek, N S.W., Australia. The 8-million gallon "Turkey Nest" tank is shown at the lower left corner. It is filled from the storm-water tributary to Badgery Creek shown at lower left below the tank. Contour drains to the storage dams are indicated.

(By courtesy of Current Affairs Bulletin on Flood Control, Volume 17, No. 3, Nov. 21, 1955, Page 40.)

controlled with electric fences and grasses are not eaten below a minimum height of two inches to retain a moist cover. To hasten growth, irrigation is carried out immediately after the cattle move off a grazed strip. An overall annual intensity of one cow to the acre appears to be possible. The problem of pasture establishment on the shallow soil at the farm has been largely overcome by the use of the sod-seeder which drills seeds and fertilizer straight into the existing sward and permits sound establishment under adverse conditions. The area submerged under the water storages accounts for about 11 per cent of total area of the property, area under irrigation represents 30 per cent of the total, the drainage is collected from about 90 per cent of the farm.

The construction procedure for storages including *Turkey nest* dams has been to excavate soil with the bull-dozer and put it forward on to the embankment, compaction being achieved by tractor trafficking only, the downstream slopes are poorly consolidated and upstream slopes are steeper than is usually accepted as good engineering practice. This type of dam is constructed by pushing soil from inside the storage area to form a circular embankment and is modification of the turkey or bird nests storages used extensively in Queensland for stock purposes. Larger *Turkey nest* reservoir has a dia. of 150 yds. and average depth of 8 ft. 8 in. giving a storage capacity of about 8 million gallons; the smaller has a capacity of 5 lakh gallons and can be constructed and filled in one day. The *Turkey nest* storage is filled by pumping from the creek in flood periods. Since these dams are filled during infrequent periods of flood flow for a few hours only it is necessary to use cheap pumps of high capacity —an axial flow pump of 4 lakh gallons per hour capacity driven from the power take-off of a Ferguson tractor. Pastures are irrigated through a medium pressure spray system by a diesel pumping unit.

Economics.—Detailed figures of cost and yields for *water harvesting* are being kept at the farm but not yet published. The few figures released so far indicate that the scheme is highly profitable under the rather specialized conditions prevailing. Geddes quotes cost of £ (A) 18 (Rs. 191) per acre and a yield of £ (A) 90-100 (Rs. 952-1058) per acre. Dairy farming is usually considered profitable when the gross return is twice the operating costs. That farm, showing a five times return, is thus operating at a high level of profit.

(B) Key-line Farming

Key-line Farming is based on the principle of absorbing as much rainfall as possible directly into the soil. This is achieved by working and treating the soil to improve its infiltration capacity and promote even water distribution. Excess run-off is stored in farm dams for stock watering and irrigation. The *key-line farming* has been developed by Mr. P. A. Yeomans, a Sydney mining contractor and businessman on his properties—Nevallen and Yobarnie at North Richmond, N.S.W.—with the object of reclaiming and improving what was formerly a worn out and seriously eroded property. The plan is based on a novel method of cultivation and incorporates pasture and soil improvement, water conservation, soil erosion control, irrigation, tree planting and farm layout.

Yeomans also experimented with contour ripping using a ripper of his own design—an implement which gave spectacular results in improving growth of pastures and reducing run-off and rendering any provision for contour drainage unnecessary. The *key-line* is a true contour located just above the break of slope on hill side country.

The *key-line* cultivation consisted of ploughing slightly across the contour with a chisel plough with the intention of running water away from gulleys on adjacent ridges to assist in an even spreading of water and preventing erosive run-off. In the concept of this basic guide-line Yeomans has hit upon an interesting relationship in 3-D geometry which appears to be capable of simple and wide-spread application. Yeomans contends that if cultivation is carried out on such a pattern, the furrows will tend to drift water outwards on to the ridges and prevent concentration of water into the gulley. It seems that this relationship does hold on most head-water valleys of reasonable normal shape, on undulating or side-long country. An advantage of the *key-line* concept is this fact that *key-line* points can be located by eye in many cases reducing survey work to a minimum except in certain circumstances, when the simple relationship may not exactly obtain.

An integral part of the *key-line system* is the principle of absorption fertility. Conventional tillage practices involve the use of mould board or disc-type ploughs which turn over the soil surface with an inverting action. In shallow soils this may result in the burying of fertile top soil and the exposure of barren soil. In addition these implements form hard compacted layers at certain depths and fine surface layers, the latter particularly susceptible to sealing under the impact of heavy rainfall. They also act in several ways to reduce infiltration, increase run-off and aggravate erosion. A deep ripping improvement which cuts a narrow furrow produces a rough surface and does not invert top soil and is effective in reducing the undesirable effects of conventional implements. Yeomans uses the Graham Chisel plough manufactured by him under licence from the Graham Home Plow Co. of Texas. The Chisel plough has the advantages that it disturbs top soil as little as possible, shatters plough soils and leaves a rough uneven bottom in the furrows. The rough surface thus formed resists sealing by rain and increases detention storage and absorption and the deep chisel furrows assist in breaking up of sub-soil and ensure penetration of rain water. Chisel plough has been shown to be of great value in working the soils or areas hitherto considered too rough for cultivation. Absorption fertility means a progressive building of the soil fertility and water absorption capacity through the use of Chisel plough. Yeomans has reported that this practice results in a continual build up in the organic content, fertility and water holding capactiy of soil. Hard shaly clay loams have been transformed into a foot or more of rich dark soil in a period of three years and that change had resulted in greatly reducing run-off and completely checking of soil erosion but no quantitative measurements are available. With the development of the *key-line plan* the emphasis has been transferred to absorption of rainfall directly into the soil and storage in the soil taking place. At the same time dams are strongly advocated by Yeomans for stock watering and supplemental irrigation and a technique of flood irrigation of sloping pastures called *key-line* pattern irrigation. Yeomans lays special emphasis on the elevation of the dam site to be located as high on the property as possible principally to provide a sufficient head for spray irrigation under gravitation.

While according to the water harvesting practice, a portion of the property is left in its natural state to yield run-off for irrigation to the remainder, the *key-line* contends that rainfall should be stored directly in the soil until required for plant growth. The latter practice seeks through a special pattern and technique of cultivation, to improve the water intake and storage capacity of soils and to reduce run-off and erosion from them.

The value of key-lining appears to depend on soil type. *Water harvesting* is little concerned with soil erosion and flood control; it is essentially a system of farm water conservation. It not only supplements natural rainfall by storing excess water and making it available in dry periods but also makes it possible to apply water in excess to natural rainfall over limited areas. The water harvesting technique might be applied over a wider area than that for which key-lining might be suitable in order to ensure pasture growth in dry periods. Natural rainfall and soil conditions govern areas over which *key-line* principle can be applied. *Water harvesting* has been successfully developed for intensive dairy production in the milk zone and represents the most profitable way in which such a system can be operated.

Yeomans is strongly critical of the technique of pasture irrigation by pumping from farm dams such as is used under Water Harvesting Project of Badgery Creek Farm and he has has developed *key-line* pattern irrigation as his alternative to it. However, no figures about economics of this latter method have been published.

In August, 1955, the Key-line Reservoir Foundation was formed for the purpose of preparing and applying on a national scale and for national reasons techniques of land development originated by Yeomans.

(C) Sprinkler Irrigation Practice

The practice of spray irrigation has greatly increased in Australia during the past few years due to the fact that, firstly, irrigation by spray equipment can be applied to lands which could not otherwise be irrigated, and secondly in part to the necessity for increased productivity methods of farming. Spray irrigation permits a greater control over the quantity and distribution of water applied at an irrigation than is obtainable by surface irrigation methods (Plates 11—14).* Preliminary preparation of the land by grading and furrowing is not necessary before water is applied. Loss of land due to construction of surface ditches and cost of maintenance of such ditches are obviated.

The system of spray irrigation is used in that country for irrigating pasture land, orchards and vegetable crops but not for crops like wheat, sugarcane, etc. Pasture land and orchards are mostly developed in valleys where flow irrigation is difficult.

Because of the wide variety of spray irrigation plants and spray units now available in Australia the design of a spray irrigation scheme involves a careful consideration of the operating pressure and delivery of the various types of sprays available, the area of coverage of these sprays, the rate of application desired, the shape and relative levels of the area to be irrigated and the manpower required in the operation of the plant.

Spray irrigation plants may be classified according to the operating pressures of the spray or sprays used and whether portable or permanently installed piping systems are employed. Further classification is done on the basis of plants using spray lines with nozzles or jet into low or medium or high pressures and Skinner and Kook systems. The low pressure plants operate at pressures varying between 10 to 20 lbs./sq. inch and consist of chokless sprays, fixed jet sprays, butterfly or other rotary and rotating-arm sprinklers. The diameter or width of coverage of low pressure sprays varies from about 20 to 48 ft. according to the type and working pressure. The rate of application of water varies from about ½ to 2 inches hour.

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*Plates by courtesy of Messrs. Ames Irrigation Pty. Ltd., Australia.

Plate 11—Spray irrigation of pasture land.

Plate 12—Spray irrigation in a Lucerne field.

Plate 13—Furrow irrigation from a gated pipeline.

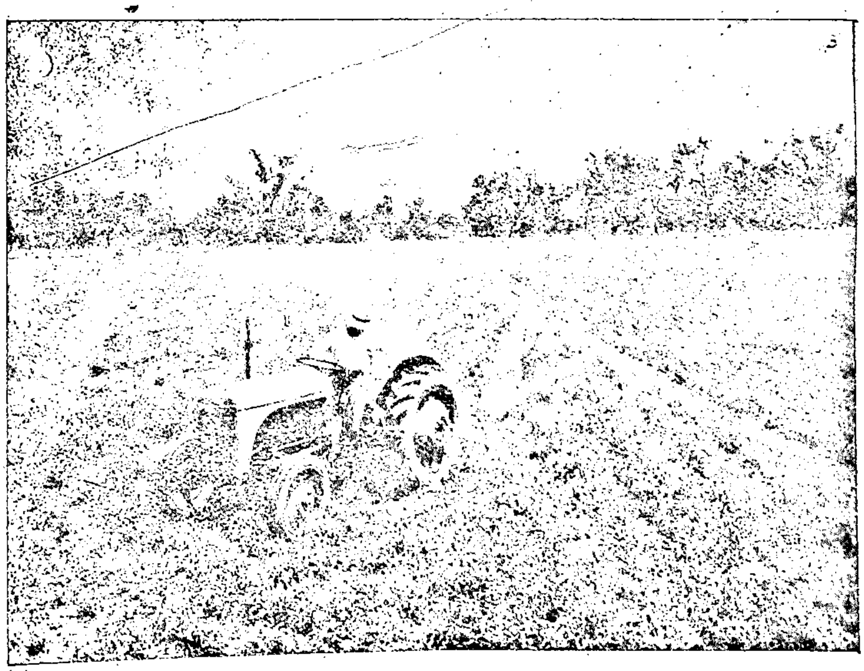


Plate 14—The spray irrigation pipe ine being towed by a tractor.

The sprays with medium pressure plants usually range from 20 to 60 lbs./sq. in. working pressure. The radius of action varies from 35-70 ft. according to the type and operating pressure and the rate of application of water for individual sprays from about 1/5 to ¼ of an inch per hour.

Spray units for high pressure plants consist of a single main nozzle which is rotated by a water motor or oscillating-arm and water is applied to a circular area of land. The operating pressures normally vary from about 60 to 100 lbs./sq. in. and the area covered by one spray unit from a half to 2½ acres. The rate of application of water by individual spray units is from about ¼ to ½ inch per hour.

The Skinner system of spray irrigation consists of permanent delivery main supplying water to any number of spray lines made portable by means of quick-acting coupling or may be permanently installed to reduce labour costs for operation.

Cost of Irrigation Plants

It is difficult to arrive at an average cost figure for a typical installation because of the very wide variation in the cost of component parts of a spray irrigation plant manufactured by different firms. The matter is further complicated because the cost of any particular system depends on some of the many factors as :—

(a) Total area irrigated.

(b) Shape and location of area as regards distance and elevation with respect to supply source.

(c) Intensity of application as governed by the type of soil.

(d) Type of spray system used (high, medium or low pressure sprays).

(e) The internal layout.

(f) Type of crop irrigated.

However, from an investigation of the designs and costs of a very large number of spray irrigation systems, it has been possible to arrive at approximate figures for the costs of irrigation plants to water areas of varying magnitude and this information is set out in the table quoted from a paper by A. F. Reddoch, Assistant Engineer, Farm Water Supplies, W. C. & I. C., N.S.W. on spray irrigation given below :

Area to be irrigated (acres)	Cost per acre (£) (Aust.) (Approx. equivalent in rupees)
0-5	70-150 (Rs. 740-1,586)
6-10	60-120 (Rs. 635-1,269)
11-20	50-90 (Rs. 529-952)
21-50	40-70 (Rs. 423-741)
51-100	30-50 (Rs. 317-529)
Greater than 100	25-40 (Rs. 264-423)

The costs are based on a plant comprising prime mover, centrifugal pump, permanent or portable main piping, portable spray piping and suction and delivery fillings. Installation or freight charges were not included. The cost of a comparatively permanent installation as used on the plantations and fruit orchards varies from £200 (Rs. 2,116) to £350 (Rs. 3,708) per acre. These cost figures are intended to give only a general indication of the cost of plant but the actual cost for a particular project shall have to be worked out with reference to local details.

The spray irrigation has fitted well in their farm economics as the products from their pasture land, orchards and vegetable farms, *viz.*, milk and milk products, wool, fruits and vegetables fetch very good price.

Mulyan Farm Near Cowra.—That farm was visited as an example where sprinkler irrigation practice had been adopted since the last few years.

In the 40's the farm was about 3,300 acres and they had about 2,000 sheep on that land. At present out of the total of about 2,800 acres they had allocated about 1,800 acres for pasture and they had about 6,000 sheep. Ordinarily the average is 1 to 1½ sheep to an acre but at that farm they were maintaining 8 to 9 sheep to an acre.

Besides Lucerne they were growing cash crop of vegetables *viz.*, Asparagus, Beetroot, Tomato, etc., which were marketed to the canning industry. A part of land was under orchard. Lucerne was cut about 6 times during the year *i.e.*, about one cutting in eight weeks, dried, baled and marketed. About 160 acres were under Lucerne which was affording them a yield of about 20 tons to an acre. Poplar trees had been planted at one edge of the property to serve as wind breakers. The farm had deep soil and being along the bank of river Lachlan had, more or less, riverain condition in at least a part of the farm.

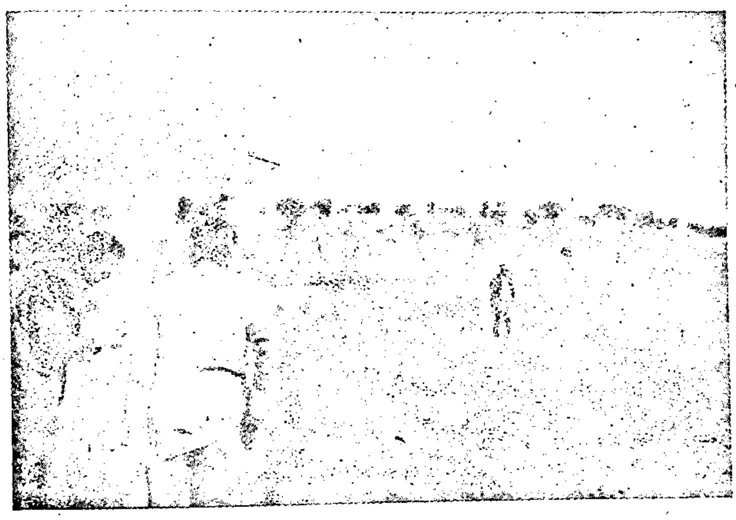
They had been forced to adopt spray irrigation as they could not withdraw from the river their full requirement of water and particularly when they needed water most. They were pumping water from subsoil from about 50 ft. depth with a 40 H.P. Pamona deep-valve turbine pump set capable of pumping about 35,000 gallons of water an hour. Their permanent mains of 8 in. dia. were underground and laterals were of 5 in. dia. with hydrants 100 ft. apart. The sprinkler toe-way line was on wheels with 20 ft. long pipe with ABC ball coupling device and with nozzle of Rain-Bird American type. The aim of irrigating by sprinkler irrigation was to supply 70-80 per cent of the moisture expected to be lost from soil by evaporation, totalling to 4-in. irrigation at that farm.

They irrigate fodder grasses by sprinkler irrigation and the plots of vegetables like Asparagus, Beetroot, Tomato, etc., by flow irrigation through gated pipe heads spaced according to the width of the furrow. Their farm operations are mechanized largely. They employ Yeomans technique of chisel plough and apply superphosphate at the rate of about 224 lbs. per acre each year. Although at other farms they sow about 25 lbs. fodder crop seed but at that farm they sow about 8—10 lbs. of seed during winter consisting of HI rye-grass (N Z perennial short rotation variety), Wimmare Rye, Sub-clover, Mt. Baker Phalaris, etc. For summer sowing they sow about 14½ lbs. per acre of Lucerne, Phalaris, White clover and perennial rye, etc.

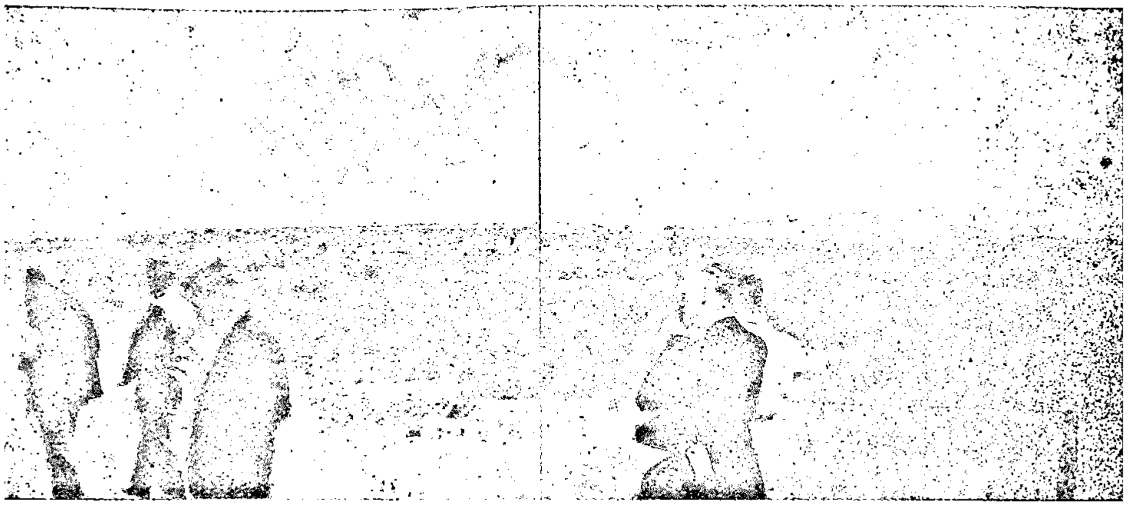
(D) Soil Conservation Practice near Broken Hill

The mining city of Broken Hill lies in the Barrier Range in Western New South Wales at an elevation of about 1,000 ft. above sea level. Most of the city's inhabitants are engaged directly or indirectly on work at the Lead-Silver-Zinc mines. The climate is semi-arid with an average rainfall under 10 inches, the minimum and maximum rainfall have been 2.17 and 17.56 inches respectively and rainfall is spread fairly evenly throughout the year. Evaporation is high compared with rainfall; average evaporation rate is about 89 in. per annum and the precipitation-evaporation ratio is 0.11. Winds are usually light and from the south-west quarter. Surface dust is a nuisance. Dust storms occur in the area but the number has declined in recent years. The soils belong to stony desert and desert loam groups with skeletal soil in the rockier parts and were typically eroded before regeneration areas were established.

Vegetation in the vicinity of Broken Hill was originally largely Acacia aneura (Mulga) association. Removal of timber and severe over-grazing resulted in a sparse degenerated vegetation principally consisting of unpalatable annuals with a few perennials. Enclosure of area (3.5 sq. miles) with consequent protection from stock and rabbits gave rise after only two years to increased vegetative regeneration of such perennial varieties as of Stipa and Cassia species and reduction in the density of some annuals and undesirable species because of competition by perennials. (*See* Plates 15 to 18).



Plates 15 & 16—A thick vegetative cover has developed within a few years.



Plates 17 & 18—The scant vegetation in the area outside the fence (left) as compared to thick growth of vegetation within the fenced experimental area in Plate 18.

(E) Soil Reclamation near Carwarp (Mildura)

Area extending from Mildura along the main Melbourne road to Lake Hallah 50 miles away was covered during the study tour with the delegation to the Australia University Arid zone climatology symposium. The first 14 miles were through irrigation areas, and the next 21 miles through wheat and sheep country. Formerly the farms were small but by late thirties it had become necessary to amalgamate the wheat farms in 2 to 3 thousand acre holdings of mixed wheat and sheep farming and since then the trend has been towards less wheat, more sheep and still larger holdings. This area was covered with Mallee and was designated as typical rolling Mallee country with east-west sand ridges. Mallee soils appear to be unknown in other parts of the world. The characteristics of soil are the presence of soluble salts, mainly NaC_l increasing with depth; the low leaching effect of the rainfall and the action of the wind in building up the sand hills. The soils are usually of a pinkish-light brown colour and are alkaline with a normal pH range of 7.5 to 9.5. They invariably contain calcium carbonate in the subsoil. The Mallee soils are characterised by low silt content with coarse sand and fine sand often in approximately equal proportions. The clay content may rise in the more useful soils to satisfactory values. The presence of an alluvial clay horizon is presumably the result of a solonization process and not of podsolization. Chemically, these soils are low in nitrogen, organic matter and phosphoric acid.

Plate 19—Mildura (Carwarp) Experimental Soil Conservation area; the stabilisation of fine sandy soil mounds by cultivation of rye.

A scheme was in progress for reclaiming about 20 thousand acres of land of mildly undulated terrain and representative of Mallee soil. The farming procedure is to cultivate wheat in the depressions and rye on the mounds. (Plate 19). Wheat grown is of short stem variety which suits conditions in that area. At a later stage it is intended to put that area under pastures with legume crop included in the rotation. Salting of soil is found to occur when water soaks through soil and connects up to the salt containing soil at lower depth; subsequent evaporation from surface brings salt up again. The treatment adopted to remedy salting is to cultivate Lucerne as a cover crop as that helps to conserve moisture in top soil. Chlorides are the main salts and Na and Mg the predominant bases in the exchange complex. The pH is generally high.

Sixty lbs. of superphosphate per acre is administered to soil at the time of sowing seeds.

5. In Situ Lining of Cast Iron Water Mains*

5.1. Introductory

In the life of a water pumping system, an increase in the gauge pressure year by year after installation is a normal feature and hence the steady rise in pumping cost of water. The cause of this increase in operating expenses is that the cast iron pipes comprising water mains, which are originally smooth in bore, become rough and reduced in area due to the formation of nodular incrustation which, if allowed to continue, will rapidly cause complete blockage of the iron pipeline.

5.2. Genesis of Corrosion of Cast Iron Pipes

Iron bacteria (*Ferruginous Gallionella*) destroy pipelines by causing to build up tubercular incrustation on the inside. These bacteria develop mainly in water containing much iron and manganese and have the property of precipitating iron and in most cases manganese. Corrosion of pipes may also be caused by chemical action between oxygen in water and iron in pipe wall and also by anaerobic organisms such as *Vibro desulfuricans* present in soils.

5.3. Remedies

Scrapping and cleaning of corroded inside of iron pipe water mains only serve as temporary palliatives and are in the long run costly processes requiring constant repetitions. The real remedy lies in coating the pipes with some substance which would prevent the corrosion of iron in pipe wall by water.

About 73 years ago Jonathan Ball lined cast iron pipes with cement. Further advance was made when the technique of cement lining of cast iron pipes *in situ* was developed in Australia. That process of *in situ* cement lining of iron pipe water mains is used by the Cement Lining Ltd., a concern in Australia under a patent.

5.4. How the In Situ Lining of Pipes is Done

The operational part is simple and some of the operations are illustrated by Plates 20—27. A convenient length of the pipeline

*The photographs and some of the observations recorded are on the basis of the visit to a site of one such cement lining jobs at the Gosford Road (Adamstown), New Castle where a length of 393 ft. of pipeline of 10 inches internal diameter was cement-lined *in situ* by the Concrete Industries Pty. Ltd., in the presence of the Author.

Plate 20—The cleaner bit coming out of the underground iron water mains after the completion of the cleaning operation.

Plate 21—The mortar-mixer unit fitted on a motor truck; sand and water being added on volumetric basis.

Plate 22—The mortar transferred from mixer into a container placed below.

Plate 23—Labour engaged in mixing the mortar in one container while the mortar from the other container is being poured into the funnel mouth of the feed pipe (Extreme left of the plate).

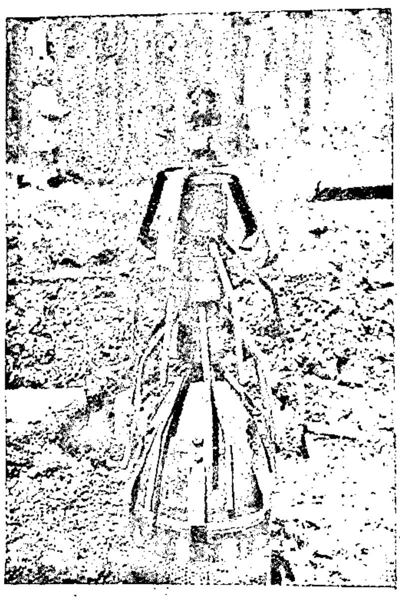


Plate 24—The 'Liner' tool to shape the lining inside the pipe: Note the perforated periphery of the tool and projections, the latter to keep it in position inside the pipe.

Plate 25—The 'Liner' Tool being inserted after all the mortar has been pushed in the pipe to be cement-lined.

Plate 26—The other end of pipe after completion of lining operations.

Plate 27—The excess of cement mortar in the pit after the 'Liner' Tool has emerged on completing lining *in situ.*

required to be so lined with cement, say about 400 ft., is isolated from both sides from the main pipeline. The incrustation deposited on the inside of pipeline is removed by working a circular cutter at the end of a cable. The operation with cutter is followed by employing steel brushes which remove all scarified incrustation and tubercles. Finally, cleaning_is completed by winching through a rubber-cupped double plunger to ensure clean smooth surface on the inside of the pipe.

The subsequent lining operations consist, firstly, of filling in a 2 : 1 sand-cement mortar to approximately one-third of that cleaned pipe length through one of its open ends fitted with a funnel-shaped receptacle and sucked into the pipe due to the vacuum applied at the other end of the pipeline. The precaution taken with respect to the mortar is that its quantity, introduced first, is of fairly thin consistency; this is followed by a second quantity of mortar which is somewhat stiffer in consistency than the one introduced in the first instance. This is followed by yet another quantity of still stiffer consistency such that it requires the employment of a rod fitted with rubber ring to introduce the same into the pipeline. After all the mortar has been introduced, the funnel is removed and the special liner tool fixed to the end of the steel rope.

Liner Tool.—The Australian-invented Lining Tool (*See* Plate 25) has made possible the process of re-lining old pipes. It is a torpedo-shaped contrivance fitted with eight guiding prongs and as it is pulled through the pipes it leaves an even coating of cement mortar from an eighth of an inch to a quarter inch in thickness, as desired, around the inner periphery of the pipeline. A series of small holes in the skirt of the lining tool allow the water in the mortar mix to escape and a slight taper on the end of that tool helps to compact the mortar under high pressure. The slurry is forced through the perforations leaving a solid tunnel of cement mortar hard and stiff to stand in a complete arch around the periphery of the pipeline. The excess of mortar is wasted at the exit end of the pipe on completion of the lining process (*See* Plates 26 and 27).

5.5. Resulting Advantages

The smooth cement mortar lining is said to stop corrosion, strengthen the pipes and joints, allow an unrestricted flow of as much water to be delivered as in the initial stage of the pipeline installation and add to the life of the pipeline. Some figures about the improvement in the working of the pipeline are reproduced from the data reported by the Company :

Diameter of pipe (inches)	Before lining		After lining		Percentage increase after lining
	Flow (gallons per minute)	Pressure (lbs./sq. in.)	Flow (gallons per minute)	Pressure (lbs./sq. in.)	
4	28	92	177	93	532
4	26	89	197	95	655
4	40	90	197	92	400
4	75	84	165	95	126
3	76	92	165	98	125
3	42	82	120	82	185
3	27·5	44	150	86	456
3	15	40	150	84	900

5.6. Cost

While the cost of laying an 8-inch pipe would be about 30 Australian shillings (Rs. 16) a yard, to line an existing pipe with cement by that process would cost about 2½ Australian shillings (Rs. 1-4-0) a yard. A new 4-inch pipeline could be laid at the rate of about 14 Australian shillings (Rs. 7-6-0) a yard; to cement line the existing pipe would cost 1½ Australian shillings (¾ rupee).

A comparison of the approximate cost per mile of cleaning and lining water mains *in situ* and laying new water mains based on figures of 1948 are presented below :

Diameter of pipe (inches)	Cost per mile of cleaning and lining £(A)	Cost per mile of laying new mains £(A)
4	650 (Rs. 6,876)	2,200 (Rs. 23,273)
6	900 (Rs. 9,521)	2,650 (Rs. 28,033)
8	1,250 (Rs. 13,223)	4,400 (Rs. 46,545)
10	1,500 (Rs. 15,868)	7,000 (Rs. 74,050)
12	2,000 (Rs. 21,157)	9,500 (Rs. 100,496)
15	3,000 (Rs. 31,736)	11,500 (Rs. 121,653)

Present Costs Compared.—The Hunter District Water Board while indicating a big improvement in water supply reticulation from the use of cement lining technique gives the comparison of costs of cement lining, as detailed below*:

Diameter (inches)	Cleaning and lining cost per mile £(A)	Laying new pipeline cost per mile £(A)
4	1,800 (Rs. 19,041)	6,670 (Rs. 70,559)
6	2,200 (Rs. 21,157)	8,500 (Rs. 89,917)
8	2,460 (Rs. 26,023)	10,000 (Rs. 105,785)
10	3,300 (Rs. 34,909)	12,500 (Rs. 132,231)
12	3,600 (Rs. 38,083)	16,000 (Rs. 169,256)
15	7,200 (Rs. 76,165)	20,000 (Rs. 211, 570)

In a table of "observations at random of improvement in flows in water mains after cement lining" the Board shows an increase, in the capacity, of 435 per cent in one 3-inch main, 260 per cent in another, and 257 per cent in a third.

*"Pipelining speeds water flow", New Castle Morning Herald, New Castle, January 4, 1957.

6. Discussions on Problems Relating to Irrigation, Water Supply, Floods, etc. in Australia

6.1. Introductory

General discussions on problems relating to irrigation, water supply, floods, etc., were held with the following officers and some of their other staff members :—

State Water Conservation and Irrigation Commission, New South Wales, Sydney.

Mr. R. A. Young, Commissioner.
Mr. C. C. Corbett, Chairman.
Mr. Hislop, Design Engineer (Channels).
Mr. Cook, Design Engineer (Dams).
Mr. Eric Smith, Farm Water Supplies Department.
Mr. B. Stasin, Materials Laboratory, WCIC.

University of Technology, New South Wales, Sydney.

Prof. H. C. Munro, Professor of Civil Engineering and other members of the staff.

Engineering and Water Supply Department, South Australia, Adelaide.

Mr. J. Dridan, Chief.

Mr. F. B. Ide, Engineer, Irrigation & Drainage.

State River and Water Commission, Victoria.

Mr. Lewis R. East, Chief.

Mr. H. G. Strom, Divisional Engineer for Rivers & Streams.

6.2. The discussions with Chairman and Commissioner, the State Water Conservation and Irrigation Commission, N.S.W., Sydney, related to the various projects and irrigation activities in general in the New South Wales. The constructional details of the Glenbawn (earth) and Keepit (concrete) Dams under construction and Burrinjuck Dam (concrete dam which had been recently heightened and reconditioned) were briefly described by them. Mr. Stan Scott, Assistant Design Engineer, described the studies they had carried with regard to the pore pressures and said that they had found that the pore pressures, as calculated from the settlement of cross-arms are less than those derived from measurement with the piezometric installation. He expected to present a paper on that study shortly.

6.2.1. Mr. Eric Smith, Engineer-in-charge, Farm Water Supplies, N. S. W., described the salient features of his Organisation. Their Drilling Unit was engaged on putting artesian wells and tube-wells. Their sub-soil strata conditions were peculiar in that no continuous sand strata was met with; instead gravel and sand occurred in thin seams. Due to low average permeability of shallow depth of each strata, the tube-wells had a special design to meet these peculiar sub-soil conditions. That special design consisted of a central metallic strainer surrounded by a 5-6 ft. diameter area devoid of fines (which were removed completely by a special procedure) to leave coarser grain of high permeability. The removal of finer fraction was achieved by fixing five or six peripheral tubes around the strainer to a diameter of 5-6 ft. of permeable coarse gravel through which graded permeable coarse gravel was fed which gradually replaced the finer fraction thus removed.

6.2.2. The delivery from those tube-wells varied fairly from 8 to 10 thousand to hundred thousand gallons per hour (20 thousand gallons was considered good generally). In reply to the query whether, in view of the tube-wells being costly did the crop so obtained pay, Mr. Smith stated that they did not permit flooding of field with irrigation water from tube-wells.

6.2.3. That Department of Farm Water Supplies merely advised and were not concerned from where the farmer bought his tube-wells. They were also not concerned with the operational expenses of those tube-wells at farms. The Government provided loan for tube-wells to farmers, which the latter were expected to repay in about 10 years to subsequently own such wells. The capacity of their storage reservoirs ranged from ½ to 20 million gallons and were a paying proposition because the water from them was used mostly for irrigation by sprinklers. These reservoirs were filled once and those in rainy district twice during each year. The cost of irrigation per acre for about 16 inches irrigation *i.e.*, about 5 irrigation of 3 inches varied from 35 to 125 £ (A) (Rs. 370 to 1,322) per year.

6.2.4. The main function of that Department was to design and advise the farmers. They charged about 15 shillings (Rs. 8) for surveys and advice; that amount was very low to what they actually spent. They did not advise regarding carrying out soil survey of land which was mostly the job of Agricultural Department, but carried out hydro-geological surveys and kept control during working period. They also maintained record of the water-table in tube-wells which were measured once in a year. The tube-well water, which was tested and discarded when bad, did not generally cause any soil deterioration. The waters designated as harmful had high percentage of CO_2 and low pH generally and were derived from Precambrian rocks. Such waters corroded pipes very badly. The general salt impurities in waters were excessive NaC, and $NaHCO_3$ which were considered bad for soil.

6.3. At the University Technological Laboratories, matters of common interest were discussed with Prof. Munro, Head of Civil Engineering and his Assistants, Messrs. Burton (Hydraulic Designs), Howell (Civil Engineering), David Neil Body (Hydrology), Watson (Soil Mechanics) and Whitehouse (Hydrographic Survey).

6.3.1. Prof. Munro stated that water was very important to Australia. For research, which was greatly lacking, they had formed that University Section. They had laid down the general lines along which research was needed in Australia. They had held a number of seminars on important engineering subjects. Modern trends in water utilization were towards spray irrigation and snow and water harvesting.

6.3.2. With regard to the hydrological work, they followed American practices in Hydrology. The Unit hydrograph was not known in Australia till a few years before. They considered recording stations as insufficient and that total rain was not as important as the rate of rainfall. When rainfall data was not available, some sort of prediction from the topographic characteristics was resorted to. They had data for rainfall but not so much of runoff. They did stream gauging and employed synthetic unit graph technique in their hydrology work. The Bristol Pressure Recorder which was in use in New South Wales with good results cost about £80 (A) (Rs. 846), as compared to Stevensons (American make) Recorder costing 50 times as much. Further research to develop an infallible type of recorder was in progress. They were, however, not doing much work on sediment load of streams and on silting of reservoirs.

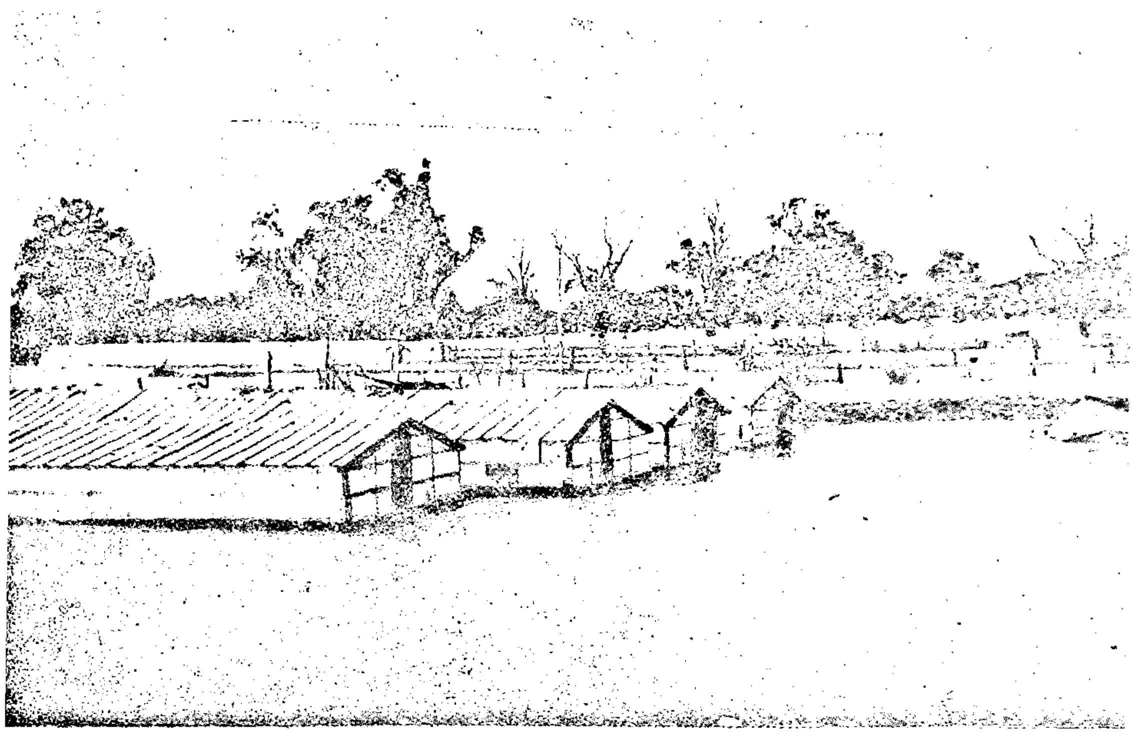
6.3.3. Among other items of research of special interest, Prof. Munro mentioned particularly the work on use of Sydney fly-ashes in concrete by Prof. Leech at Cooma Laboratories. moisture stimation in soils by Holmes at the Waites Research Station, Adeaide and by Philip on the fundamental researches on flow of water nd infiltration in soil at the Deneloquin Institute.

6.4. At Adelaide, general discussions were held with Mr. J. Driden, Engineer-in-Chief. Engineering and Water Supply Department, South Australia and Mr. F. B. Ide, Engineer for Irrigation and Drainage, Adelaide with regard to floods in the Murray river and he reclamation of the overflow and swamp lands along that river. They advocated planting of willows on river side of levees to avoid any damage to the latter. During floods they had sand bags for closing damage to levees but at times the levee got damaged below the reach protected by bags.

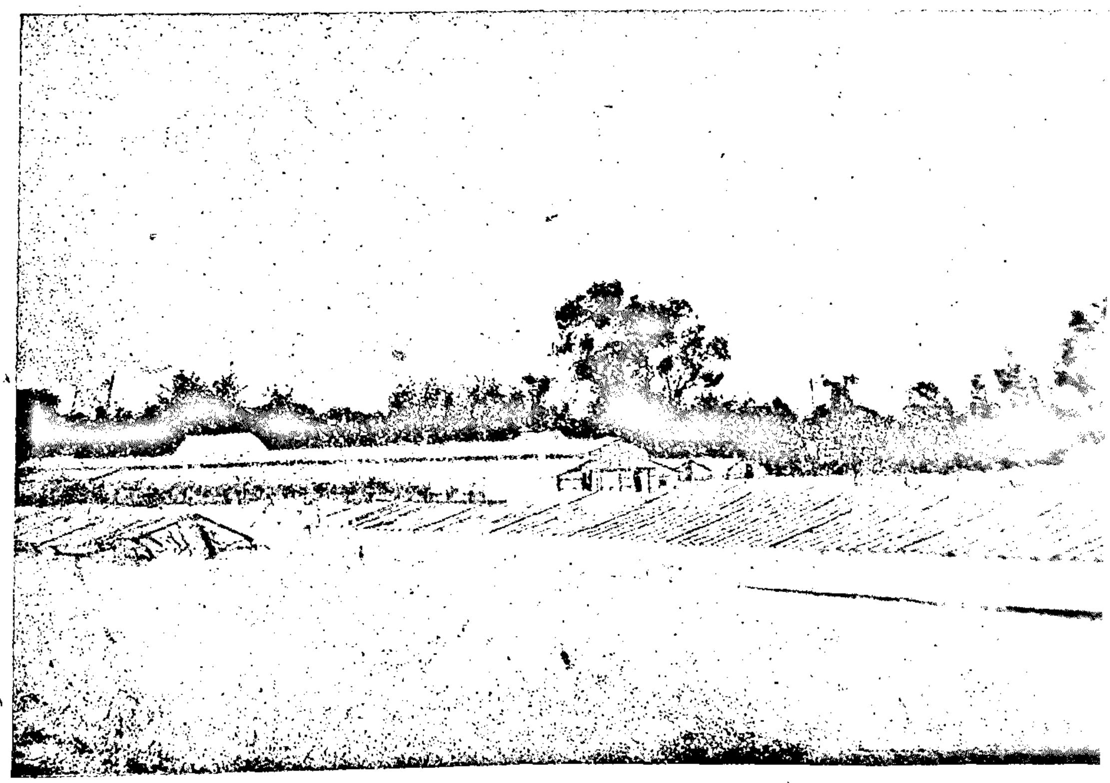
6.4.1. They were using the area reclaimed from swamps for rearing cows; 30 to 50 acres were needed for one cow and one cow yielded about £(A)100 (Rs. 1,058) per annum. In those reclaimed lands there had been several cases of settlement of structures due to the fact that the soil was of very fine type.

6.5. During the flight from Canberra to Broken Hill and then to Mildura with the UNESCO Symposium Delegates, the flooded areas along the Murrumbidgee, Lachlan, Darling and Murray rivers were viewed from the air. Some of the photogrphs taken in that connection are included (Plates 28 to 30).

6.6. At Melbourne, discussions were held with Mr. Lewis R. East, Chief of the State River and Water Supply Commission, Victoria, Mr. H. G. Strom, Divisional Engineer, River and Streams Division and the group of Engineers. Those discussions mostly centred on the flood problems, more particularly the recent floods in the Murray and its tributaries, the construction of levees and their subsequent protection. The recent floods were due to the unusual rains supplemented by the thawing of snow on their mountain ranges. They had been having a higher average rainfall in the State from 1954 and their levees, which were designed on the basis of 1931 floods, were overtopped by floods which rose higher than in 1931. The peculiar feature of the Murray river was its very even slope along its course which resulted in rather a very low velocity of flow in the river so that the flood rose gradually and also that the spill of flood flow from the area took a long time to clear out. They built their levees somewhat distant apart to permit rise in the river and thus the river did not attain a high velocity. Their levees were built in earth and there was no zoning as they were low ones. They protected their



Plates 28 & 29— Floods in the Murray river (Mildura); Showing the glass houses at low level in the vicinity of the river submerged partly in flood waters of the Murray river near Mildura.



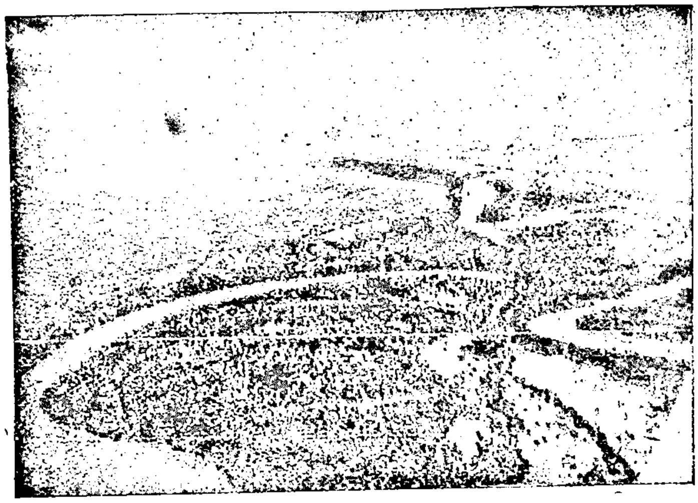


Plate 30—Aerial view of the inundation of the low lying areas along the Murray river.

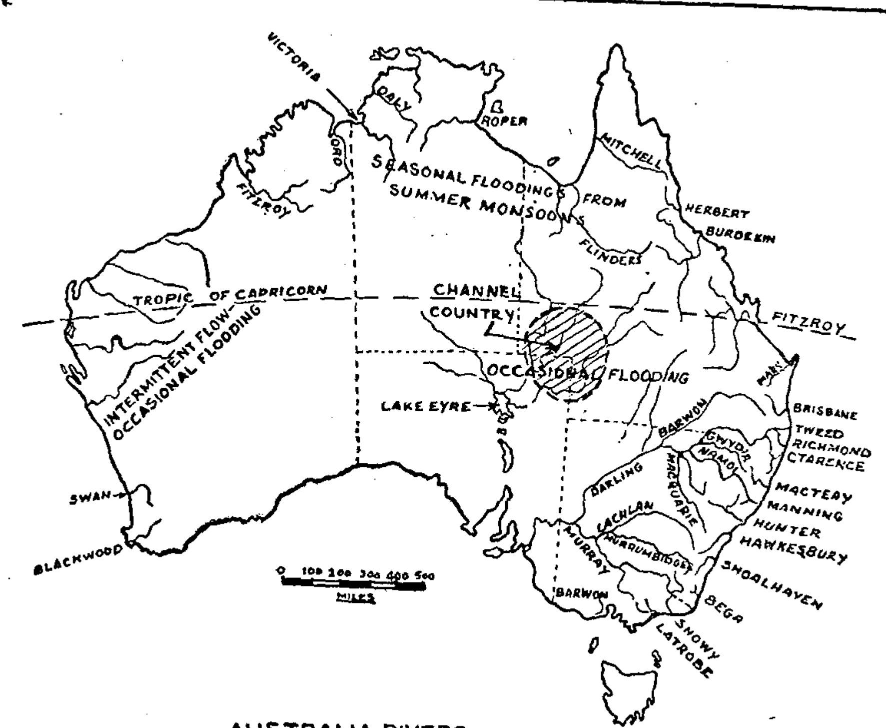
levees with willows grown horizontally at times so that they served as break and prevented erosion of banks. They were appraised of the work on problems of silt measurements on rivers and reservoirs and on construction of levees etc. in India.

6.6.1. They have taken up new work of hydrological observation sites in that State. As silt was not a problem with them, they had not given much thought to that aspect of their rivers. They had a Board in their State to deal with inter-State matters relating to withdrawals of water in their rivers and had passed a Bill in their State Assembly on that subject.

6.7. General Information about Floods

The floods during 1955 and 1956 caused great damage throughout Australia. The Hunter valley stands cut as the most significant area in Australia for flood damage as in the last 47 years the valley has experienced a major flood nearly every other year *i.e.,* 21 of the 47. The incidence of flooding in that country is illustrated in the accompanying map.

6.7.1. It is no accident that the coastal streams in Australia are so susceptible to flooding; it is but rather the combined result of their conformation and of the types of streams that occur in the area. Most of the streams drain a large area of country in their upper tracts so that after heavy rain great quantities of water converge through the tributaries on the main channel in the middle and lower tracts. The upper tract is usually high so that rainfall is heavy with steep



AUSTRALIA RIVERS

(BY COURTESY OF CURRENT AFFAIRS BULLETIN ON FLOOD CONTROL VOLUME 17 NO. 3, NOV. 21, 1955 PAGE 40.)

Map of Australia showing the incidence of flooding.

and rapid runoff. On the other hand, the lower tract usually has a very slight gradient so that drainage is slow and when more water enters the river in this section than the channel can carry, there is no true spillover of the surplus which only slowly finds its way out to sea.

6.7.2. The Darling river and its tributaries in south-east Queensland and northern New South Wales show flood characteristics. Benefits to pasture are offset by damage to crops. Stock losses may be high in the initial stages or may result from starvation if stocks are marooned for long periods. Same applies to the Lachlan river.

Severe flooding along the Murrumbidgee river is perhaps less frequent but there have been some major disasters in the past. The Murray and its Victorian tributaries, especially those which are snow-fed, cause widespread inundation.

6.7.3. In general, the nature and intensity of floods varies widely from one part of Australia to another in accordance with the conformation of the catchment area and the nature of the high rainfall storms experienced. The destructive effects differ from valley to valley. One point does stand out, however, that the damage is greatest where towns sprawl across the flood plains.

6.7.4. *Flood Control.*—The best that is done is to mitigate floods and the main methods for doing this in that country are:—

(i) Reduce and delay runoff by soil conservation and by afforestation;

(ii) Hold the flood water or part of flood—in dams;

(iii) Levee banks, bank protection, dredging, strengthening of streams, use of flood by-pass channels; and

(iv) Shift towns and industries to flood-free ground.

6.7.5. Authorities in that country are at a disadvantage in initiating effective flood regulation measures of any kind because of the lack of adequate records concerning river behaviour and related data. Very little work has so far been done in that country on sediment load of rivers. They are realizing that the first vital step in a flood regulation programme is to get under way a system of recording river flows, siltage and general behaviour.

6.7.6. Different opinions are expressed on the utility of levees for flood protection. Where flood waters move slowly they are considered adequate. For instance, ring leveeing around towns or wide flood plains is used effectively along the Murray. But on fast flowing streams such as the Hunter, river-side levees are reported to be cut during floods.

6.7.7. The levees are built in Australia as protection from floods. They are built somewhat distant apart to permit rise in the river without building high velocity. Planting of willows on the river side of the levees, and horizontal at times, is advocated to avoid their damage by erosion. Measures for protection of levees against damage include use of sand bags, stone and wooden walls or groynes to deflect strong current away from bank.

7. Visits to Dams and Water Supply Schemes

7.1. Adaminaby Dam

The Adaminaby Dam, one of the highest earth and rock-fill dams in the world, is being built for the Snowy Mountains Authority across Eucumbene river—one of the main tributaries of the Snowy river, by the Kaiser-Walsh-Perine-Raymond group of contractors from the U.S.A. working under the supervision of the N.S.W. Department of Public Works.

The Project is one of the several major dams included in Australia's Snowy Mountains Scheme to divert the rivers, at present flowing into the sea, through tunnels to irrigate the rich western plains of S. E. Australia and in its travel falling 2,000 ft. through the mountains it will turn the turbines of 17 power stations, most of them deep underground. When completed, the dam will be about 2,300 ft. thick at the base and 380 ft. high. Catchment area is about 260 sq. miles and the storage area about 55 sq. miles. The gross storage capactiy of the reservoir will be 3.86 million acre ft. (dead storage 0.36 million acre ft. and active storage 3.5 million acre ft.), roughly a little over a half of the storage capacity of the reservoir to be formed by the Bhakra Dam. When the reservoir is full, the water will rise above the present Adaminaby township. A new township is now being built on the diverted Snowy Mountains highway, about 5 miles to the south-east of the present town.

From Adaminaby reservoir, water will be released through the 14 mile by 12 ft. diameter Eucumbene-Tumut Tunnel, at present being driven by the same contracting Company, westward through the Great Dividing Range to the Tumut river.

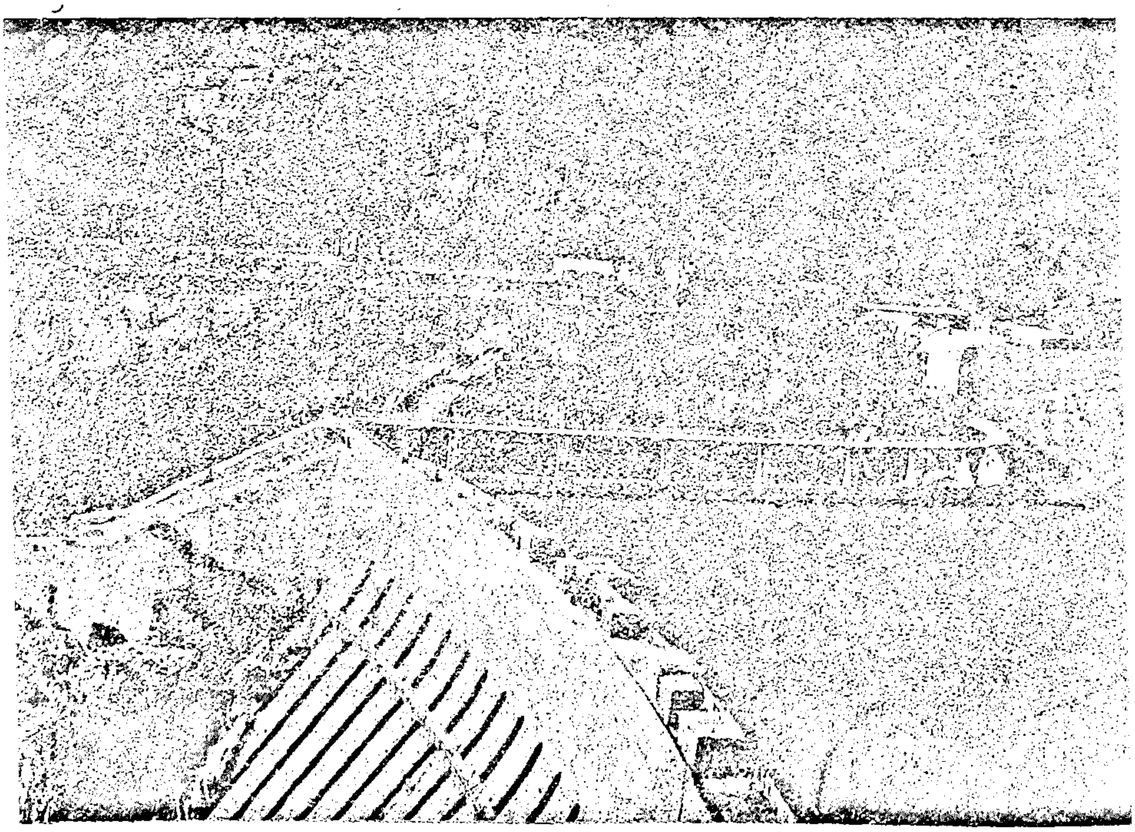
With regard to the salient features of the design of the earth dam, its central core is being built in clayey sand and compacted by sheepsfoot rollers. Outer to the central core on both sides is the zone in silty sand which is also being compacted by sheepsfoot rollers. Still outer on both sides is the zone of rock fines compacted by Crawler-type tractors. Finally, the outermost zone on both sides is rockfill dumped. On the downside of the impervious zonebase a triangular zone of permeable sand and gravel compacted with Crawler-type tractor is provided which is continued below the two outer zones also but discontinued below the rockfill zone. The foundation is provided with grout curtains.

7.2. Burrinjuck Dam (W. C. and I. C.), New South Wales

The Burrinjuck Dam served as an example of the concrete dam construction in Australia where some alterations and additions had been carried out recently with the object of strengthening and raising the height of the structure built earlier. (Plates 31 to 33 and Fig. 10).

The Burrinjuck Dam, the construction of which was commenced in 1907, is situated on the Murrumbidgee river, about 37 miles by road from Yass. While the primary object of constructing this dam was to supply water for the Murrumbidgee irrigation areas, it was also to have the effect of ensuring a reasonably continuous flow in the Murrumbidgee river itself for the benefit of riparian landholders. The Dam was designed and constructed as a monolithic structure. In 1925, following an average precipitation of 6¼ inches of rain over the 500 sq. miles of catchment in four days, the inflow so exceeded the discharge capacity of the spillways at that time that for 29 hours water poured over the crest of the main wall itself rising to a maximum height of 3 feet 4 inches above the parapet without causing any damage to the structure. Due to the magnitude of that flow,

Plate 31—A view of a portion of the Burrinjuck Dam showing the concrete buttresses built against the downstream face which besides strengthening the structure enabled its height to be increased. Wing wall is in the background.



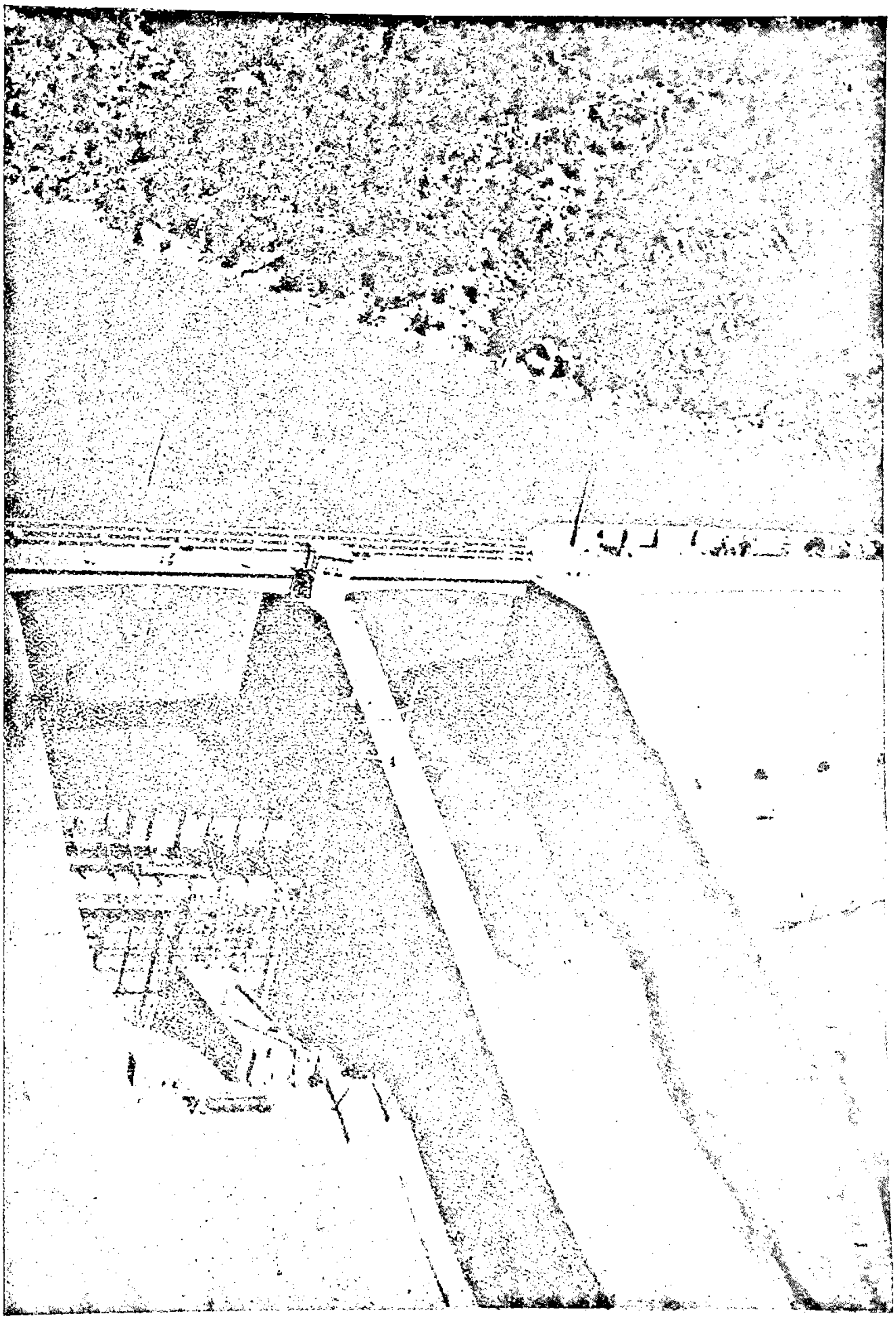


Plate 32—Burrinjuck Dam; showing spillways being fitted with steel sector gates.

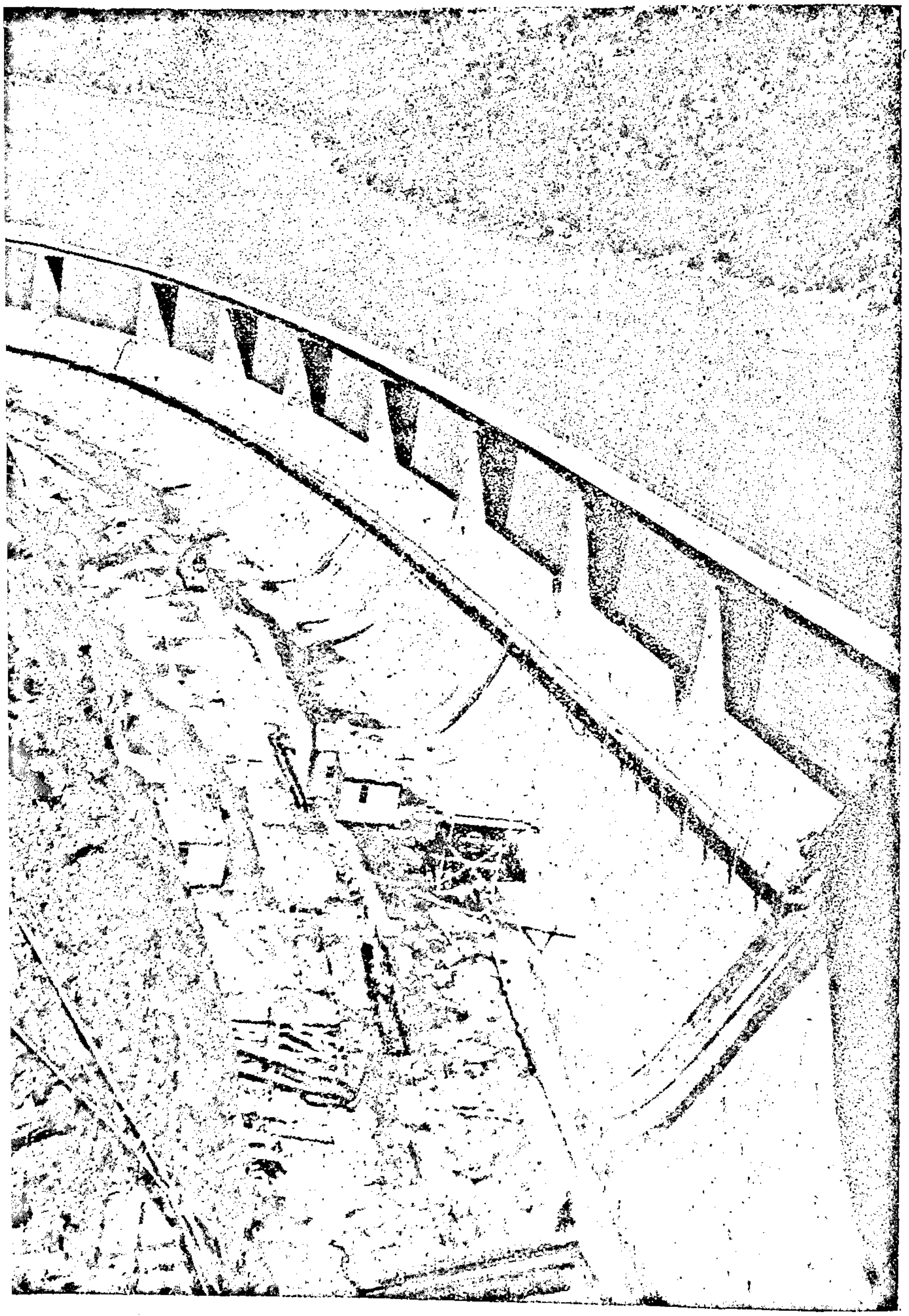
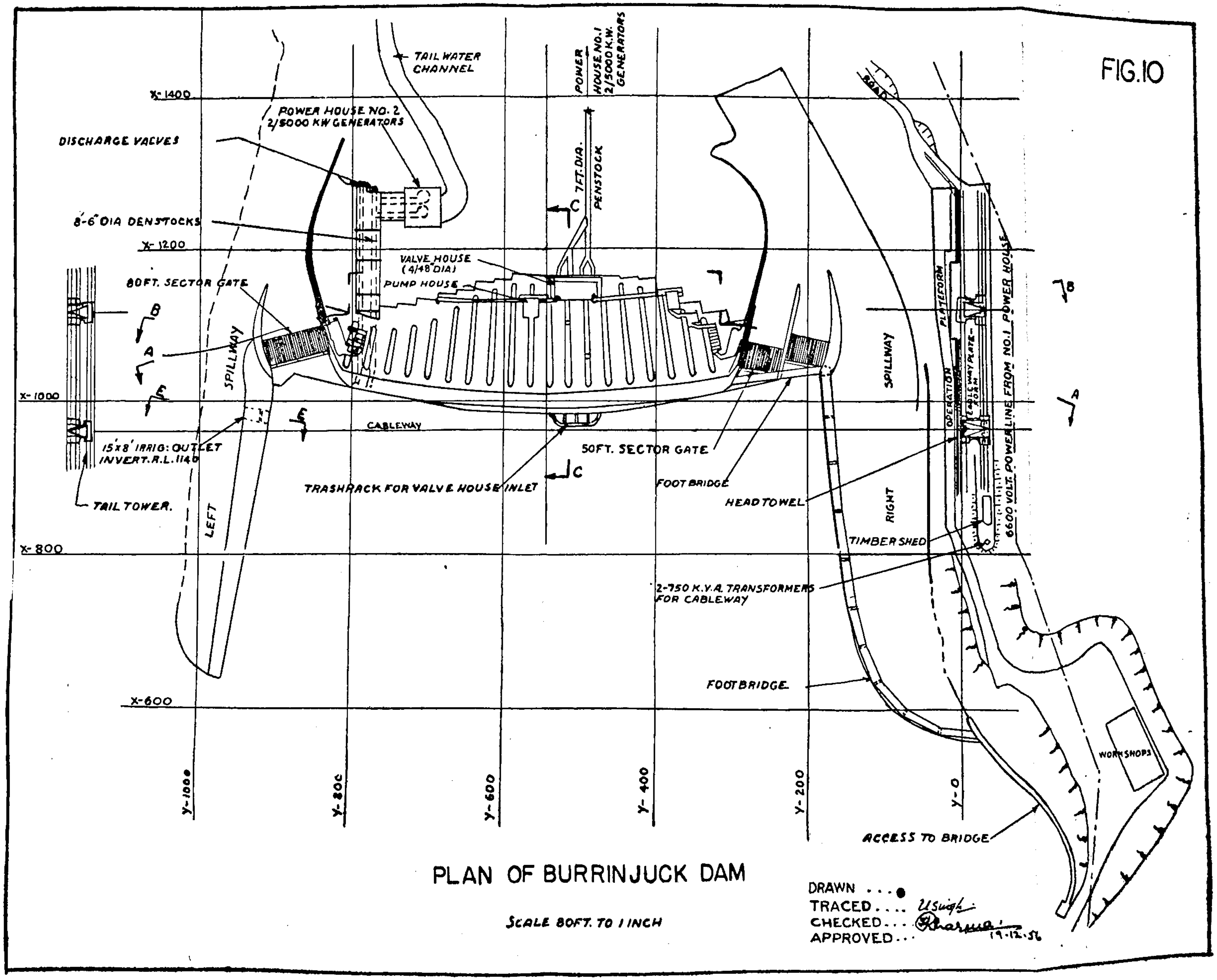


Plate 33—Burrinjuck Dam ; Another view of wingwall.



PLAN OF BURRINJUCK DAM

SCALE 80FT. TO 1 INCH

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APPROVED ...
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6—3 C. W. & P. C./57

which exceeded all previously recorded floods, consideration was given to increasing the discharge capacity of the spillways. This work was commenced not long before the start of the Second World War. The alterations and additions, as shown in plan (Fig. 10) included the following :—

(a) *Elimination of Seepage through the Dam.*—Cement grout injected into a line of drill holes extending vertically through the dam near the upstream face and into the foundation rock below the dam formed a curtain against any leakage.

(b) *Provision of Drainage System and Inspection Galleries within the Dam.*—A shaft 85 ft. deep had been sunk at the downstream toe of the dam and a series of galleries (6′-6″ by 6′-6″) driven in the dam and bed rock below it. Those provisions involved driving 432 ft. through the concrete of the dam and 1,003 ft. through solid granite rock comprising the foundations.

(c) *Increased Height of Dam.*—23 concrete buttresses have been built against the downstream face of the wall which, in addition to strengthening of the structure, enabled its height to be increased by an extra 13 ft. to the top of the dam enabling a greater storage capacity.

(d) *Enlargement of the Spillway to Cope with Flood Discharges.*—This involved putting two steel sector gates 50 ft. wide and 15 ft. high (Plate 32) on the northern side and a steel sector gate 80 ft. wide and 15 ft. high on the southern side. When in closed position, the top of the gates will be at the same level as the top of the side spillway crests and when opened they will provide for speedy discharge of the top level of stored water before the main body of oncoming flood water reaches the dam. Moreover, the enlarged spillways comprise two side channels and 3 gate overfalls designed for a maximum flood discharge of 342,000 cusecs; the maximum discharge during 1924 record flood was 174,000 cusecs.

(e) *Increased Capacity of the Dam.*—The increase in the side spillway weirs by 5 ft. above original level increased the effective storage capacity of the dam from 652,000 acre ft. to 837,000 acre ft. and thus afforded greater insurance against drought.

Details of Burrinjuck Dam as enlarged

Storage capacity	837,000 acre ft.
Area of stored water	14,000 acres.
Area of catchment	5,000 sq. miles.
Maximum height of wall	264 ft.
Crest length of wall	500 ft.
Width of crest	20 ft.
Maximum width of base	200 ft.
Concrete in main wall	396,000 cu. yds.
Concrete in buttresses	55,000 cu. yds.
Spillway crest length	1,140 ft.
Spillway discharge capacity	342,000 cusecs.

A plan of the final structure incorporating the improved features is shown in Fig. 10.

Water released from the Dam for irrigation flows down the Murrumbidgee river for 240 miles before it is diverted into the main canal and then to approximately 820 miles of supply canals and 800 miles of drainage channels within the Murrumbidgee irrigation area.

The water discharged from the Dam for irrigation passes through two hydro-electric power stations, each of which has a generating capacity of 10,000 kW.

The newly-constructed galleries made it possible to see the condition of concrete placed during earlier construction. That old concrete near the foundation level showed the presence of big-sized rock pieces, some of them were very flat-shaped, with hollows remaining unfilled by mortar due to lack of proper vibration technique at that time. That accounted for the excessive seepage at the earlier stage but that had been considerably reduced by grouting. They were also installing piezometers at the base and roof of the galleries to measure pressure. At the galleries about the middle of the height of the dam, the concrete did not manifest any unusually large-sized rock pieces as seen in the lower galleries and hence the seepage there was not as great as at foundation level. Piezometers had also been installed in the galleries at that level also.

The Power House at the base of the downstream side of dam had two turbines of horizontal type each of 6,250 kVA. The switch-yard was located at the base of a steep hill near the end of the Right Spillway Channel. The second Power House was further downstream of the river.

The Left Spillway had a hand-operated mechanism for operation of the aerating jet for dissipation of energy of about 10,000 cusecs of water passing out through that.

7.3. Glenbawn Dam (W. C. & I. C.), New South Wales

Special Features.—The Glenbawn Dam was another example of zoned earth dam under construction (Plate 34 and Fig. 11). The Dam is being built as one of the number of major water conservation and flood mitigation projects designed to protect and develop the valley of the Hunter river contained by the Mount Royal Range which includes some of the most fertile river flats to be found anywhere in Australia. That valley has its problems of alternating floods and dry seasons. The plan has as its objective maximum control of the flow of the Hunter river so that in wet seasons the intensity of floods can be substantially mitigated and through periods cf drought a constant and ample supply of water will be available for the normal requirements of agriculture and for stock and domestic purposes.

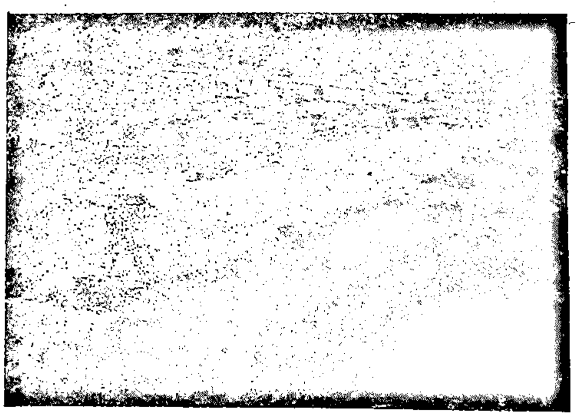
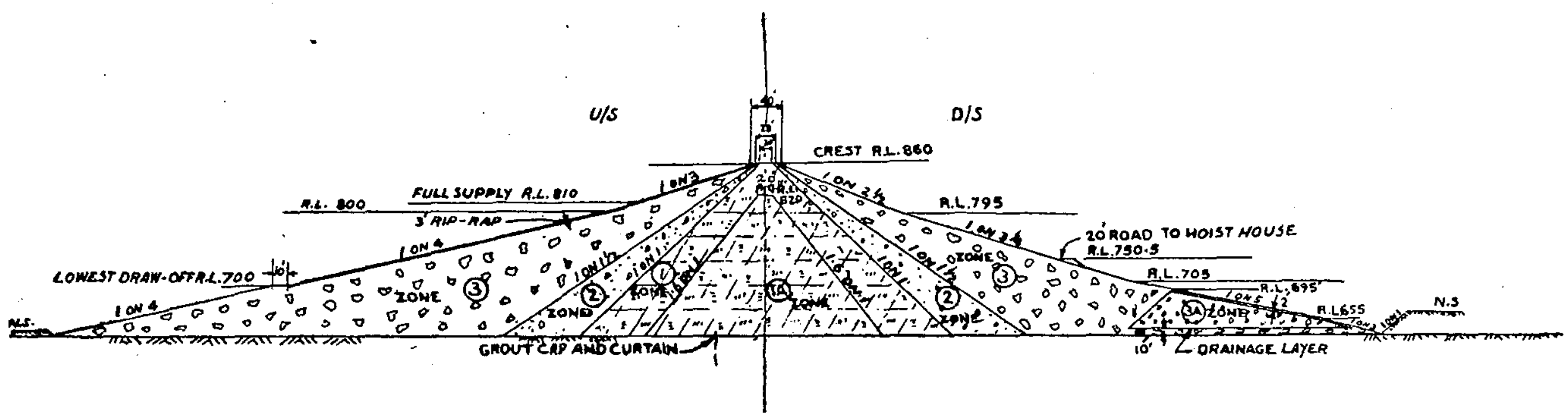


Plate 34—View of the Glenbawn Earth Dam under construction. The central dark coloured portion is the impervious zone ; the lighter coloured zones at extremities represent the rockfill. The semi-pervious zone is seen interposed between those two zones on each side.

TYPICAL CROSS SECTION
OF
GLENBAWN DAM

SCALE 1" = 200'-0"



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Design Details

Catchment area	500 sq. miles.
Storage capacity	Total 296,000 acre ft.
For irrigation	183,000 acre ft.
For flood mitigation	113,000 acre ft.
Length of crest	2,700 ft.
Width of crest	40 ft.
Quantities of Materials in earth dam	Total 9,730,000 cu. yds.
Impervious earth	3,400,000 cu. yds.
Semi-pervious gravel	1,600,000 cu. yds.
Pervious rock	4,730,000 cu. yds.

Excavation from foundation area: 1,700,000 cu. yds.; Heights of coffer dams : Upstream 80 ft., downstream 30 ft.; Diversion tunnel, length : 2,025 ft., dia. not less than 31 ft.; Discharge capacity : 25,000 cusecs.

Spillway

Length of concrete-lined chute	940 ft.
Width at inlet	300 ft.
Width at outlet	125 ft.
Discharge capacity	100,000 cusecs

A plan of the typical cross-section of the Dam is shown in Fig 11.

A tunnel has been driven through the hill, through which the Hunter river flow has been diverted while the construction of the earth dam is in progress. It is proposed to close the tunnel when the dam is completed with a steel gate weighing 120 tons and permanently sealed with a massive concrete plug, the steel gate would then be withdrawn.

After completion of the dam, the outflow of water which exceeds the capacity of the flood control storage will be discharged over a concrete-lined spillway out into the saddle of a hill some distance away from the main wall. The spillway discharge capacity is to be 100,000 cusecs; thus it will be capable of coping with a flood of much greater intensity than any previously experienced in that part of the Hunter valley.

Rock and earth-fill for the zones of the earth dam were being obtained from the hills and flats adjacent to the dam. The watering of the borrow area for impervious material was being done by sprinkler where scrapers were excavating. In the borrows worked by shovel the area to be cut was watered at the face. The moisture at the fill on the earth-fill was done by water lorries.

The Quarry Master Drill (Ingersoll-Rand) was in use in the quarry supplying stone for upstream and downstream rock-fill zones. That drill made 40 ft. deep holes in the rock at the rate of 20 ft. an hour in a row which were later blasted and thus all the rock loosened to work with shovel. They had found that Drill very much more economical than Ruston Table-Type Drill used earlier. While quarrying cost with latter worked to 35 shillings (Rs. 18-8-0) per foot, that with the Ingersoll-Rand Drill had been reduced to about 7/6 shillings (Rs. 4) per foot. That drill was thus good for the type of limestone rock at that site but might not be so cheap working for quartzite. At the fill they had a Cat D8 which, besides the blade at one end, had a scarifier gadget at the other end. They were employing big-sized sheepsfoot rollers (450—500 lbs./sq. in.) to compact the impervious zone by giving normally six passes. The semi-pervious zones were not compacted except what was achieved by the heavy machinery moving on the zone.

There was a field laboratory to exercise quality control during construction. They had special forms for reporting results to the head office.

The storage capacity of the reservoir would be of the order of 296,000 acre feet and the dam was expected to cost about 14 million pounds (Australian). The reserve storage of 113,000 acre ft. which will be held ready to take the first onslaught of flood in the Hunter river will need to be supplemented by other similar storages on tributaries entering the river lower down and other dams shall have to be built to give effective control of flooding throughout the valley.

7.4. Tomago Sand-beds Water Supply Works (Hunter District Water Board, New Castle)

The major source of water supply has been developed by the Board, by tapping ground water stored in an extensive area of sand-beds existing northerly along the coast from the Hunter river estuary towards Port Stephens. The actual area of such sand-beds which is suitable for water supply development approximates 50 square miles.

The water-bearing sands vary in depth, but the portion developed has a depth to an impervious bottom of approximately 60 feet. The sand-beds are charged with water to within a few feet of the surface where the ground is level for the most part. The source of the water is the rainfall on the surface.

The constructed scheme consists of primary pumping units extracting water from the sand-beds by tube-wells and delivering to two spraying basins and secondary pumps delivering the water from the spraying basins through delivery pipelines either to the Chichester Pipelines at Shortland and thence direct to Waratah Reservoirs or to North Lambton Reservoir and thence to Waratah Reservoirs.

The original scheme was developed to provide for 15 primary pumping stations over the sand-beds area. Each of these draw water from the sand-beds in the following manner:—

Sixty tube-wells, each consisting of 4-in. galvanised wrought iron pipe with a slotted well point 5 feet long, are sunk about 44 feet into the sand-beds, and are connected to a suction header, consisting of 12-in. enlarging to 15-in., thence to 18-in. and to 20-in. pipes leading to the primary pumps drawing the water. These pumps are located in concrete wells, sunk in the sand, over which a pump house is built. The pumps are electrically operated.

Before reaching the primary pump a gas and sand extractor intercepts sand (if any) and collects any gas released. Vacuum is maintained by automatically operated pumps. Each of the pumps at the Pumping Station then delivers through branch pipelines into a common delivery header, the size of which increases from 15 in. up to 37½ in. diameter. This delivery header takes the water to the spraying basins of which there are two.

The water is then forced through spray nozzles at the spraying basins to aerate it, and eliminate gases. These basins hold storage for about 2 hours' normal supply. The water is chlorinated and treated with alum and lime, as it leaves the spraying basin. Secondary pumps then deliver the water through two pipelines, one a 20-in. cement lined cast iron pipe and the other a 36-in. cement-lined mild steel pipe laid from the secondary pump house to short land, crossing the north channel of the Hunter river by pipes buried in the river bottom and thence across Ash Island, crossing the south channel of the Hunter river on piled supports ; thence on the mainland, connecting to the 36-in. Chichester Pipeline at Shortland.

The secondary pumping plant at Tomago was augmented during 1951-52 by the bringing into service of additional pumping plant to provide for a maximum output of 25 million gallons per day.

The Board authorised the laying of a 48-inch cement-lined mild steel continuously welded pipeline from Shortland (where the Tomago delivery pipes junction with the 36-inch Chichester Pipeline to North Lambton Reservoir), together with branch pipe from that reservoir to this new pipeline and the laying of a 36-inch pipeline from North Lambton Reservoir to Waratah Reservoirs together with new pipe connections at Waratah Reservoirs. The 48-inch pipe was brought into service during August, 1949 and the remaining work has since been constructed and is in use.

The installation of this pumping plant and the construction of these pipelines enable the full capacity of the existing 15 stations of the Tomago Sand-beds Scheme to be developed.

Each of the original 15 pumping stations is estimated to have an average capacity of one million gallons a day normally, or to be capable of delivering up to nearly two million gallons per day for a short period, under favourable conditions. The pumps and pipelines have been designed to accommodate a maximum delivery rate of 25 million gallons per day. The original scheme is capable of delivering 5,500 million gallons per year.

The Board has approved of the full development of the Tomago sand-beds by the construction of five additional primary pumping stations. These stations will deliver water to the existing spraying basins to the extent of 5 million gallons per day. Further amplification of pipelines will eventually be required to accommodate the additional quantity of water which will become available. The capacity of the Sand-beds Scheme will be increased to 7,300 million gallons per year.

These works are proceeding and in addition to Station No. 20 which first contributed water during December, 1953, Stations 18 and 19 were brought into operation during December, 1954.

Construction work on Stations 16 and 17 commenced during October, 1954 and is still proceeding.

In addition to the amplification work, three existing Primary Pumping Stations were converted to deep bore pump stations. Two of these stations were brought into operation during October, 1954 and construction work associated with the remaining stations is still proceeding.

8. Visits to Research Stations, Hydraulic and Material Testing Laboratories, Dams and Other Places of Engineering Interest

8.1. Materials Laboratory, Water Conservation and Irrigation Commission, New South Wales, Sydney

The W. C. & I. C. have got a well-equipped laboratory for testing of soils for their engineering properties. Among the various equipments in that laboratory to test the engineering properties of soils were :

(a) Electrically-driven horizontal breaker tube for soil pulverization.

(b) Soil permeability cylinders made of aluminium and employing plastic pipes for water connections.

(c) Triaxial shear test apparatus fabricated by them and capable of testing soil cylinder of 4 in. dia. and 11 in. height under both drained and undrained conditions.

(d) Battery of direct shear test equipment, consolidation test apparatus, etc.

The laboratory has a Chemical Section to test water samples for their suitability for irrigation and domestic uses. They have prepared a manual of construction control and testing at earth dams.

8.2. University Technological Laboratories, Sydney

These laboratories have sections engaged on research on (a) Soils, (b) Physics, (c) Photo-elasticity, (d) Concrete and prestressed concrete and (e) Hydrology. Due to certain alterations being done to the building, most of the activities in those laboratories were suspended temporarily at the time of the visit of the delegation.

They have a Section dealing with aerial photography. There they take trainees who are afforded training in plotting contour maps from aerial photos. A training of about 3 months is considered enough to afford practice for setting up the model for contour maping.

In the Hydrological Section they were employing the Synthetic Unit Hydrograph method. In New South Wales they were employing Bristol Pressure type recorder which had given them fairly good results and cost about £(A) 80 (about Rs. 846) as compared to Stevenson recorder (American make) which was 50 times more expensive. They were, however, still engaged on research to improve the Bristol recorder. In Australia, they were collecting a lot of data of rainfall but not so much of run-off.

8.3. Hydraulic Laboratories at Manly (N.S.W.)

Each of the following four organisations of N.S.W. had their separate hydraulic laboratories to investigate their problems.

(a) *University of Technology.*—The hydraulic laboratory was still under construction; only the administrative blocks were ready till then.

(b) *Public Works Department.*—Some of the problems under investigation there included :—

(i) Spillway design at the Hume reservoir on the Murray river (Plate 35).

(ii) Ski-jump on the Oberon Dam on the Fish river (Plate 36).

(iii) Short and long period wave motions at the Kembla Port Model.

(c) *Water Conservation and Irrigation Commission.*—They were investigating (a) the bulk heads for the emergency gates for the Keepit Dam (under conditions when, say, the radial gates needed repairs, etc.) and (b) calibration of the Dethridge outlet model (Plate 37).

(d) *Metropolitan Water and Sewage Board.*—They were investigating the position where the rectangular shape of concrete apron, provided to dissipate energy below spillway of the Warragamba Dam, should change to the elliptical section of the canal take-off to restrict the hydraulic jump on the concrete apron. The velocity at the end of the apron was of the order of 60 ft. per second; they had to contend with a discharge of 354 thousand cusecs (Plate 38).

8.4. Testing and Research Station (Cooma) of the Snowy Mountains Authority

The Station has Hydraulic, Physics, Soil Mechanics, Cement and Concrete and Field Metrology Sections.

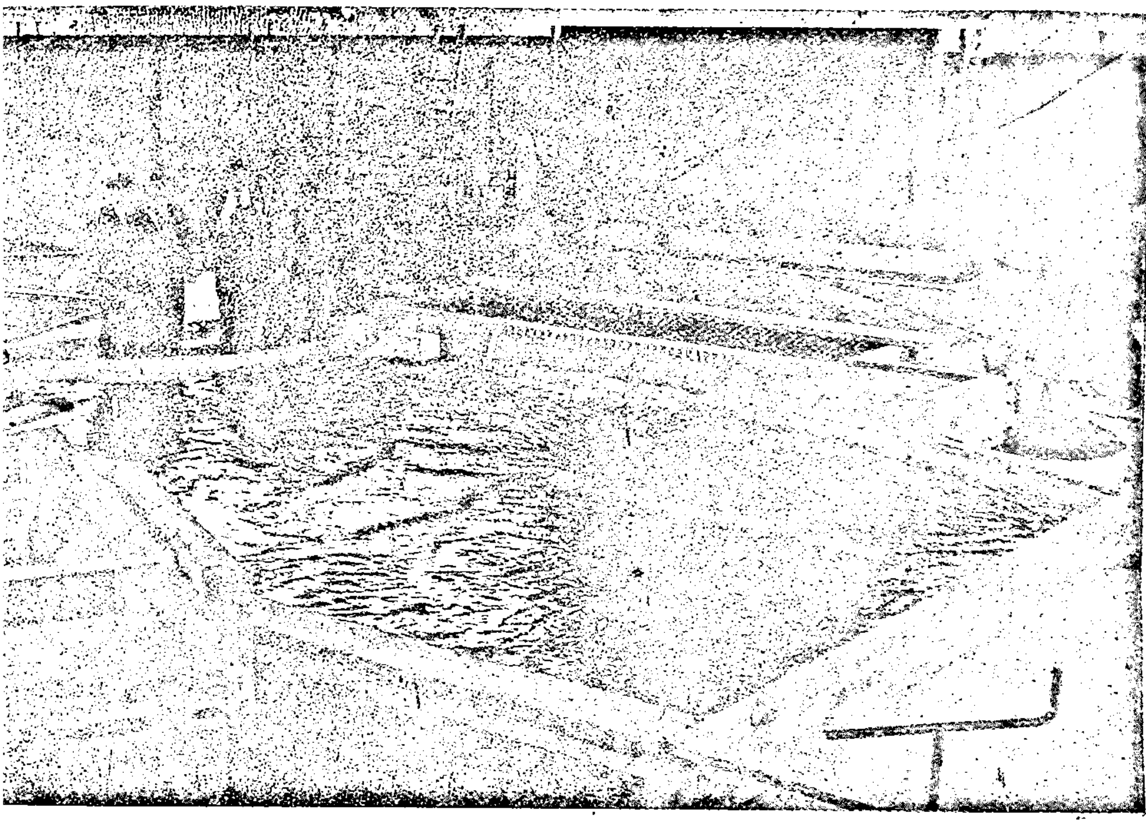

Plate 35—P. W. D. Hydraulic Laboratory, Manly, N.S.W. : Model studies of the Hume Reservoir (Murray river).

Plate 36—P. W. D. Hydraulic Laboratory, Manly : Model of the Oberon Dam on the Fish river to investigate the effect of ski-jump on earthen abutment.

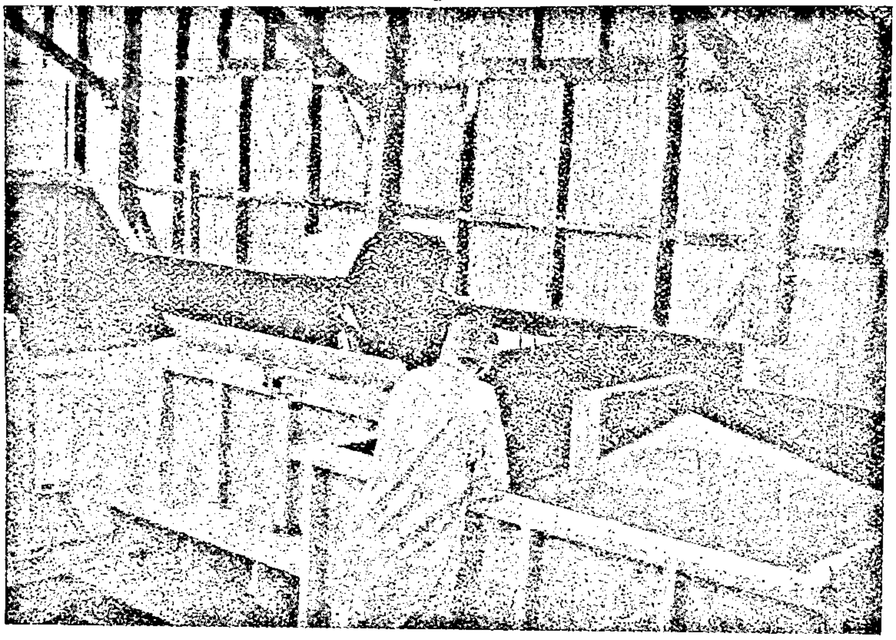

Plate 37—W.C.I. Commission Hydraulic Laboratory, Manly : Calibration of the 5-cusec Dethridge outlet device.

Plate 38—Sydney Water Board Hydraulic Laboratory, Manly : Model of Warragamba Dam to investigate the point where the rectangular design could be changed to elliptical.

One unusual hydraulic problem undertaken by the Fluid Mechanics Branch recently concerned the admission of water, collected by surface aqueducts, into the tunnel which supplied water to the Munyang power station turbines. The conditions of operation required the water to be fed into the tunnel through a vertical surge-shaft approximately 100 feet in height, while ensuring that no entrained air was carried through into the turbines. After investigating several proposals, one was developed and found to give a satisfactory solution. This proposal provides for a small well at the aqueduct discharge point, from which a siphon which has its upstream leg greater than 28 feet in height feeds through the surge shaft into the surge chamber at the foot of the shaft. The unique feature of this style of siphon is that the drawdown in the well feeding the siphon cannot exceed a depth determined by atmospheric pressure : at the altitude of the aqueduct entry this length is approximately 28 feet. Due to the high vacuum in the upper part of the siphon, a certain amount of air is drawn out of solution from the water passing through the siphon. This air is collected in the siphon and periodically discharged into the lower chamber. The quantities of air so discharged have been found to be so small that, by carrying the discharge point of the siphon a short distance upstream and by directing it against the roof of the lower chamber, the air so released is carried forward to the surge shaft by the water feeding through the tunnel. In the shaft, the bubbles are free to escape upwards.

The conditions of dynamical similarity between a prototype and the corresponding model, in the type of problem just described, cannot be fulfilled unless the model as a whole is enclosed within a vessel at pressures below atmospheric. An alternative method of approach is the examination of a family of similar atmospheric models, at different scales. The latter method has been used, and analysis of observations upon two models having scale *modulii* of 36 and 18 have made forecasts upon the behaviour of the prototype possible to an accuracy satisfactory for practical purposes.

At the Hydraulic Laboratory investigations were also in progress on (i) the spillway study on the 1 : 60 model of Tooma Dam, (ii) intake galleries study of de-aeration chamber model (1 : 6 : 3) to study break in priming, and (iii) Surge tank stability study on a distorted model. They have a calibration station for calibrating current meter from ½ ft. to 13 ft. The tank was fitted with an automatic braking system to cut out motion of the carriage at the other end of the calibration tank.

In the Physics Laboratory, thermal and specialized electronic, supersonic and X-ray diffraction measurements are made to accumulate data for design purposes. In Sydney (Rydalmere) an X-ray plant is used to examine welds made in the pipes manufactured for the Munyang (MIB) penstocks. These 24-foot pipes are taken to the site and welded together. To ensure that all the welds are sound, portable X-ray equipment is being used. The plant consists of a 'bomb' containing an isotcpe, Iridium-192, with a half-life of 70 days, prepared at the Atomic Research Establishment, Harwell. The plant is set up on the axis of the pipe and in the plane of the circumferential welded joint. A photographic film contained in a rubber 'cassette' is wrapped around the outside of the pipe. Between the film and the source of X-rays a sheet of aluminium foil is interposed to intensify the images of defects. The X-ray plant has the merit of extreme portability, no component weighing more than 35 pounds.

In the Physics Section they had built a crystal clock for giving radio time signals and established a photo-elastic laboratory to investigate various stress problems. Among other equipments, in that Section, they had X-ray defraction apparatus, photo-meter, etc.

In the Soil Mechanics Section they had a set of new type German Direct Shear machines with automatic recording device and a triaxial shear test equipment capable of taking different-sized soil test specimens *i.e.*, 3, 4 and 8 in. in height and an automatic arrangement for varying the pressure to be applied for triaxial testing.

The Cement and Concrete Laboratory was equipped to carry out various tests on aggregate, concrete, pozzolans, etc. Extensive experiments were carried out with crushed granite, both for coarse and fine aggregate. The effects of certain additives were also studied. Test specimens made up with potentially satisfactory mixes were subjected to accelerated freezing and thawing tests over a temperature range from 10°F. to 70°F. Air-entraining agents were added, to produce a system of fine sealed air-pores throughout the concrete, and so increase durability. Calcium chloride was added, to reduce the deleterious effects of placing and curing concrete at low temperatures.

One very interesting problem confronting the Field Metrology Section is the setting out and subsequent control of the alignment of the long tunnel between Adaminaby and Tumut Pond. This tunnel will be approximately 14 miles long, and must fulfil the condition that, on occasions, it will be blocked off and drained for inspection. In addition it must permit water to flow by gravitation from either end.

The engineering chemists are concerned with a wide range of problems. Some of these are of a routine character, such as water analyses designed to control the purity of water supplies to construction camps and towns within the area of the Scheme, dust analyses in tunnels and quarries to provide information for the control of 'silicosis', cement analyses and the testing of paints, lubricants and the like for compliance with specifications. In addition to this routine work, special investigations are undertaken, such as the metallurgical examination of steels and the determination of the causes of abnormal corrosion in diesel-engine cylinders.

The laboratory workshops are divided into two groups—the precision machine shop and the instrument repair shop. In these, work is carried out which cannot be undertaken readily by private enterprise. Nearly all of the work calls for high orders of accuracy and a high degree of skill.

8.5. **Waite Research Institute (CSIRO), Adelaide**

In the Soil Physics Section they have developed an apparatus 'Neutron Moisture meter' which has been employed extensively in the field for the last two years for determining the moisture content of soils in some soil-water investigations. The method works on the principle of slowing down of fast neutrons by the 'H' atoms in the water contained in soil. The equipment is covered by patent.

Among other investigations on which that Section is engaged are measurement of evaporation losses from soils, saturated permeability of soils and land drainage, permeability, swelling and surface area of soils, stability of soil aggregates, soil stabilisers, soil tillage, etc.

In the work relating to soil surveys undertaken by the Soil Survey and Pedology Section, the policy is to work with the broader soil categories backed up by sufficiently detailed surveys of selected small units to establish the pattern of soil types without mapping them *in extenso*.

The Soil Chemistry Section is very well equipped for soil work. They are using an electrical equipment (manufactured by G. M. Phillips) for determining the total salt content of soils. Their flame photometer is affording reproduceable results for estimation of N_a and K. Their spectroscopic equipment for the chemical analysis of refractory materials and plant ash are giving satisfactory results. Those are of three types, one using air and acetylene, the second air and hydrogen, and the third air and oilgas; the last mentioned afforded best results. Other activities of the Section included work on up-take of micro-neutrient elements on plants, physical chemistry of soils, exchangeable-ion equilibria in soils, rain water studies, etc. Their glass house has a room where temperature and humidity are kept constant. The glass house experiments related to studies on superphosphate dosage to clover, effects of such elements like Mn, Cs, etc.

They have a small section engaged on problems of soil mechanics and geology relating to soils of Adelaide and suburbs.

8.6. Laboratories of the Civil Engineering University, Adelaide

The various sections of the laboratories *viz.* Hydraulics, Soil Mechanics, Concrete and Physics were visited. In the Hydraulic laboratories, among other investigations, they were studying the spillway model of Myponga reservoir for the dissipation of energy. In the Soil Mechanics Section, their triaxial machine with a minor adjustment can be employed to test cylindrical specimens of different dimensions such as 1½ in. dia. and 4 in. long, 4 in. dia. and 8 in. long and 4 in. dia. and 11 in. long respectively. They were investigating contact pressure of loading of soil specimens and measuring pressure on the inside of a hollow cylinder of soil by filling it with oil and using a manometric arrangement of measurement. The University makes available facilities in their Soil Mechanics Laboratory to the Irrigation and Supply Department of the State directly under the officers of the latter Department.

The Concrete laboratories were engaged on routine work. They employed plywood pieces to be placed at the top and bottom as alternative to regular capping of concrete cylinders prior to testing for their compressive strength and had found that that technique worked quite well.

In the Physics Section they were working on an electrical resistance network analogue for the solution of moment distribution problems as an alternative to the Hardy Cross Method.

8.7. Technical Laboratories, CSIRO (Melbourne): Cement and Ceramic Section

They were engaged on such problems as cement aggregate reaction, use of pozzolans in concrete, relationship between surface area and pozzolanic reactivity, temporary and permanent changes on the strength of hardened pozzolana-lime and portland pozzolan cement mortars, activation of pozzolanas by treatment with acid, air entrainment in cement and silica pastes, etc. The work done in that Section on concrete with special reference to the use of pozzolans and air entraining agents was discussed with the officers with reference to similar work done in India.

The work on Cetyl alcohol reported briefly in the earlier part of this Report was being done at those laboratories and was discussed with the Chief of the Division of Industrial Chemistry, Dr. Wark, in the absence of Mr. Mansfield.

8.8. Commonwealth Research Station, Merbein

This Station investigates problems of irrigation, irrigated horticulture and irrigated pastures for 130 miles up and down the Murray valley in the three States of N.S.W., South Australia and Victoria. Current projects deal with tile drainage, drainage by pumping from deep bores and the study of underground water, cultural and manurial treatments in irrigated vineyards and the factors affecting yield of Sultanas, the drying and processing of grapes, nemalotogy, establishment and maintenance of pastures, tomato breeding, etc.

The Station has a typical irrigated vineyard of 33 acres, out of about 78 acres of experimental farming area, where Sultanas, Current and Gordo Blanco vines are grown with methods employing furrow irrigation and various cultural practices including non-tillage. Experiment is in progress to attempt to influence flower bud initiation in Sultanas by varying the amount of light and heat that the vines received in spring time by shading and/or heating them.

They have oil burning frost pots for frost protection.

As the soil at the farm is saline with pH as high as 9.5 at places, they have a system of subsoil tile drainage.

Variations of yield of Sultanas from 25 to 140 cwt./acre is being investigated by examination and counting of fruitful buds which also affords an idea of future crop.

They maintain a constant temperature room for investigations relating to pH, permeability of dry skin of grapes, etc.

They have a Soil Section where they carry out soil analysis and such investigations as responses to fertilizers. They had found that the use of nitrogenous fertilizers showed good response with vines; generally two applications of ammonium sulphate are done, one in spring and the other in winter. They also spray urea on leaves in spring which gives good results.

8—3 C. W. & P. C./57

It was stated that the soil in the field showed textural variations *i.e.*, while soil of the ridges was lighter, that forming the depression in between was more clayey.

As they have a short drying period, they dip the fruit in an oil-water emulsion containing 2.5% potash and 2% dipping oil. Gordos were dipped in alkali solution. The friut was dipped in 500-gallon tank for 5 min. and then spread on racks and thus dried in 7-10 days. Boiling the grapes in Ethylene dichloride removes wax from surface of fruit. The chlorosis in plants is avoided by cultivation of Lucerne as cover crop which is later ploughed in to increase organic content of soil.

They had a solar still producing distilled water for laboratory use at a rate of 1 gallon in 3 hours. The base and sides of still were made of asbestos sheets and top of inclined glass plates.

To stop fall of current fruit they had previously been practising cintring of stems but now they sprayed PCPA. The average yield at the farm is about 1½ tons per acre, but they obtain yields as high as 5 tons to an acre on virgin land but it falls to about 1½ tons per acre within a few years.

8.9. Field Soil Test Laboratory, Glenbawn Dam

As the Glenbawn Dam is a zoned earth construction in progress, there is a laboratory set up to maintain a quality control during the construction period. They have a device with which they could dry soil samples within 8 minutes. They followed a graphic technique of representation of in-place density test record which afforded at a glance the density and moisture conditions of the fill. Some of their forms used in the laboratory seemed very convenient for recording and representation of data.

8.10. Soil Laboratory, Adaminaby Dam

This dam is under construction by contractors. The engineers keep a watch during construction by testing soil samples in the laboratory. There was, however, no particular feature of the laboratory for purposes of this Report.

9. Miscellaneous

9.1. Water Desalting by Ion Exchange Membranes

The lecture on the subject delivered by Dr. Walter Judas of the Ionic Inc., U.S.A., at the University of Technology Theatre, Kensington, N. S. W. on the 8th October was attended. In that lecture Dr. Judas described some of the salient features and latest developments of the desalinisation process. Some information relating to the proposal to undertake trials of that process in India and on points arising out of the lecture was sought from the Lecturer.

9.2. 'Ultravision' Projection Screen

The delegates attended the demonstration of the 'ultravision' projection screen. The screen affords several advantages over that normally employed for projecting films. Firstly, it makes projection possible under conditions where complete dark-room facilities cannot be arranged as reasonable day light does not interfere with projection. Secondly, more than one film can be projected simultaneously, for instance when the gathering is big and the audience views the screen from different angles.

9.3. In situ Cement Lining of Water Distribution Pipes

The delegates saw the film shown by Messrs. Concrete Industries (Australia) Ltd.; Villawood, N.S.W. After a few days the author saw the actual demonstration of the process at one of the jobs in hand in New Castle. The details of the process have already been described earlier.

9.4. Works of M/s. Le Tourneau Westing House Pty. Ltd., at Rydalmere, N.S.W.

The delegates visited the works and saw the various phases relating to the manufacture of heavy earthmoving and compacting machineries.

9.5. Guthega Power Station (Snowy Mountains Scheme)

The delegates, during their visit to the Snowy Mountains, saw the Guthega Power Station. The project, which came into commercial operation in February, 1955 and which was a relatively simple hydro-electric development on the Upper Snowy River, constituted major construction work of the Snowy Mountains Scheme. ...r putting in roads, power supplies and camps, the Authority let a contract for the design and construction of the project to F. Selmer of Oslo, Norway. Construction began in November, 1951. At Guthega, a mass concrete gravity dam 110 ft. high stands across the Snowy River, forming a pondage with a gross capacity of 1.260 acre feet. Water is drawn from the pondage through a 3-mile tunnel to a valve house at a point on the hillside, 720 ft. above the Snowy River at Munyang. A steel pipeline carries the water down the steep slopes to the power station on the bank of the river. To increase the output of the station, 18 miles of aqueducts collect waters at high elevations from creeks which flow into the Snowy River downstream of the dam, and lead them around the contour of the hills to the dam and pipeline intake. Initially, Guthega Power Station is operating as a "run-of-the-river" station with a capacity of 60,000 kW. As such, its energy output will vary with the river flow. Later, a large regulating storage will be built at Spencers Creek and a third turbo-generator will then be installed in the power station, increasing the total capacity of the project to 90,000 kW.

9.6. The Winery included in the Itinerary of the UNESCO Delegates During their Visit to Mildura

As the author accompanied the delegates on their tour he had an opportunity to see the Winery. All the processes involved in the production of different types of wines were described. Later, the Workmen's Club, Mildura, which is known to be one of the very important institutions of its kind in Australia, was also visited.

9.7. Storage Water Reservoir for Town Supply at Broken Hill.

After completing the visit to the Stephens Creek Reservoir to see the Cetyl alcohol experiment being carried out there, Mr. Alam R. Grant, President, Broken Hill Water Board kindly showed the author round some of the steel water storage tanks and the water purification plant for town water supply.

APPENDIX

Itinerary for the Period (7th to 27th October 1956) Spent in Australia

October 7th . .	Arrival Sydney, 5 p.m.
October 8th . .	Sydney. Discussions with officers of the W. C. & I. Commission, N.S.W. ; Visit to Materials Laboratory, W.C.&I.C.: attended lecture on Desalting Ion Exchange Membrane by Dr. Walter Judas.
October 9th . .	Visit to the Laboratories, Civil Engineering Department, University of Technology, N.S.W., and discussions with officers. Demonstration of 'Ultravision' Projection Screen and film on "*In situ* Lining of Water Mains".
October 10th . .	Sydney. Visit to Hydraulic Laboratories, Manly ; Visit to the Works of M/s. Le Tourneau Westinghouse Pty., Ltd., Rydalmere, N.S.W.
	Departure Sydney. Arrival Canberra.
	Visited the Parliament Building and watched the Federal Parliament in session.
October 11th . .	Canberra to Cooma by plane to see the demonstration of arid seeding of clouds ; Visit to the Laboratories of the Snowy Mountains Hydro-electric Authority at Cooma and later to Guthega Power Station ; Night at Island Bind.
October 12th . .	Visit to Adaminaby Dam ; Laboratories of the Snowy Mountains Hydro-electric Authority at Cooma.
	Cooma to Canberra.
October 13th . .	Canberra to Burrinjuck Dam ; Night at Yass.
October 14th . .	Yass to Cowra; Visit to the Mulyan Pty., Ltd., for sprinkler irrigation; Night at Cowra.
October 15th . .	Discussion with Director and other officers at the Mulyan Farm.
October 16th . .	Departure Sydney ; Arrival Adelaide; Visit to the Waite Research Station (CSIRO).
October 17th . .	Adelaide. Visits to Laboratories of the Civil Engineering Department, University of Adelaide and later to the Waite Research Station (CSIRO); Discussions with Chief, Engineering and Water Supply Department, South Australia.
October 18th . .	Departure Adelaide ; Arrival Melbourne; Visits and discussions with the Chief and other Officers of the Irrigation and Water Board, Victoria, Officers of the Imperial Chemical Industries and Division of Industrial Chemistry Laboratories, (CSIRO).

October 19th	Departure Melbourne ; Arrival Canberra ; Attended the session of the UNESCO Symposium with Prof. Thacker.
October 20th	Canberra. Visit to the Entomological Research Laboratories (CSIRO) with Prof. Thacker.
October 21st	Departure Canberra with the party of UNESCO symposium delegates ; Arrival Broken Hill; Visited the Soil Conservation Experiments at Broken Hill.
October 22nd	Visit to the Stephens Creek Reservoir to see the Cetyl alcohol experiment in operation and Water Supply Works, Broken Hill.
	Departure Broken Hill ; Arrival Mildura ; Visit to Horticultural Research Station, CSIRO, Merbein.
October 23rd	Visit to Reclamation Area, Carwarp near Mildura; Departure Mildura; Arrival Sydney.
October 24th	Sydney.
October 25th	Departure Sydney ; Arrival New Castle ; Saw job of *in situ* cement lining of water mains and later visited Tomago Sandbeds Water Scheme.
	Departure New Castle ; Arrival Scone.
October 26th	Visit to Glenbawn Dam.
	Departure Scone ; Arrival Sydney.
October 27th	Sydney to Badgery Creek to see Water Harvesting Experimental Farm and back.
	Departure Sydney for Singapore *en route* to New Delhi.