CHAPTER 7

WATER CONSERVATION AND IRRIGATION

RESOURCES, UTILIZATION AND NATIONAL AND INTERSTATE ASPECTS

Official Year Book No. 51, pages 228–31, contains a description of recent developments in the measurement of Australia's water resources. For information concerning general, descriptive and historical matter *see also* Year Book No. 37, pages 1096–1141.

For further details on geographical and climatic features determining the Australian water pattern, *see* the chapter Physiography; on water supply and sewerage in metropolitan areas, cities and towns, the chapter Local Government; and on the generation of hydro-electric power, the chapter Electric Power Generation and Distribution, of this issue.

A series of maps showing the location of major dams and reservoirs and the various irrigation schemes operating in each of the States may be found on pages 259–65 of Year Book No. 46, and a map showing the extent of known artesian basins throughout Australia is shown on page 273 of Year Book No. 48.

Water resources and their utilization

Surface supplies

An assessment of Australia's surface water resources has been made, based on measured and estimated stream flows within 197 river basins, as follows. The total average annual discharge of Australian rivers has been assessed at 280 million acre feet. This can be divided into 108 million acre feet measured discharge and 172 million acre feet estimated for areas where there are generally no gauging records. For the whole area of Australia (approximately 3 million square miles) only 1.9 million square miles are regarded as contributing to stream flow (i.e. there is practically no flow from Western Plateau drainage division and from arid parts of other divisions).

The flow of Australian rivers is small in comparison with the flow of rivers in other continents, some examples of which, expressed as mean annual discharges in millions of acre feet, are: Amazon, 2,950; Mississippi, 465; Mekong, 405; Niger, 308; Volga, 205; and the ten major rivers of the United States of America in the aggregate, 900.

Major dams and reservoirs

The table below lists existing major dams and reservoirs, together with those under construction and those projected, at June, 1965. The list is confined to dams and reservoirs with a capacity of 100,000 acre feet or more. There are many others of smaller capacity in Australia.

MAJOR DAMS AND RESERVOIRS IN AUSTRALIA

Name	Location	Capacity (acre feet)	Height of wall (feet)	Remarks
EXISTING DAMS AND RESERVOIRS				
Eucumbene	Eucumbene River, New South Wales	*a*3,540,000	381	Part of Snowy Mountains Hydro-electric Scheme
Eildon	Upper Goulburn River, Victoria	2,750,000	260	Storage for irrigation and for the generation of electricity
Hume	Murray River, near Albury, New South Wales	2,500,000	142	Part of Murray River Scheme—storage for domestic, stock and irrigation purposes. Hydro-electric power also developed
Warragamba	Warragamba River, New South Wales	1,670,000	379	For Sydney water supply. Also provides for generation of hydro-electricity and flood mitigation

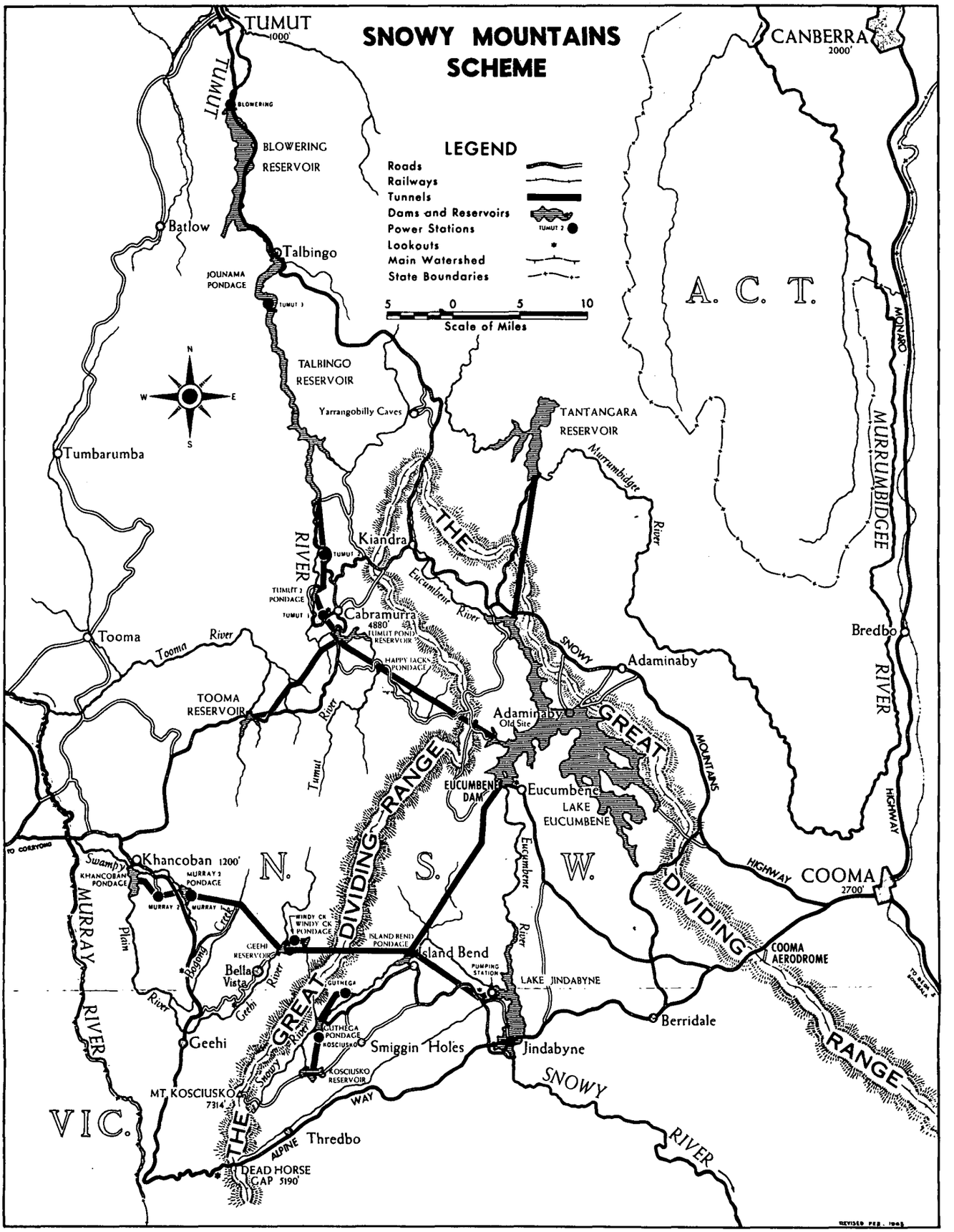
(*a*) Useful storage only.

MAJOR DAMS AND RESERVOIRS IN AUSTRALIA—*continued*

EXISTING DAMS AND RESERVOIRS—*continued*

Name	Location	Capacity (acre feet)	Height of wall (feet)	Remarks
Menindee Lakes Storage	Darling River, near Menindee, New South Wales	1,470,000	..	Part of Darling River Water Conservation Scheme for irrigation
Miena	Great Lake, Tasmania	a1,300,000	40	Storage for Poatina hydro-electric power station. (*See also* under Dams and Reservoirs under Construction)
Burrinjuck	Murrumbidgee River, New South Wales	837,000	264	Storage for irrigation and production of hydro-electric power
Somerset	Stanley River, Queensland	735,000	173	Brisbane-Ipswich water supply, flood mitigation and small hydro-electric power station
Lake Victoria	Murray River, near South Australian border, in New South Wales	551,700	..	Natural off-river storage for irrigation in South Australia. Storage improved by construction of embankments and control regulators
Lake Echo	Lake Echo, Tasmania	(a)412,200	60	Storage for Lake Echo, Tungatinah, Liapootah, Wayatinah and Catagunya hydro-electric power stations
Keepit	Namoi River, near Gunnedah, New South Wales	345,000	177	For rural water supplies and hydro-electricity, generation
Arthur Lakes	Source of Lake River, near Great Lake, Tasmania	(a)343,000	50	Part of Great Lake hydro-electric power development
Waranga	Goulburn River, Victoria	333,400	..	Irrigation storage
Tinaroo Falls	Barron River, North Queensland	330,000	136	For irrigation purposes in the Mareeba-Dimbulah area
Glenbawn	Hunter River, near Scone, New South Wales	293,000	251	Part of Hunter Valley conservation work, for irrigation and flood mitigation
Rocklands	Glenelg River, Victoria	272,000	..	Part of Wimmera-Mallee domestic and stock water supply system
Clark	Derwent River, Tasmania	(a)253,400	200	Storage for Tarraleah, Liapootah, Wayatinah, and Catagunya hydro-electric power stations. (*See also* under Dams and Reservoirs under Construction)
Eppalock	Campaspe River, near Heathcote, Victoria	252,860	150	To supplement supply to Bendigo and for irrigation
Wyangala	Lachlan River, New South Wales	(b)245,000	200	Storage for domestic, stock and irrigation purposes and for generation of hydro-electric power. (*See also* under Dams and Reservoirs under Construction)
Tantangara	Murrumbidgee River, New South Wales	(a)193,000	148	Part of Snowy Mountains Hydro-electric Scheme
Avon	Avon River, New South Wales	173,800	232	Part of Sydney water supply
Glenmaggie	Gippsland, Victoria	154,300	100	Storage for irrigation
Lake St. Clair	Central Highlands, Tasmania	(a)154,200	..	Improved natural storage for Tarraleah hydro-electric power station
Wellington	Collie River, Western Australia	150,100	112	For supply of water to irrigation districts and to agricultural areas and country towns
Koombooloomba	Tully River, North Queensland	146,000	123	For hydro-electric and irrigation purposes
Serpentine	Serpentine River, Western Australia	144,000	171	For Perth water supply
Lake Brewster	Lachlan River, near Hillston, New South Wales	123,900	..	Storage of rural water supplies for the lower Lachlan
Cairn Curran	Loddon River, Victoria	120,600	..	Storage for irrigation
Upper Yarra	Yarra River, Victoria	110,000	270	For Melbourne water supply

(*a*) Useful storage only. (*b*) Temporary reduced level.


SNOWY MOUNTAINS SCHEME
LEGEND
Roads
Railways
Tunnels
Dams and Reservoirs
Power Stations
Lookouts
Main Watershed
State Boundaries
5 0 5 10
Scale of Miles
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CANBERRA
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Batlow
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JOUNAMA PONDACE
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Adaminaby Old Site
GREAT
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MOUNTAINS
EUCUMBENE DAM
Eucumbene
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KHANCOBAN PONDACE
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MURRAY RIVER
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ISLAND BEND PONDACE
Island Bend
PUMPING STATION
LAKE JINDABYNE
COOMA
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COOMA AERODROME
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Geehi River
GEEHI RESERVOIR
GUTHEGA
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KOSCIUSKO
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Jindabyne
Berridale
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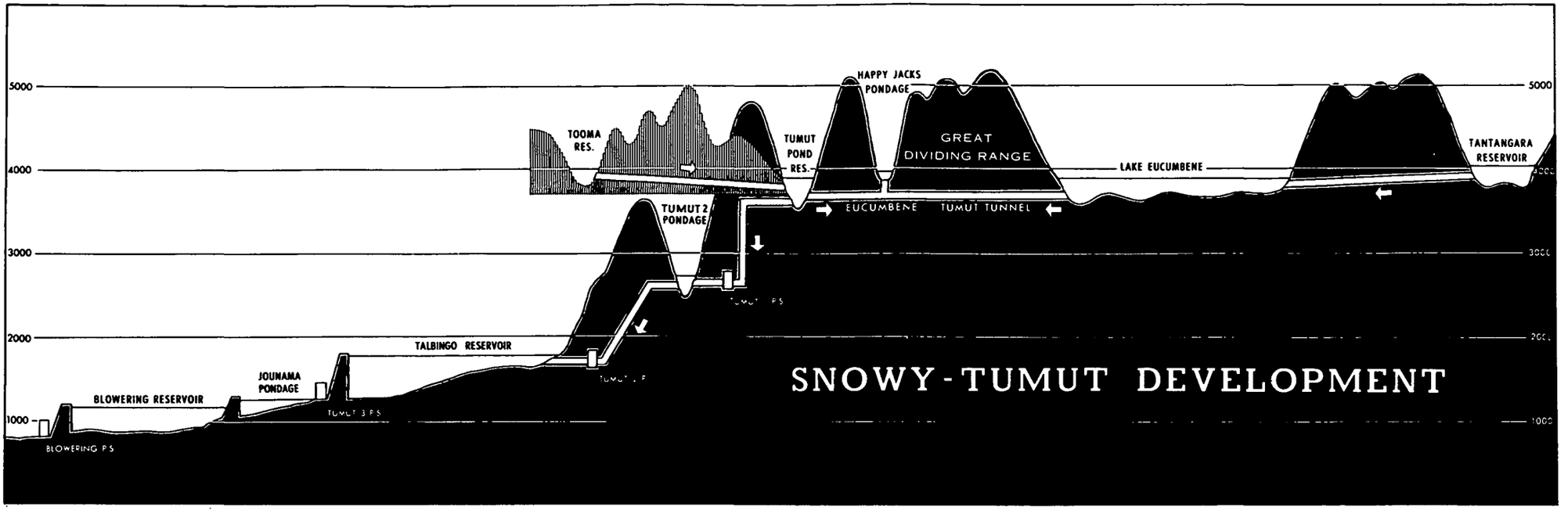
REVISED FEB. 1965

PLATE 18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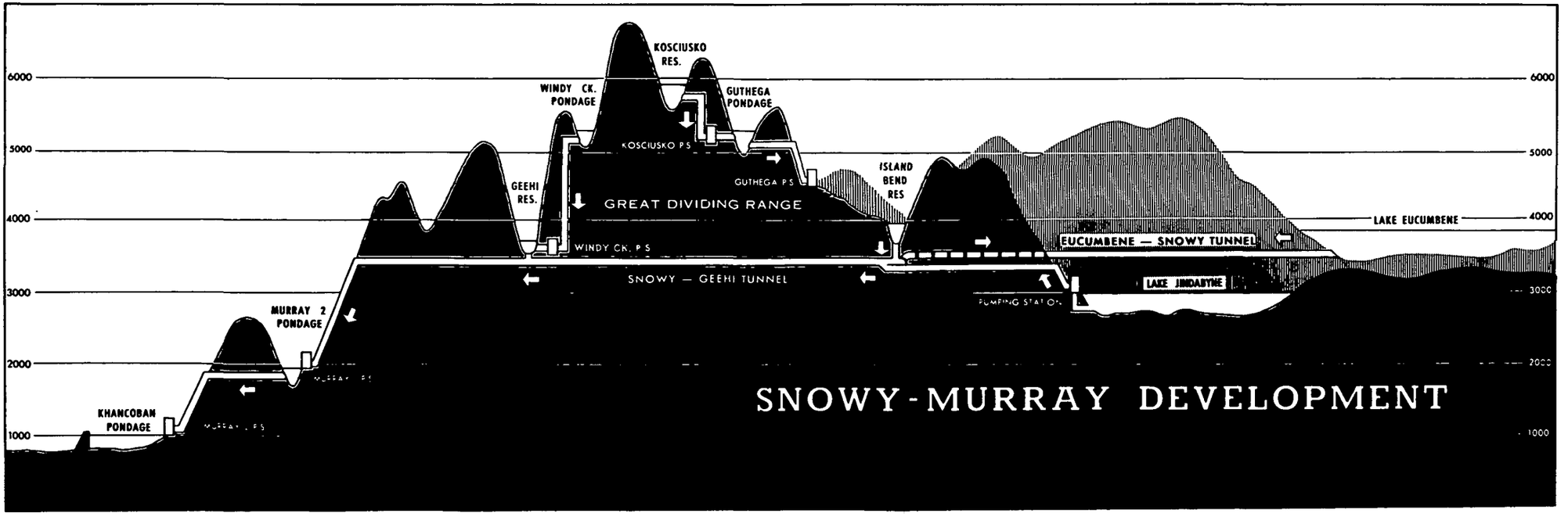
SNOWY-TUMUT DEVELOPMENT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GREAT DIVIDING RANGE
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EUCUMBENE — SNOWY TUNNEL
WINDY CK. P.S
SNOWY — GEEHI TUNNEL
LAKE JINDABYNE
MURRAY 2 PONDAGE
KHANCOBAN PONDAGE
SNOWY-MURRAY DEVELOPMENT

PLATE 19

MAJOR DAMS AND RESERVOIRS IN AUSTRALIA—*continued*

Name	Location	Capacity (acre feet)	Height of wall (feet)	Remarks
DAMS AND RESERVOIRS UNDER CONSTRUCTION				
Miena	Great Lake, Tasmania	1,710,000	40	Miena Dam (*see also* under Existing Dams and Reservoirs) is at present being replaced by a new dam to increase storage for Poatina hydro-electric power station
Burrendong	Macquarie River, near Wellington, New South Wales	1,361,000	250	For rural water supplies, flood mitigation and possible hydro-electric power generation
Blowering	Tumut River, New South Wales	*a*1,300,000	370	For regulation of discharges from stations of Snowy Mountains Hydro-electric Scheme, primarily for irrigation but also for hydro-electric power generation
Wyangala	Lachlan River, New South Wales	1,000,000	270	Strengthening and enlarging of existing dam for increased water supply and hydro-electric power generation. (*See also* under Existing Dams and Reservoirs)
Clark	Derwent River, Tasmania	432,000	220	Enlarging of existing dam for increased storage capacity for Tarraleah, Liapootah, Wayatinah and Catagunya hydro-electric power stations. (*See also* under Existing Dams and Reservoirs)
Jindabyne	Snowy River, New South Wales	(*a*)314,000	225	Part of Snowy Mountains Hydro-electric Scheme
Wuruma	Nogo River, Central Queensland	157,000	120	For irrigation storage
Rowallan	Mersey River, North Tasmania	110,000	140	Storage for Mersey Forth power development
Eungella	Broken River, North Queensland	104,000	150	Provision of cooling water for Collinsville power station and for irrigation purposes
DAMS AND RESERVOIRS PROJECTED				
Chowilla	Murray River, in South Australia, near Victorian border	*b*5,000,000	41	Regulation of the lower Murray River
Ord River	Near Wyndham, Western Australia	3,500,900	200	For irrigation, generation of hydro-electric power and flood mitigation. (Additional 6,000,000 acre feet flood control proposed)
Maraboon	Nogoa River, Central Queensland	1,170,000	148	For irrigation and probable thermal power station
Buffalo (second stage)	Buffalo River, near Myrtleford, Victoria	800,000	260	For irrigation
Warkworth	Wollombi Brook, Hunter Valley, New South Wales	406,000	130	Flood mitigation and irrigation dam for the Hunter Valley
Mokoan	Winton Swamp, near Benalla, Victoria	300,000	35	To store flood flows in Broken River for irrigation
Talbingo	Tumut River, New South Wales	(*a*)130,000	530	Part of Snowy Mountains Hydro-electric Scheme

(*a*) Useful storage only. (*b*) Subject to final survey.

Irrigation

For some brief remarks on the history of irrigation in Australia *see* issues of the Year Book prior to No. 39. Trends in irrigation practice in more recent years were described in Year Book No. 37, pag. 1099.

AREA OF LAND IRRIGATED, STATES AND TERRITORIES, 1960-61 to 1964-65

(Acres)

Season and crop	N.S.W. (a)(b)	Vic. (c)	Qld	S.A.	W.A.	Tas.	N.T. (d)	A.C.T.	Aust. (e)
1960–61	837,191	1,007,180	186,697	102,023	48,551	18,934	602	1,432	2,202,610
1961–62	964,748	1,117,900	209,419	108,400	48,679	23,189	538	1,303	2,474,176
1962–63	1,036,846	1,151,555	221,161	112,813	51,501	24,285	434	1,247	2,599,842
1963–64	1,060,479	1,137,241	252,082	117,870	55,194	33,570	973	1,081	2,658,490
1964–65—									
Cotton	1,385	..	4,148	..	5,496	..	..	..	11,029
Hops	..	(f)	..	..	(g)	1,553	..	..	(h) 1,553
Orchards	27,605	44,743	(i) 8,092	30,094	11,710	5,955	83	8	128,290
Rice	61,617	..	..	..	(g)	..	(j)	..	(h)61,617
Sugar-cane	(f)	..	120,556	..	..	..	..	..	h 120,556
Tobacco	n.a.	n.a.	13,170	..	..	..	..	..	(h)13,170
Vegetables	4,375	26,884	35,020	9,917	9,379	8,302	114	69	94,060
Vineyards	14,305	47,778	(k)	28,286	1,081	..	..	..	(h)91,450
Other crops (including fodder and fallow land)	265,125	90,579	71,634	18,878	5,259	4,318	247	425	456,465
Total, crops	*374,412*	*209,984*	*252,620*	*87,175*	*32,925*	*20,128*	*444*	*502*	*978,190*
Pastures	552,888 (b)	979,071	28,224	35,964	30,110	14,194	143	618	1,641,212 (e)
Total, 1964-65	1,198,404	1,189,055	280,844	123,139	63,035	34,322	587	1,120	2,890,506

(a) *Source:* Water Conservation and Irrigation Commission. (b) Includes total area irrigated by licensed diversions, but details for individual crops, etc., (in 1964–65 271,104 acres), are not available. (c) *Source:* State Rivers and Water Supply Commission. (d) Incomplete, excludes area of rice irrigated. (e) *See* footnote (b) to New South Wales. (f) Not available separately; included in Other crops. (g) Not available for publication; included in Other crops. (h) Incomplete, *see* footnotes to individual States. (i) Includes vineyards. (j) Not available for publication; excluded from totals. (k) Included with Orchards.

Irrigation research

Comprehensive programmes of research and investigation are being pursued by State water and agricultural authorities and the Commonwealth Scientific and Industrial Research Organization, often in collaboration. Special attention is being given to the following: high water tables due to the application of water; surface accumulation of salt and other soil changes associated with irrigation; methods of applying water efficiently; soil treatments to improve the physical condition of irrigated heavy clay soils; the utilization of irrigated pastures by stock; growth problems affecting plants and trees; the prevention of evaporation from water storages; the potability of saline waters for stock; the de-salting of brackish waters; and cloud-seeding over catchments.

Irrigation is studied by the Commonwealth Scientific and Industrial Research Organization at a number of its research stations and laboratories, the principal one being the Irrigation Research Laboratory at Griffith (New South Wales), where investigations are concerned with limiting the degradation of land by irrigation, improving the quality and range of irrigated crops, and assessing the amount of water required by irrigated crops and the most economical means of applying it. The crops being studied include citrus, cotton, wine grapes and lucerne. The Organization's Division of Plant Industry studies irrigated pastures at Deniliquin (New South Wales) and Canberra (Australian Capital Territory), and tobacco at Mareeba (Queensland). At Adelaide (South Australia) and Merbein (Victoria) the Horticultural Research Section is working on problems of the dried-fruit industry. The Division of Land Research conducts research on rice at the Coastal Plains Research Station, Darwin (Northern Territory), and on a number of irrigated crops, including rice, safflower, linseed and cotton, at the Kimberley Research Station (Western Australia). The Division has also carried out a number of hydrological investigations in connection with the utilization of underground water for irrigation. The Division of Soils and the Soil Mechanics Section are studying methods of reducing seepage from earthen dams, and take part in the examination of the physical properties of sediments beneath proposed dam sites. The Division of Soils is also looking at underground water movement and the water balance in the south-east of South Australia, and at the drainage and soil moisture regime of the irrigated swamps of the lower Murray River. The Division of Physical Chemistry is investigating methods of minimizing evaporation losses from water storages by the use of monomolecular layers.

The Irrigation Research and Extension Committee plays an important part in the agricultural activity of the Murrumbidgee Irrigation Areas. It is representative of the New South Wales Department of Agriculture, the Commonwealth Scientific and Industrial Research Organization, the Rural Bank of New South Wales, the Soil Conservation Service of New South Wales, the

Water Conservation and Irrigation Commission and the Rice Marketing Board of New South Wales, and certain farmers' organizations (including the M.I.A. Council of Horticultural Associations). Finance is provided by these authorities on an agreed basis. The objectives are: to enable the agricultural extension services to the farmers in the defined sub-region to be continued and developed; to provide a system for advising on local agricultural policy and organization; to provide means for farmer opinion to have due weight in the consideration of regional agricultural administration and policy; to achieve a unified approach to sub-regional extension in all branches of agriculture; to advise on the research needs of the sub-region and to co-ordinate the agricultural research of the various rural institutions working therein; to achieve close liaison between research and extension; and to conduct research in extension methods.

Preservation of catchments

Since water conservation commences on the catchments it is becoming increasingly recognized that anything which interferes with catchment efficiency affects the quantity of water available for all purposes. Active steps are b ing taken to counteract soil erosion, to conserve soil generally, and to minimize the effects of floods, overstocking, bush fires, and the destruction of vegetative cover. All States and the Commonwealth have initiated forestry policies which provide for reforestation and the preservation of catchments. In recent years efforts to counteract soil erosion have been intensified, and there is some evidence of a more unified approach to catchment, water, forestry, and land use factors regarded as parts of a single problem.

Sub-surface supplies

Much of Australia's underground water is obtained from artesian and sub-artesian basins and is used for stock purposes. These supplies are indispensable in most inland areas. The quality of the water ranges from usable to very saline. In inland areas a considerable amount of water has been tapped that is unusable because of its high salt content. Because of this, development of an economic desalting process would provide the interior with additional large quantities of usable water.

Considerable use is also made of sub-surface water, other than pressure water, from local storages, particularly in the well-settled areas. The water is used mainly for domestic and stock purposes. Compared with other countries with similar rainfall and climate, underground water is not used extensively for town and individual industrial supplies, but its use for these purposes is increasing.

Artesian and sub-artesian supplies. Pressure water (either artesian or sub-artesian), variable in quantity and quality, is obtainable in many parts of Australia, the various artesian basins extending over about half the continent. A map of Australia showing the extent of the known artesian basins appears on page 273 of Year Book No. 48.

The Great Artesian Basin, the most extensive in the world, underlies an area of approximately 676,250 square miles, comprising about 421,000 in Queensland, 135,000 in South Australia, 81,250 in New South Wales and 39,000 in the Northern Territory. The table on page 164 shows the principal defined water-bearing basins in Australia.

More than 18,000 artesian bores have been drilled within the Great Artesian Basin, while the daily free discharge from all bores continuing to flow in Australia has been stated as exceeding 350 million gallons, of which the loss by evaporation and seepage has been estimated at more than 90 per cent. Sub-artesian bores and wells throughout Australia number more than 200,000.

Artesian water generally is good stock water, but most is unsuitable for plant life, while in certain areas sub-artesian waters are suitable for all uses including irrigation. In the Eucla Basin and parts of the Murray and Pirie-Torrens Basins the water is of poor quality, being barely suitable for stock.

In common with other countries possessing artesian supplies Australia has been faced with the problem of flow diminution. It was recognized early that flows were diminishing as more bores were drilled, but it is now considered that while many of the bores will ultimately cease to flow, others will assume a perpetually steady rate of flow, corresponding with the average intake of water from rainfall absorbed by permeable outcrops, mainly sandstone and limestone. Diminution in flows from artesian bores has emphasized the need to eliminate wastage as much as possible, and investigations have been made regarding wasteful methods of distribution of artesian water by open channels or bore drains and the careless use of water. (For greater detail on this subject *see* Year Book No. 37, pages 1103–4.)

PRINCIPAL WATER-BEARING BASINS IN AUSTRALIA

Name	State	Geological age of chief aquifers	Approximate area	Depth to pressure water
			square miles	feet
Great Artesian	Queensland, New South Wales, South Australia and Northern Territory	Mesozoic	676,250	Up to 7,000
Canning	Western Australia	Mesozoic-Palaeozoic	150,000	100 to 1,800
Murray	Victoria, New South Wales and South Australia	Miocene-Eocene	109,000	100 to 1,300
Georgina (including Barkly and Daly)	Northern Territory, Queensland	Cretaceous, Ordovician, Cambrian and Upper Proterozoic	108,000	150 to 1,000
Eucla	Western Australia, South Australia	Pliocene-Miocene	74,000	300 to 2,000
Carnarvon	Western Australia	Cretaceous, Permian	45,000	200 to 4,000
Perth	Western Australia	Recent, Jurassic	21,000	200 to 2,500
Western District (Otway)	Victoria	Pleistocene-Upper Cretaceous	13,000	100 to 4,500
Basins of Ord-Victoria region	Northern Territory, Western Australia	Mainly Cambrian and Permian	12,000	200 to 1,000
Pirie-Torrens	South Australia	Recent, Pleistocene	9,000	Up to 600
East Gippsland	Victoria	Pleistocene-Eocene	3,500	200 to 3,500
Adelaide	South Australia	Recent, Oligocene	1,100	200 to 600

Shallow groundwater. Shallow groundwater supplies are used in various parts of Australia for industry, irrigation, stock and domestic purposes. Two examples of the use of these shallow supplies for industrial and domestic purposes occur in New South Wales. The Hunter District Water Board pumps 15 million gallons a day for general use from the Tomago coastal sands near Newcastle, and at Botany, Sydney, private industry pumps 8–10 million gallons a day for its own use from similar sands. Exploration of the coastal sands north of the Tomago Sands has revealed a further potential production of 25 million gallons a day. Examples of the use of shallow groundwater supplies for irrigation include the Burdekin Delta and the Bundaberg area in Queensland. In the Burdekin Delta, which covers an area of some 200 square miles, the present extraction for irrigation from underground sources is in the region of 200,000 acre feet per annum (about 150 million gallons a day) and in the Bundaberg area it is approximately 50,000 acre feet per annum (about 37 million gallons a day).

In recent years there has been a marked increase, particularly in Queensland, New South Wales and Victoria, in investigation into the groundwater resources of river and coastal alluvium for irrigation and town water supplies.

National and interstate aspects

As the Commonwealth Constitution makes special reference to water rights, both the Commonwealth and the State Governments have an interest in the control and conservation of water. The main responsibility for control of water resources rests with the individual State Governments, but as political boundaries sometimes intersect river valleys and catchments, co-operation between Governments has been necessary to develop resources in certain cases. Specific examples of Commonwealth-State and interstate co-operation and approach are given in the following paragraphs.

Australian Water Resources Council

The Australian Water Resources Council was established by joint action of the Commonwealth and State Governments in 1962. The council comprises the Minister for National Development as Chairman, the Minister for Territories, and the Ministers for Water Supply in each State. It has as its principal objective the provision on a continuing basis of a comprehensive assessment of Australian water resources and the extension of measurement and research so that future planning can be carried out on a sound and scientific basis.

An important factor is that the Council is not concerned with particular works projects, normally the responsibility of the States or the Commonwealth, for which there are established channels, such as the Premiers' Conference and Loan Council, for the exchange of views and allocation of funds.

Assisting the Council is a Standing Committee of senior officers from Commonwealth and State water authorities, and there are a number of committees advising the Standing Committee,

namely: Water Research and Education Steering Committee, Technical Committee on Surface Water, Technical Committee on Underground Water, Advisory Committee on Hydraulics Laboratory Facilities and several *ad hoc* panels.

The Water Resources Council published, early in 1965, a *Review of Australia's Water Resources* (*Stream Flow and Underground Resources*) 1963. Among important matters receiving attention the more urgent include the recommendation of accelerated programmes of stream-gauging and underground water investigations.

In 1964 Australian Governments adopted an accelerated programme of stream-gauging (surface water measurement) to extend over the next ten years. They have also recognized the need for a continuous programme of underground water investigations. Under the *States Grants* (*Water Resources*) *Act* 1964 the Commonwealth Government grants financial assistance to the States in connection with the measurement and investigation of their water resources. This means that $3,692,000 of additional funds (a sixty per cent increase on current rates of expenditure) relative to these programmes could be made available over the three years to 1966–67.

All authorities represented on the Council and its committees have agreed to work towards a common, nation-wide system of recording hydrologic data in a digital form suitable for rapid analysis by computer. The Council is also giving attention to the extent to which particular kinds of water research, and specialized training of research workers, can assist in bringing about the comprehensive water resources assessment envisaged as the Council's objective.

Murray River scheme

The Murray River and its tributaries form the largest river system in Australia. The catchment is approximately 408,000 square miles, or one-seventh of the area of the Australian continent, comprising five-sixths of New South Wales, over one-half of Victoria, one-sixth of Queensland and one-fortieth of South Australia. The Murray proper is 1,600 miles long. Its main tributaries are the Darling (1,700 miles), the Murrumbidgee (980 miles), and the Goulburn (350 miles). The average annual flow of each of the chief contributory streams is as follows: Upper Murray, including the Mitta Mitta and Kiewa Rivers, 3,820,000 acre feet; Darling River, 2,820,000 acre feet; Goulburn River (including Broken River), 2,580,000 acre feet; Murrumbidgee River, 2,050,000 acre feet; and Ovens River, 1,266,000 acre feet. Irrigated production in the Murray River Basin is mainly grapes for wine, dried fruits, fresh fruits, rice, vegetables, dairy produce, wool, and fat lambs.

River Murray Waters Agreement. For a brief summary of the historical events leading up to the River Murray Agreement (1915) by the Governments of the Commonwealth, New South Wales, Victoria, and South Australia, *see* issues of the Year Book prior to No. 39. Under the Agreement construction works are carried out by the States (which are also responsible for maintenance) subject to the approval and direction of the River Murray Commission. The Agreement provides that the minimum quantity of water to be allowed to pass for supply to South Australia in each year shall be sufficient to maintain certain specified flows in the lower river varying from 47,000 acre feet a month in the winter months to 134,000 acre feet a month in the four summer months of maximum demand—the total amounting to 1,254,000 acre feet over twelve months. The flow at Albury is shared equally by New South Wales and Victoria, and each of these States has full control of its tributaries below Albury, subject in each case to the fulfilment of the South Australian allocation. For a brief outline of the operation of the Agreement prior to 1949, *see* Year Book No. 40, page 1065, and earlier issues.

At a conference of Ministers held in 1949 to consider the diversion of the Snowy River it was decided that, by diversion of streams in the Snowy Mountains area, an average of approximately 440,000 acre feet per annum would be added to the Murray River (*see* Snowy Mountains Hydro-electric Scheme, page 144) and that increased storage should be provided in order to give additional regulation of the Murray River itself as well as to provide for regulation of the diverted waters. Hydro-electric potentialities would also affect the size of the storage.

The River Murray Commission investigated the position and subsequently recommended to the contracting Governments that the River Murray Waters Agreement be amended to provide for enlargement of the Hume Reservoir by 500,000 acre feet to 2,500,000 acre feet. A conference of Ministers in 1954 agreed to the enlargement, and it was also agreed that the Commission should be given power to construct regulators and to carry out such other work on the Murray River between Tocumwal and Echuca as it considered necessary to reduce the losses from the regulated flow in that stretch of the river. The amended Agreement was ratified in the Parliaments of the Commonwealth and the three States and was proclaimed on 7 April 1955. In view of the proposed diversions by the Snowy Mountains Authority to and from the Murray River, and for other reasons, amendments to those sections of the River Murray Waters Agreement dealing with

the distribution of the waters of the Murray were considered desirable. Following ministerial conferences, amendments were ratified by the four Parliaments concerned, and came into force on 6 November 1958.

Further amendment of the Agreement to provide for the construction of a storage of approximately 5,000,000 acre feet capacity at Chowilla in South Australia was ratified by legislation in the Commonwealth and State Parliaments and came into force on 30 April 1964. The dam will be located some six miles downstream from the border between Victoria and South Australia, and will consist of concrete outlet structures and a bank forty-one feet high across the flood plain. The overall length of the dam will be three and one-third miles, and the lake formed behind it will extend to Wentworth Weir, a distance of about 120 miles by river.

As a temporary measure, to assist in drought mitigation pending completion of the Chowilla reservoir, it has been agreed that portion of the waters in the Menindee Lakes storage will be made available to the Commission for allocation between the States of New South Wales, Victoria and South Australia. The arrangement, to operate for a period of seven years from 1 January 1963, was approved by the *Menindee Lakes Storage Agreement Act* 1963.

The quantity (in acre feet) of water diverted during 1964–65 from the Murray and its tributaries for irrigation and other purposes was as follows: New South Wales, 2,115,000; Victoria, 2,555,000; South Australia, 291,000; a total of 4,961,000 acre feet.

River Murray works. One of the major works of the Murray River scheme is the Hume Reservoir, situated just below the junction of the Murray and Mitta Mitta Rivers, ten miles above Albury, forming a lake of 56,000 acres. The design comprises a mass concrete spillway and outlet works extending for 1,000 feet, and an earthen embankment 142 feet high extending for 4,000 feet across the river flats, the length of the total structure being approximately one mile. Work on the enlargement of the reservoir to its approved capacity of 2,500,000 acre feet was completed in 1961.

The Yarrawonga Diversion Weir, which was completed in 1939, raised the river level so that water could be diverted by gravitation into main channels constructed on either side of the river. Between the Yarrawonga Weir and the Murray mouth, thirteen weirs and locks have been built. Two flood diversion weirs have been constructed on the Murrumbidgee—one between Hay and the Lachlan junction and the other below the Lachlan junction.

The Mulwala Canal, supplied from the Yarrawonga Weir, has an off-take capacity of 2,500 cubic feet a second, servicing 1,800,000 acres of land in New South Wales. The Yarrawonga Channel, on the Victorian side, has an off-take capacity of 1,250 cubic feet a second, serving 300,000 acres. Not all of this area is irrigated.

Adjoining the river in New South Wales, and 35 miles from the Murray-Darling junction, Lake Victoria storage, with a surface area of 27,670 acres, was completed in 1928. The water released from Lake Victoria is used by the South Australian settlements. The inlet channel to Lake Victoria was enlarged in 1957 to permit greater diversion of periodical flood flows of short duration.

Five barrages across channels near the Murray River mouth connecting Lake Alexandrina with the sea were completed in 1940 to prevent ingress of salt water to Lakes Alexandrina and Albert and to the lower river, thereby increasing the productivity of adjacent lands. The structures maintain a sufficiently high level for 50 miles up river to permit watering by gravitation of a considerable area of reclaimed river flats. The total distance across the barrages and intervening islands is 15 miles.

In addition to the works carried out under the auspices of the Commission, the separate States have constructed thousands of miles of distribution channels and have provided a number of storages on the tributaries, thereby contributing very materially to the large amount of irrigation development in the Murray Basin. The main storages are: New South Wales—Menindee Lakes Storage (Darling), Burrinjuck (Murrumbidgee), Keepit (Namoi), Burrendong (Macquarie), and Wyangala (Lachlan); Victoria—Eildon (Goulburn), Waranga (Goulburn), Eppalock (Campaspe), and Cairn Curran (Loddon). Details of these and other State works on Murray tributaries will be found in the sections dealing with State systems. No storages exist on the Murray in South Australia at present, but the construction of a large storage at Chowilla is proposed (*see* above).

New South Wales-Queensland Border Rivers Agreement

The catchments for the border streams of New South Wales and Queensland (2,000 square miles) extend to the granite areas in the vicinity of Tenterfield (New South Wales) and Stanthorpe (Queensland), and elevation rises to 3,000 feet. Average rainfall is 30 inches. The catchments and the areas suitable for irrigation are approximately equal in each State. Climatic conditions are such that from April to October it is necessary to supplement rainfall by irrigation to stabilize

and increase production. The capacity of the area to grow lucerne and tobacco under irrigation has already been demonstrated. Other possible development of the area includes irrigation of cotton, root crops, cereals, and citrus fruit, and expansion of the fat stock industry.

The New South Wales-Queensland Border Rivers Agreement came into effect on 1 July 1947. The Agreement provides for the construction of certain works on those sections of the Severn, Dumaresq, Macintyre and Barwon Rivers which constitute part of the boundary between New South Wales and Queensland for the furtherance of water conservation, water supply and irrigation in those States.

The works to be constructed comprise a dam on the Dumaresq River at a site to be selected by the Water Conservation and Irrigation Commission of New South Wales (the constructing authority) to give a storage basin with a capacity as large as is reasonably practicable and not less than six nor more than twelve weirs as may be found necessary to meet the requirements of irrigation along the rivers. Provision is also made for the construction of not more than four regulators in the effluents from the barrier rivers and for the taking over of the existing weir on the Macintyre River at Goondiwindi and the existing weir on the Barwon River at Mungindi (the Irrigation and Water Supply Commission of Queensland is the constructing authority for new weirs and regulators). The cost of these works and of administration are to be borne by the States in equal shares. The Agreement further provides that the water discharge from the Dumaresq storage, whether by regulated or unregulated flow, shall be available to the two States in equal shares.

After unfavourable foundation conditions were disclosed at several dam sites on the Dumaresq River, investigations were extended to tributary streams, and superficially suitable sites located on Pike Creek and the Mole River. A geophysical survey was made at each of these sites and preliminary comparative estimates were prepared to determine the relative economy of providing one large storage at Mingoola or two smaller storages on the tributaries. Following exploratory drilling of the tributary sites, a report dealing with alternative storage proposals and possible amendments to the existing Agreement was submitted to the participating States. It was subsequently agreed by the State Governments that, at the appropriate time, the existing Agreement would be amended to include, *inter alia*, provision for the construction of storages on Pike Creek (Queensland) and the Mole River (New South Wales).

Completed works include Bonshaw and Cunningham Weirs on the Dumaresq River, a weir and regulator on the Barwon River at the offtake of the Boomi River, and a low level weir to establish a pumping pool at Glenarbon on the Dumaresq River. The existing Goondiwindi and Mungindi Weirs are being maintained, operated and controlled by the Queensland Irrigation and Water Supply Commission. Until a dam has been constructed it is unlikely that any other weirs will be required.

Snowy Mountains Hydro-electric Scheme*

Following a comprehensive investigation into both the water and power potential of the Snowy River waters by a Technical Committee representative of the Commonwealth and the States of New South Wales and Victoria in 1947 and 1948, and the submission by the Committee of reports in 1948 and 1949, the Commonwealth Parliament passed the *Snowy Mountains Hydro-electric Power Act* 1949 setting up an Authority to implement the proposals agreed upon.

The basis of the proposals is to impound the Snowy River waters at high elevations and, by diverting them into tunnels passing under the Alps, to use their potential power for the generation of electricity and then to discharge them into the Murray and Murrumbidgee River systems for use in the irrigation areas.

The scheme involves two main diversions, that of the Eucumbene, a tributary of the Snowy, to the Upper Tumut River, and that of the main stream of the Snowy River at Island Bend and Jindabyne to the Swampy Plain River. In addition, works required to make use of the waters of the Upper Murrumbidgee, the Upper Tumut, the Upper Tooma and the Geehi Rivers for power generation also provide additional regulation of these streams, and this makes more water available for irrigation. Details of the two trans-mountain diversions and the associated power works together with details of progress and construction are given in the chapter Electric Power Generation and Distribution (*see* pages 144–6).

An additional 500,000 acre feet of water per annum is now available for irrigation in the Murrumbidgee Valley. When all works are completed, it is estimated that the total gain to the Murrumbidgee by diversion and regulation will amount to 1,120,000 acre feet per annum and the total gain to the Murray will be 800,000 acre feet per annum. This additional water should be sufficient to provide irrigation for approximately 1,000 square miles of land, which is expected to result in a substantial increase in annual primary production.

* *See also* the chapter Electric Power Generation and Distribution, page 144. For more detailed information *see* special article by the Commissioner, Snowy Mountains Hydro-electric Authority (Sir William Hudson) which appeared in Chapter XXIX. Miscellaneous of Year Book No. 42.

International aspects

Australia maintains contact with international developments in water conservation and irrigation through its membership, since 1952, of the International Commission on Irrigation and Drainage. This Commission was set up in India in 1950 in order that the technical experience of all countries might be pooled for the benefit of all, and to promote the development and application of the science and technique of irrigation and drainage in the engineering, economic and social aspects. The Commission is constituted of National Committees of participating countries, and fifty-four countries, including Australia, have already been admitted to membership.

The Central Office of the International Commission is situated in New Delhi, India. Congresses, which are held every three years, have taken place in India, Algeria, the United States of America, Spain and Japan, in that order. The sixth Congress was held in India in January 1966.

An Australian National Committee was established following a meeting of representatives of Australian authorities held in Melbourne in 1953. At that meeting it was decided, *inter alia*, 'that a National Committee should be formed and that the National Committee would consist of representatives of Government Departments, Statutory Authorities, firms and individuals actively interested in irrigation and drainage'. The Committee meets annually.

STATES AND TERRITORIES

The foregoing text deals with water conservation and irrigation in Australia generally and with international, national and interstate aspects. The following survey covers the local pattern of water resources and the steps taken by the State Governments to bring about their development. In the various States water policies tend to assume a distinctive and characteristic pattern closely allied with climatic conditions and specific local needs.

In Victoria almost every form of water scheme is in operation. In New South Wales major emphasis at present is on irrigation and stock development in the dry areas along the Murray and Murrumbidgee Rivers, though a substantial scheme of intensive irrigation is being conducted in the Murrumbidgee Irrigation Areas. In Queensland, up to the present, the predominant emphasis has fallen on water (mainly underground sources) for stock, and the development of small irrigation schemes in sub-humid and humid areas, especially to stabilize sugar production. Apart from regular irrigation practices along the Murray River, South Australian authorities are vitally concerned with reticulated supplies for rural areas and towns. Western Australia has developed unique rock catchments and piped supplies for agricultural areas and towns in dry districts. Tasmanian interest relates almost exclusively to hydro-electric generation. The Northern Territory is concerned primarily with stock supplies and the safeguarding of long stock routes.

New South Wales

On page 1110 of Year Book No. 37 information is given on the pattern of rainfall and the history of irrigation in New South Wales. (*See also* the chapter Physical Geography and Meteorology of this issue.)

Administration

The Water Conservation and Irrigation Commission of New South Wales consists of three members appointed by the Governor. The operations of the Commission cover water conservation, control of irrigation areas, the establishment, operation and maintenance of works for domestic and stock water supply, irrigation districts, flood control districts, sub-soil drainage districts, constitution of water trusts, the issue of licences for private irrigation, artesian and shallow boring, assistance under the provisions of the farm water supplies scheme, and river improvement works.

Under the Water Act, 1912–1955 the right to the use and flow and the control of water in all rivers and lakes which flow through, or past, or are situated within, the land of two or more occupiers, is vested in the Commission for the benefit of the Crown. A system of licences operates for the protection of private works of water conservation, irrigation, water supply, drainage, and prevention of inundation.

For particulars of the New South Wales-Queensland Border Rivers Agreement ratified by Acts of both States in 1947, *see* pages 166–7 of this chapter.

Schemes summarized

The bulk of irrigated land is along the Murray and its tributary the Murrumbidgee. Smaller areas are served by the Wyangala Dam, Lake Cargelligo and Lake Brewster on the Lachlan (a tributary of the Murrumbidgee), by Glenbawn Dam on the Hunter River, by Keepit Dam on the Namoi River, and by the Menindee Lakes Storage on the Darling River. None of the other rivers is regulated by large head storages, though weirs and dams have been provided for town supplies, etc. in many places. A head storage on the Macquarie River is nearing completion and construction of a dam has commenced on the Tumut River near Tumut. In addition, substantial use is made of artesian and sub-artesian water in pastoral areas.

New South Wales legislation provides for the constitution and control of various schemes having different characteristics and including irrigation areas, irrigation districts, water trust districts, flood control and irrigation districts, and river improvement districts. There are nine irrigation areas, although two of these, Yanco and Mirrool, are generally described under the one heading, namely, the Murrumbidgee Irrigation Areas. The Areas are: The Murrumbidgee Irrigation Areas, consisting of 451,263 acres served with water through a channel system stemming from the river at Berembed Weir; the Coomealla Irrigation Area of 34,672 acres, served by pumping from the Murray; the Curlwaa Irrigation Area of 10,393 acres, supplied from the Murray by pumping; the Hay Irrigation Area of 6,850 acres, supplied with water pumped from the Murrumbidgee; the Tullakool Irrigation Area of 18,006 acres, supplied from the Edward River by diversion at Stevens Weir; the Buronga (8,693 acres) and Mallee Cliffs (1,900 acres) Irrigation Areas, served by pumping from the Murray; and the Coleambally Irrigation Area (127,235 acres), served by diversion from the Murrumbidgee River. All these Areas are administered by the Commission, and details of the various schemes are given in the table on page 170.

The capacities of the main storages (in acre feet) are:

Darling—Menindee Lakes Storages (1,470,000);

Murray—Half share of Hume Reservoir, weirs and locks to Wentworth (1,361,420); Stevens Weir, Edward River (7,165);

Murrumbidgee—Burrinjuck Dam (837,000); Berembed Weir (10,000); Redbank Weir (7,360); Maude Weir (6,740);

Namoi—Keepit Dam (345,000);

Lachlan—Wyangala Dam (temporary reduced level 245,000); Lake Brewster (123,900); Lake Cargelligo (29,435); Jemalong Weir (2,200); and

Hunter—Glenbawn Dam (185,000 acre feet irrigation storage; 108,000 acre feet flood mitigation storage).

The total length of supply channels, drains, escape channels and pipe lines constructed by the Water Conservation and Irrigation Commission in New South Wales is 4,922 miles. This comprises 3,420 miles of supply channels (including main canals), 1,433 miles of drains and escape channels, and 69 miles of pipe lines.

Extent of systems and nature of irrigated culture

The table on page 170 shows the areas of the various irrigation systems and the areas irrigated in 1964–65 and corresponding particulars for the State as a whole during the seasons 1960–61 to 1964–65.

AREAS OF SYSTEMS AND OF LAND IRRIGATED: NEW SOUTH WALES 1960-61 TO 1964-65

(*Source:* Water Conservation and Irrigation Commission)

(Acres)

Season and system	Total area	Area irrigated(*a*)										
		Rice	Other cereals grown for grain	Fodder crops		Pastures		Vineyards	Orchards (*b*)	Vegetables	Fallow land and miscellaneous	Total
				Lucerne	Other	Sown	Natural					
1960–61	6,901,105	46,116	33,436	34,950	10,490	458,360	5,412	12,388	17,962	3,362	36,195	*c* 837,191
1961–62	6,952,579	50,223	57,779	40,273	14,024	522,748	5,097	11,515	18,080	2,784	50,443	*c* 964,748
1962–63	6,972,239	53,578	85,459	42,814	18,296	509,927	10,240	13,086	21,559	4,033	72,179	*c* 1036846
1963–64	6,912,942	59,331	82,376	45,823	11,846	496,787	8,389	12,810	24,451	2,859	82,046	*c* 1060479
1964–65—												
Irrigation Areas—												
Murrumbidgee (within the Areas)	451,263	30,233	38,843	6,435	939	93,409	3,515	6,213	23,424	3,740	29,438	236,189
Lands adjacent supplied under agreement	n.a.	..	..	342	333	1,047	..	..	102	7	200	2,031
Coomealla	34,672	..	..	..	3	..	..	4,848	1,801	..	..	6,652
Curlwaa	10,393	..	..	..	23	..	..	355	1,263	..	..	1,641
Hay	6,850	..	..	160	635	1,784	136	..	..	..	..	(*d*) 2,715
Tullakool	18,006	1,022	115	75	210	6,960	..	..	..	..	140	8,522
Buronga	8,693	..	..	..	1	..	..	202	520	..	..	723
Mallee Cliffs	1,900	..	..	..	56	..	..	132	128	..	..	316
Coleambally	127,235	11,273	26,989	287	220	11,194	155	50	46	195	29,815	80,224
Total, Areas	*e 659,012*	*42,528*	*65,947*	*7,299*	*2,420*	*114,394*	*3,806*	*11,800*	*27,284*	*3,942*	*59,593*	*339,013*
Irrigation Districts—												
Benerembah	112,818	5,162	14,915	2,140	390	37,687	330	..	..	155	8,256	69,035
Tabbita	32,330	309	830	230	15	2,845	150	..	..	..	480	4,859
Wah Wah	575,716	..	5,995	1,745	725	7,888	..	..	..	..	2,073	18,426
Berriquin	803,737	..	23,112	17,286	2,658	240,270	1,205	..	..	187	5,072	289,790
Wakool	503,322	7,187	8,404	1,845	1,924	70,942	..	..	..	..	4,095	94,397
Denimein	147,005	2,656	4,489	1,012	340	19,355	..	..	12	10	540	28,414
Jemalong and Wylde's Plains	224,556	..	3,801	9,436	537	14,996	460	..	..	..	30	29,260
Gumly	353	..	37	38	..	9	..	..	20	41	..	145
Deniboota	338,054	3,775	5,094	1,870	482	38,301	250	..	..	..	1,355	51,127
Total, Districts	*2,737,891*	*19,089*	*66,677*	*35,602*	*7,071*	*432,293*	*2,395*	..	*32*	*393*	*21,901*	*585,453*
Flood Control Districts—												
Lowbidgee	399,707	..	..	..	..	..	..	..	..	..	..	n.a.
Medgun	272,800	..	..	..	..	..	..	..	..	..	..	n.a.
Total, Flood Districts	*672,507*	..	..	..	..	..	..	..	..	..	..	*n.a.*
Irrigation Trusts—												
Pomona	1,580	..	..	..	..	..	..	760	130	..	..	890
Goodnight	1,104	..	..	..	..	..	..	580	46	..	..	626
Bungunyah-Koraleigh	1,810	..	..	..	..	..	..	935	113	40	..	1,088
Glenview	661	..	..	..	..	..	..	230	..	..	..	230
Bringan	4,933	..	..	..	..	..	..	..	..	..	..	n.a.
Bama	3,446	..	..	..	..	..	..	..	..	..	..	n.a.
Total, Trusts	*13,534*	..	..	..	..	..	..	*e 2,505*	*(e) 289*	*(e) 40*	..	*(e) 2,834*
Water Trusts—												
Domestic and stock supplies	2,829,791	..	..	..	..	..	..	..	..	..	..	..
Licensed diversions	n.a.	..	..	..	..	..	..	..	..	..	..	*f* 271,104
Total, 1964-65	6,912,735	61,617	132,624	42,901	9,491	546,687	6,201	14,305	27,605	4,375	81,494	1,198,404 (*c*)

(*a*) Excludes Flood Control Districts and some Irrigation Trusts, particulars for which are not available. (*b*) Citrus and deciduous; in 1964–65 deciduous amounted to 11,818 acres, of which 11,556 acres were in the Murrumbidgee Irrigation Areas. (*c*) Includes total area irrigated by Licensed Diversions, but details for individual crops, etc., are not available. (*d*) Includes lands outside irrigation areas supplied under special agreement. (*e*) Incomplete. (*f*) Details for individual crops, etc., are not available.

Irrigation Areas

Murrumbidgee. These areas, together with adjacent lands supplied under agreement, received 429,100 acre feet, or nearly a quarter of the total water (2,158,813 acre feet) allocated within the State for stock, domestic supply and irrigation. They are served by the Burrinjuck Dam on the Murrumbidgee, forty miles north-west of Canberra. The catchment above the dam is about 5,000 square miles. The river rises on the high plateau north of Mount Kosciusko where the average annual rainfall exceeds 60 inches. Flow for the irrigation areas and districts is supplemented by unregulated flow from the Tumut River below the dam. The dam also provides town supplies for Gundagai, Wagga, Narrandera, Hay, Balranald, and for towns served by the South-West Tablelands scheme.

Domestic and stock water and water for irrigation are supplied to the Irrigation Districts of Tabbita, Benerembah and Wah Wah, and the Flood Control and Irrigation District of Lowbidgee. Flood flows are relied on to serve the Lowbidgee district, and water is not released from the dam for that purpose. For the other undertakings, however, water is stored during the winter, fed by melting snows and spring freshets, and is released during the September-May irrigation season. It passes along the river channel to Berembed Weir, 240 miles westward, where it is diverted to the main canal with an off-take capacity of 1,600 cubic feet a second. The main canal has been completed to beyond Griffith, 106 miles from the off-take. Reticulation channels aggregate approximately 900 miles and drainage channels 880 miles. In addition, approximately 440 miles of supply channels run through irrigation districts adjacent to the Murrumbidgee Areas in which the water supply is operated and maintained by the Water Conservation and Irrigation Commission.

The Water Conservation and Irrigation Commission controls land transactions and water supplies for the Murrumbidgee Irrigation Areas only, and has no jurisdiction over land transactions in the adjacent irrigation districts, although it is responsible for the operation and maintenance of the water supply in these areas. Other local government services, including electricity and town water supply, are provided by Councils. Land is disposed of by the Commission by purchase or under perpetual lease tenure or leased for short terms for grazing or cultivation. The area under occupation at 30 June 1965 was 414,929 acres, including 38,083 acres held for short lease grazing, agriculture, etc.

The land on which the Murrumbidgee Irrigation Areas and associated districts are situated originally comprised large sheep stations and was sparsely populated, but at 30 June 1965 its population was approximately 29,425, that of Leeton Shire being 10,725 and that of Wade Shire, 18,700. The principal products of the Murrumbidgee Irrigation Areas are wool, livestock for slaughtering, rice, citrus fruits, peaches and nectarines, grapes, tomatoes, peas, beans and root vegetables. Rice growing was initiated on the Areas in 1924 and has since become the most important crop. In a normal season the water supplied for rice represents about half the total delivered to the Areas.

Other Irrigation Areas. The Coomealla, Tullakool, Buronga, Mallee Cliffs, Hay, Curlwaa and Coleambally Irrigation Areas follow the same administrative pattern as the Murrumbidgee Areas—that is, land transactions are administered by the Water Conservation and Irrigation Commission which is responsible also for the operation and maintenance of works to supply water.

Irrigation Districts

These districts are set up under the Water Act, 1912–1955 for (*a*) domestic and stock water supply and (*b*) irrigation. They differ from water trusts in that the cost of the works is not required to be repaid over a period, but annual charges are made by the State for water supplied to landholders.

Since the completion of the Hume Reservoir, several such districts have been established along the Murray to utilize the New South Wales share of the storage. Water is not available for the whole of the 5,000,000 acres adjacent to the Murray in New South Wales, and therefore the schemes are based on 'extensive' irrigation, that is, water rights are allotted to holdings on the basis that only a portion of each holding (one acre in three, five or ten, according to the district, etc.) will be irrigated, but additional water, when available, may be obtained by landholders. 'Water right' means right to such a quantity annually of water, 12 inches deep, as will cover an area of one acre.

Water to serve Berriquin, Deniboota and Denimein Districts is diverted through a main canal which is approximately 100 miles long. Water for the Wakool Irrigation District and the Tullakool Irrigation Area is diverted from the Edward River at Stevens Weir, and a supplementary supply is also obtainable from Mulwala canal. At 30 June 1965 the total length of completed canals and channels in Berriquin District was 997 miles, comprising Mulwala canal 75 miles, Berrigan channel 22 miles, subsidiary channels 785 miles, escape channels 105 miles, and cross drainage channels 10 miles. Off-take capacity of the Mulwala canal is 5,000 acre feet a day. Wakool, with 418 miles of channel, contains 315 holdings, and the area developed by irrigation

includes about one acre in six of the total area. Sheep raising is the main industry. Considerable subdivision has occurred within the Berriquin District, and the proportion of the total area developed for irrigation is higher than in the case of Wakool. Sheep (including fat lambs), dairying and wheat growing are the main industries.

Water Trust Districts, Irrigation Trusts and Flood Control and Irrigation Districts

The Water Act, 1912–1955 provides for the constitution of Trust Districts for domestic and stock water and irrigation, and empowers the Commission to construct, acquire or utilize necessary works. When the works are completed, they are handed over to trustees to administer. The trustees are elected by the occupiers of the land and act with a representative of the Commission. They are empowered to levy and collect rates covering the cost of the works repayable to the Crown by instalments and also the cost of operation and maintenance of the works. The rates are struck according to the area of land which benefits. The following are the water trusts, other than irrigation, as at present constituted (the area in acres of each district being shown in parenthesis): *Murray River*—Little Merran Creek (157,440), Bullatale Creek (68,320), Poon Boon (34,300), Minnie Bend Flood Prevention (2,190); *Murrumbidgee River*—Yanco, Colombo and Billabong Creeks (1,007,780); *Lachlan River*—Marrowie Creek (292,640), Torriganny, Muggabah and Merrimajeel Creeks (170,240), Ulonga (64,960), Micabil Weir (11,500), Condobolin West Weir (4,480); *Miscellaneous*—Great Anabranch of Darling River (959,184), Nidgery Weir (46,880), Algudgerie Creek (9,760), Collarenebri town water supply (117)—making in all a total area of 2,829,791 acres. Twelve of these trusts have been formed for the provision of water for domestic and stock purposes, one for a town supply and one for flood prevention.

Irrigation Trusts are established under the same Act and are administered by trustees in a similar way.

The Lowbidgee Provisional Flood Control and Irrigation District, the first of its kind, was constituted in 1945. Its purpose is to provide flood irrigation for pasture lands on the lower Murrumbidgee by water diverted from the Maude and Redbank Weirs. Another district, Medgun, near Moree in the north-west, is also in operation.

River, lake and farm water supplies

During recent years the numbers of licences and permits issued to individuals to draw water from rivers and lakes for irrigation have increased substantially, especially along the coastal streams in sub-humid districts where the value of supplementary irrigation is becoming more recognized as a means of stabilizing production in dry months. There has also been a considerable increase along the Murrumbidgee and Lachlan.

Under the Farm Water Supplies Act, 1946, technical advice and assistance, and also financial assistance, are made available to help individual farmers and groups of farmers to provide and improve water supplies for domestic, stock and irrigation purposes by means of wells, bores, excavated tanks, weirs or dams, flood and spray irrigation systems.

Underground water

Extensive use is made of artesian, sub-artesian, and shallow underground water. The Great Artesian Basin underlies an area of some 81,250 square miles in north-western New South Wales. Eighty-seven Bore Water Trusts and twelve Artesian Wells Districts have been constituted. Bore Trusts are administered in the same way as Water Trusts, but in Artesian Wells Districts the settlers maintain the drains. Bore Trusts and Artesian Districts cover 5,597,202 acres and distribute water through 3,673 miles of open earth drains. At 30 June 1965, 1,137 artesian bores had been constructed in the New South Wales section of the Basin. At that date 664 bores were flowing and were capable of producing about 62,500,000 gallons per day. Conservation measures control this to about 50,000,000 gallons per day. The total length of bore drains, including those for Trusts and Districts, is approximately 8,000 miles.

Of other structural basins of sedimentary rocks, e.g. Murray, Sydney, Oxley and Clarence Basins, the Murray is the largest and also the most important in that it affords stock water supplies over an extensive area of the south-western section of the State. Only a few of these bores flow, the remainder being sub-artesian. Good supplies for stock and, in some instances, small scale irrigation, are obtained from porous sandstone in the Moss Vale-Picton area, but the remainder has limited potential. Stock supplies are obtained from bores in the fringe zones of the Oxley Basin, but the centre of this basin lies under the Liverpool range. The Clarence Basin is relatively unimportant from a groundwater viewpoint, but stock supplies are obtained from some sections.

In other parts of the State the largest and best quality groundwater supplies are obtained from sands and gravels in the alluvium of the major rivers and their tributaries, particularly the western-flowing rivers, e.g. Lachlan, Macquarie and Namoi. Supplies of up to 80,000 gallons an hour are obtained from wells and screened bores in these areas and are used for irrigation

and town water supply. The Government is carrying out investigations to determine the groundwater potential of the alluvium of such valleys, particularly with regard to irrigation use, and a test-boring programme is in progress in the Lachlan Valley. Coastal river systems have a much more limited potential in this regard, the main exception being the Hunter. Old sand dune areas along the coast provide large supplies of good quality water. However, since the soils of these areas are not suited to agricultural pursuits, exploitation has been largely confined to the Sydney and Newcastle areas. Initially a source of Sydney's water supply, the Botany sands are now utilized mainly by industry. The Tomago sands provide a considerable proportion of the Newcastle water supply.

The older rocks, which are mostly folded and jointed, are very variable in their groundwater potential and only rarely do they yield supplies sufficient and suitable for limited irrigation. Where suitable conditions obtain, they yield useful stock supplies, mostly at depths between 50 and 250 feet.

A license under the Water Act, 1912–1955 is required for all bores sunk in any part of New South Wales and details of over 20,500 bores and wells in the State are recorded. When assessed in relation to the geologic and topographic conditions of any particular area, such records provide valuable evidence of the groundwater potential and are thus of considerable benefit to landholders.

Future programme

The programme of development in hand includes the provision of additional dams and storages, diversion weirs, and flood mitigation and river protection works in various parts of the State. Construction of Burrendong Dam on the Macquarie River is nearing completion, and work has commenced on a dam at Blowering on the Tumut River. Legislation has been passed authorizing the construction of a flood control and irrigation dam at Warkworth in the Hunter Valley. The Hunter River development, of which Glenbawn Dam is an integral part, concerns an exceptionally fertile coastal valley, forming the hinterland to Newcastle, where the annual rainfall is not heavy and variations from month to month are considerable. This is the first coastal scheme intiated in New South Wales. At Wyangala Dam, on the Lachlan River, the fixed crest of the dam spillway has been lowered temporarily to enlarge the spillway for passage of greater floods. Construction has commenced on a new earth and rock-fill dam which will be built behind the present dam to give a storage of 1,000,000 acre feet. Within the new Coleambally Irrigation Area further development of farms has been carried out and water is being supplied by the new diversion weir at Gogeldrie. At 30 June 1965, 194 large area farms and 12 horticultural farms had been allotted

Victoria

Particulars of the rainfall pattern of Victoria were given on page 1117 of Year Book No. 37. (*See also* the chapter Physical Geography and Meteorology of this issue.)

Administration

Victorian Governments have been active in the development of country water supplies since the 1860's when major works to supply the Bendigo goldfields were undertaken. Local trusts to construct and operate waterworks under Government supervision were provided for in the *Water Conservation Act* 1881. Development under the trust system was greatly stimulated by the *Irrigation Act* 1886 which provided for the construction of national headworks by the State, and vested in the Crown the right to the use and control of all surface waters. By 1900 there were 33 irrigation trusts and 18 other rural water supply trusts, but the system of local control was then breaking down under financial difficulties.

The *Water Act* 1905 established the State Rivers and Water Supply Commission to take over the Irrigation Trust districts (except the still-existing First Mildura Irrigation Trust) and to exercise the State's functions in the further control and development of surface waters outside the metropolis. The Commission now supervises all private diversions from streams and directly administers irrigation districts covering 2,250,000 acres, rural waterworks districts covering 7,000,000 acres, drainage and flood protection districts covering 170,000 acres, and urban water supplies serving 200,000 people. It also supervises the activities of local urban water supply authorities supplying 600,000 people in more than 200 towns, as well as 80 local sewerage authorities and 25 drainage and river improvement authorities.

Works summarized

Since the State Rivers and Water Supply Commission began its operations in 1906 the capacity of storages under its control has been increased from 172,000 acre feet to 4,542,420 acre feet. In addition, Victoria has in effect a half share in River Murray Commission storages totalling 2,722,840 acre feet, bringing total capacity available to Victoria at 30 June 1965, to 5,903,840 acre feet. Most of the water used from these storages is for irrigation. The area irrigated has

increased from 105,000 acres in 1906 to 1,189,055 acres in 1964–65. Irrigation deliveries in 1964–65 totalled 1,859,173 acre feet. The value of irrigation production in 1963–64 was estimated at $153,000,000, about one-fifth of Victoria's total rural production. Of the total irrigation production about one-fifth was from lands irrigated by 'private diverters' i.e., irrigators who are authorized to take water from streams,lakes, etc., but who do not come within the boundaries of an irrigation district.

Storages

Capacities of storages (in acre feet) at 30 June 1965 were as follows:

Goulburn System—Eildon, 2,750,000; Waranga, 333,400; total 3,104,100;

Murray System—half share of Murray storages, 1,361,420; Lake Buffalo, 19,500; total, 1,423,780;

Loddon System—Cairn Curran, 120,600; Tullaroop, 60,000; total, 266,450;

Campaspe River—Coliban storages, 62,730; Eppalock, 252,860; total, 315,590;

Wimmera-Mallee Systems—Rocklands, 272,000; total, 563,800;

Gippsland-Glenmaggie—154,300; total, 154,340;

Werribee-Bacchus Marsh—total, 34,900;

Mornington Peninsula—total, 17,640.

Nature of irrigated culture

The following table shows the areas irrigated in the various irrigation systems in 1964–65, and corresponding particulars for the State as a whole during the seasons 1960–61 to 1964–65.

AREA OF LAND IRRIGATED: VICTORIA, 1960-61 TO 1964-65

(*Source:* State Rivers and Water Supply Commission)

(Acres)

Season and system	Cereals	Fodder crops		Pastures			Vine-yards	Orch-ards	Market gardens	Fallow and miscel-laneous	Total
		Lucerne	Other	Native	Sown						
					Annual	Peren-nial					
1960–61	7,940	39,872	10,239	67,014	358,727	395,596	44,817	40,274	21,735	20,966	1,007,180
1961–62	27,586	41,253	16,468	69,505	421,277	409,648	44,563	42,671	22,197	22,732	1,117,900
1962–63	26,113	43,180	22,820	61,317	418,025	440,360	45,757	43,059	22,634	28,290	1,151,555
1963–64	14,878	42,878	21,031	41,360	427,160	453,986	45,257	43,891	24,422	22,378	1,137,241
1964–65—											
Goulburn-Campaspe-Loddon	3,694	19,123	8,391	25,673	243,787	192,707	371	23,542	3,253	11,657	532,198
Murray—											
Torrumbarry	3,213	3,815	3,102	17,274	117,844	73,995	4,779	1,369	831	2,699	228,921
Murray Valley Irrigation Area	225	7,167	538	1,406	53,264	45,621	115	6,405	373	329	115,443
Pumping(*a*)	141	788	192	310	224	112	38,386	3,303	107	759	44,322
Total, Murray	*3,579*	*11,770*	*3,832*	*18,990*	*171,332*	*119,728*	*43,280*	*11,077*	*1,311*	*3,787*	*388,686*
Other northern systems	46	1,248	..	686	1,511	10,530	..	3,410	478	99	18,008
Southern systems	59	1,257	197	3,184	556	62,636	..	618	5,438	344	74,289
Private diversions (*b*)	670	8,922	1,696	2,677	26,041	99,033	4,127	6,096	16,404	10,208	175,874
Total, 1964-65	8,048	42,320	14,116	51,210	443,227	484,634	47,778	44,743	26,884	26,095	1,189,055

(*a*) Includes First Mildura Irrigation Trust. (*b*) Excludes private diverters in the Torrumbarry System, but includes all other private diverters along the Murray River.

Irrigation systems

Goulburn–Campaspe–Loddon. The principal storage for Goulburn waters is Lake Eildon, which was completed in 1956, submerging the original 306,000 acre feet Eildon storage completed in 1927. For the distribution of additional supplies available from Eildon and from other new storages on the Loddon and Campaspe rivers it has been necessary to undertake major enlargements in the distribution system by a long term programme of channel works which is still in progress. Deliveries have already increased from 395,000 acre feet in 1954–55 to 758,000 in 1964–65. Goulburn river water is diverted to the irrigation areas by gravitation from the pool

formed by the Goulburn Weir, near Nagambie, completed in 1890 as a State work. The East Goulburn main channel of 1,000 cusecs capacity supplies the areas around Shepparton. Two 1,500 cusec channels to the west convey water to the off-river Waranga Reservoir and supply part of the Rodney area through offtakes on the way. From Waranga Reservoir there are two main outlets, one supplying the western part of the Rodney area and the other, of 1,200 cusecs capacity, supplying the Waranga Western Main Channel, which runs more than 100 miles west across the Campaspe and Loddon valleys to Boort.

Flows in the Waranga western main channel are augmented by the injection of Campaspe water through a pumping station of 200 cusecs capacity near Rochester. Supply to the Tragowel and Boort areas is augmented by gravitational diversion of Loddon water.

The gross area of holdings in the Goulburn–Campaspe–Loddon systems is 1,351,460 acres. The main products are dairy produce, fruit, wool and fat lambs. Annual production of deciduous canning fruits in the eastern part of the system is about two-thirds of Australia's total.

Murray River system. Water is diverted from the Murray by gravity at the Yarrawonga Weir for the Murray Valley Irrigation Area and at the Torrumbarry Weir for the Torrumbarry irrigation system which extends to Swan Hill. Holdings in the Murray Valley area total 301,818 acres, devoted mainly to dairying, fat lambs and canning fruit. Holdings in the Torrumbarry system total 365,199 acres, devoted mainly to dairying and the production of fat lambs, with a concentration of vineyards, orchards and market gardens around Swan Hill.

Downstream from Swan Hill there are five districts supplied by pumping: the district of the First Mildura Irrigation Trust, and the four Commission districts of Nyah, Robinvale, Red Cliffs and Merbein. These districts together serve 80,763 acres, producing mainly dried vine fruits, with some citrus fruit and table and wine grapes.

Southern systems. The Macalister district, covering 130,582 acres around Maffra and Sale, is supplied from the Macalister River, regulated by Lake Glenmaggie, and from the unregulated flow of the Thomson River. Dairy farming is the principal activity. The Bacchus Marsh and Werribee Districts, supplied from storages in the Werribee River only twenty miles west of Melbourne, cover 16,342 acres intensively developed for dairying and vegetables.

Wimmera-Mallee domestic and stock supply system

Storages in the Grampians in south-west Victoria ensure farm water supplies over an area of 11,000 square miles extending northward through riverless pastoral and cereal lands to the Murray. Farm dams throughout this region, which covers one eighth of the total area of the State, are filled once each year, in the winter–spring season, through the medium of 6,500 miles of Commission channels and 3,000 miles of private channels. Without this supply, occupation of the region would be extremely hazardous. Headworks storage capacity is now being increased from 563,800 acre feet to 627,400 acre feet by construction of Lake Bellfield. Forty-seven towns, with a population of 40,000, receive their supply from the same system. Near Horsham, which is close to headworks in the south, a supply is maintained for the irrigation of an area of 7,000 acres, mainly for dairying.

Drainage, flood protection and river improvement

The largest work in this category undertaken by the State Rivers and Water Supply Commission is the Koo-wee-rup–Cardinia flood protection district embracing 80,000 acres of a continuous depression along the seaboard of Westernport. Once useless, indeed a hindrance to communication, this area now yields primary products worth several million pounds each year.

By the *River Improvement Act* 1948, the formation of local river improvement and drainage trusts under the supervision of the Commission has been greatly facilitated and, since 1950, 24 such trusts have been formed. The importance of river improvement work is expected to continue to grow.

In 1963 the Dandenong Valley Authority was created, by special legislation, with jurisdiction over the whole catchment of the Dandenong Creek (300 square miles) for purposes of arterial drainage, river improvement and flood protection. The Authority will in due course take over the Commission's Carrum Drainage District.

Finance

The net capital liability of the Commission at 30 June 1965 for works under its direct control was $252 million. Of this amount, $168 million was expended for irrigation and $24 million for rural, domestic and stock supplies, the costs being borne entirely by the State. The total liability for urban supply was $40 million, shared about equally between the State and the districts concerned. The remaining $20 million was for expenditure on flood protection and drainage districts ($4 million), and items such as loan flotation expenses, miscellaneous surveys and investigations, and buildings, plant and stores ($16 million).

Underground resources

Underground water. The investigation, exploration and survey of underground water resources in Victoria is carried out jointly by the State Rivers and Water Supply Commission and the Department of Mines. The Commission is concerned mainly with investigation of shallow waters in irrigation districts, while the Department covers all other work, including exploratory drilling to 5,500 feet. Underground water is the only available source of supply other than rain in some areas of the State. It is of particular importance in the western portions of the Wimmera-Mallee districts where annual rainfall ranges between 10 and 20 inches and there are no surface streams. Elsewhere underground water is used to supplement surface supplies and in places it may be the only developed source for town, industry, rural, domestic, stock or irrigation use.

The Wimmera and Mallee districts are situated over part of the Murray Basin where, to the west of the Wimmera River, Miocene marine limestones form an aquifer with water suitable for town supply and irrigation. It is used for this purpose at Kaniva, Murrayville and Nhill where yields between 10,000 and 60,000 gallons per hour may be obtained. North of Murrayville and Underbool the water in the limestones is more saline and in the extreme north it is too saline even for stock use. East of the Wimmera River to Lake Tyrrell and north of Swan Hill the marine rocks consist of marls and silts with calcareous beds capable of yielding saline water at less than 1,000 gallons per hour. These aquifers are not developed. Lower Tertiary swamp, deltaic and estuarine carbonaceous and ligneous sediments underlie and extend eastward of the marine rocks. Sands in these sediments contain water of greater or lesser salinity than that of the marine deposits. Yields from the estuarine aquifers are not known, but exploration and testing by the Victorian Mines Department are in progress. Overlying the marine and estuarine sediments there are aquifers consisting of Pliocene to Pleistocene terrestial, fluviatile and lacustrine sands and sandstones. Yields from these rocks are limited to windmill supplies. The quality is variable and in the north-west highly saline. East of the Avoca River the deposits of the Murray Basin are entirely non-marine and consist of terrestrial, fluviatile and lacustrine gravels, sands, silts and clays to a maximum depth of about 600 feet. Water from the sands and gravels is of variable quality. In places it is too saline for stock use, but the quality improves towards the east and it is used for town supply at Katunga and Wangaratta, and at Barnawartha, Bright and Chiltern where the deposits partly fill valleys in the bedrock of the highlands.

In the Otway Basin in the south-west of Victoria the Upper Cretaceous-Lower Tertiary sands have been developed for underground water supplies to Portland, Heywood, Port Fairy, Peterborough, Port Campbell and Timboon. In the central (Warrnambool and Koroit) and northern parts of the basin the waters are suitable only for stock. In the areas of better quality water the depth of the aquifers (2,000–4,500 feet) renders their development uneconomic except for town supply and industry. Oligocene to Miocene marine limestones occur in the south-central and western portions of the basin. The salinity of the water in the limestones is often less than that of the water in the sands beneath, but the limestone waters are generally hard. They are used in part to supply Portland and also for irrigation. Small underground water supplies are obtained from the Pliocene-Pleistocene deposits of ferruginous sands, marine sandy limestones and dune limestones in the west and from the dune limestones along the coast between Warrnambool and Portland.

In and around the structural depressions of the Port Phillip and Western Port Bay districts there are several small areas where underground water of good quality occurs. Among these are the Lower Tertiary sand aquifers at Anglesea which have not been developed as yet (1965); the Middle Miocene sands, shelly silts and limestones which have been developed for market garden watering south-east of Melbourne; and the Pleistocene sands and shelly silts on the Nepean Peninsula where the water is used for market gardens and pasture.

Irrigation. Brackish waters in the Eocene to Oligocene sands under the Werribee Plains have some potential for industrial use. The Western Port area has yielded large supplies of water from Tertiary marine and non-marine sands, and from fractured fresh basalt in some areas. Extensive use is made of water from the sands for irrigation of pastures and cash crops in the Koo-wee-rup Swamp area. Yields of up to 30,000 gallons per hour are common. In the Lang Lang area the water is used for town and industrial supply, but not as yet for irrigation. Stock supplies with one or two minor exceptions are available at shallow depth over the whole of the area.

The Gippsland Basin contains two main groups of water-bearing rocks, viz. the Lower Tertiary coal measures and marine sands, and the Upper Tertiary sands and gravels. Water from the Lower Tertiary rocks is frequently high in bicarbonate and therefore soft. It is used for irrigation at Bairnsdale and Yarram, and some abnormally hot water is used for industrial purposes at Maryvale. The Upper Tertiary rocks yield large quantities of very good quality water, mainly in the east-central part of the basin, where it is used extensively for irrigation. Stock supplies are generally available at shallow depth in rocks of various types and ages.

The pre-Upper Cretaceous sedimentary and igneous rocks of the highland areas generally yield small supplies of water suitable for stock. Exceptions to this are the Devonian sandstones of the Grampians where large supplies of good quality water may be obtained, and the better quality waters suitable for domestic use from the higher rainfall area of the Eastern Highlands of the State.

The Lower Tertiary volcanic rocks, mainly basalts, yield large supplies, up to 15,000 gallons per hour where the basalt is well jointed and little weathered, but only small quantities where the rocks are weathered. Where yields are large as in the west and south-west of Gippsland and on French Island the water quality generally is suitable for irrigation, but on the Bellarine and Mornington Peninsulas, Phillip Island and at Cranbourne the small yields of water are suitable for limited stock use only. Pliocene to Pleistocene volcanic rocks, basalts with tuffs and agglomerate occur extensively over the Werribee Plains and Western District and in valleys in the western half of the Central Highlands. Yields from these rocks are variable, the maximum recorded being 16,000 gallons per hour. From the weathered basalt yields are usually less than 1,000 gallons per hour. The quality is generally suitable only for stock but may be suitable for irrigation. Underground water derived from the later basalts of the stony rises west of Colac usually has high nitrate content.

Future programme

In July 1963 the Government announced plans for a long-term storage programme to cost a total of $75 million between 1963–64 and 1973–74. Three storages, namely Chowilla Reservoir (a River Murray Commission Storage), Lake Buffalo, and Lake Mokoan, appear in the list of dams and reservoirs projected in the table on page 161.

Other works are:

(*a*) Lake Bellfield on Fyans Creek (Grampian Mountains) to supplement the supply to the Wimmera-Mallee system (*see* page 175);
(*b*) An extensive channel enlargement and remodelling project in the Goulburn system (*see* page 174);
(*c*) Tarago Reservoir on the Tarago River to supplement supply to the Mornington Peninsula area;
(*d*) Nillahcootie Reservoir on the Broken River below Mansfield, to be used for irrigation;
(*e*) Lake Merrimu on Coimadai Creek, to be filled mainly from the Lerderderg River and Goodmans Creek, and used to supplement irrigation water supplies at Werribee and Bacchus Marsh; and
(*f*) Corop Lakes, two natural lakes near Rochester to be used as an adjunct to Waranga Basin for off-river storages for irrigation.

Queensland

Particulars of the rainfall pattern of Queensland are given in Year Book No. 37, page 1122. (*See also* the chapter Physical Geography and Meteorology of this issue.)

Administration

In Queensland, the right to the use and flow of non-tidal surface water contained in, or flowing through or past, the land of two or more occupiers, and all artesian and sub-artesian water vests in the Crown. Subject to certain reservations for local authority and other purposes, such water is controlled by a Commissioner of Irrigation and Water Supply. Private diversions from watercourses, artesian wells and, in certain declared areas, sub-artesian wells, are subject to licence by the Commissioner. Dams and weirs are constructed by the Commissioner to safeguard supplies in streams from which private pumping for irrigation takes place, and also to provide water for irrigation areas established by the Commissioner. For a description of the development of the present administration *see* Year Book No. 42 and earlier issues.

Irrigation—extent, systems and methods

In Queensland sugar cane represents in value nearly half the total agricultural production of the State. In 1964–65, 20 per cent of the sugar cane acreage was irrigated, representing 43 per cent of the total area irrigated in the State. Tobacco is another major crop, and the area irrigated during 1964–65 represented 96 per cent of the total plantings.

Most irrigation in Queensland is undertaken by farmers operating under licence to obtain water by pumping from streams or from natural underground storages. Over half the total area irrigated in Queensland is supplied from underground water. The main areas where these supplies have been developed extensively are the Burdekin Delta (Ayr-Home Hill area), the Pioneer Valley, Callide Valley, Lower Burnett (Bundaberg area), Lockyer Valley and Redland Bay.

Furrow irrigation is used for cotton, sugar cane, some tobacco, and miscellaneous row crops. Spray irrigation is used widely on fruit, vegetables, fodder crops, and the major part of the tobacco crop. Irrigation is required round-the-year for most of Queensland, as the timing and duration of the summer 'wet' season are too variable to enable a definite non-irrigation season to be fixed, as can be done in southern States.

AREA OF LAND IRRIGATED: QUEENSLAND, 1960-61 TO 1964-65

Season and division	No. of irrigators	Area irrigated (acres)							
		Vegetables	Fruit and vineyards	Sugar cane	Tobacco	Cotton	Other crops	Pastures	Total
1960–61	7,932	29,698	5,758	68,987	13,789	2,675	50,139	15,651	186,697
1961–62	8,433	32,139	6,537	74,541	13,671	2,040	59,947	20,544	209,419
1962–63	8,562	34,258	7,020	81,506	15,801	2,206	58,029	22,341	221,161
1963–64	8,930	36,329	7,315	98,204	15,079	2,717	65,078	27,360	252,082
1964–65—									
Southern Queensland	6,510	29,071	6,910	38,944	2,450	2,073	55,709	22,289	157,446
Central Queensland	668	1,119	277	210	22	2,033	12,336	2,747	18,744
Northern Queensland	2,132	4,830	905	81,402	10,698	42	3,589	3,188	104,654
Total, 1964–65	9,310	35,020	8,092	120,556	13,170	4,148	71,634	28,224	280,844

Areas under private irrigation

In two important areas irrigation has been developed by private pumping. In the Lockyer Valley, 30 miles west of Brisbane, about a third of an estimated total irrigable area of 60,000 acres is under irrigation. The valley comprises an extensive flood plain where heavy black alluvial soil thickly overlies gravels and sands carrying water suitable for irrigation, which is necessary for continuous agricultural production. A number of small weirs with a total storage of 1,340 acre feet have been constructed on Lockyer Creek by the Irrigation and Water Supply Commission; these also tend to augment and conserve underground supplies. The Lockyer Valley produces a substantial proportion of Queensland's onions, potatoes, pumpkins, lucerne, hay, green fodder, maize and dairy products.

The other important area is the fertile delta region of the Burdekin River, where the irrigated area is over 56,000 acres. The delta has ground water supplies at shallow depth, and these have been tapped to obtain supplies in the dry periods of the year. Sugar is the main crop irrigated, together with citrus fruits, pineapples, vegetables and tobacco. In 1940 the Burdekin River Trust was formed to safeguard the sugar areas of the delta from erosion and floods, and an irrigation research station studies the development of pastures and crops. In May 1965 the North Burdekin Water Area and Water Board were constituted for the purpose of utilizing part of the flow of the Burdekin River to replenish the subterranean water supplies of the northern part of the Burdekin Delta. A similar proposal for the South Burdekin Delta is at present under consideration.

Government irrigation areas and projects

The Irrigation and Water Supply Commission has constructed and operates four dams and forty-two weirs with a storage capacity of 529,626 acre feet. Water from these storages supplies the following four irrigation areas operated by the Commission and supplements numerous streams from which pumping for private irrigation takes place.

Mareeba-Dimbulah Irrigation Area. In 1952 an irrigation undertaking was established to assist tobacco production in the valleys of the Walsh and Barron Rivers. Tinaroo Falls Dam on the Barron River (330,000 acre feet) has been completed, and construction is proceeding on irrigation works to serve 78,000 acres (comprising 910 tobacco farms and 180 mixed farms) of which 49,000 acres will be irrigated. One hundred and sixty-five miles of channels have been constructed, and irrigation water from the dam is available to 549 farms. Tinaroo Falls Dam is also providing a regulated flow of water in Barron River at Kuranda for the generation of hydro-electric power at Barron Falls.

Burdekin River Irrigation Area. The Clare, Millaroo and Dalbeg sections of the Burdekin River Irrigation, Hydro-electric and Flood Mitigation Project have been completed. Located from twenty-five to sixty-five miles from the mouth of the Burdekin, these areas comprise 18,862 acres and obtain water from central pumping stations drawing from the river. Two storages of 7,670 acre feet and 2,550 acre feet capacity have been constructed about seventy-nine miles and seventy-two miles respectively from the mouth of the river. Originally developed for tobacco production, the growing of sugar cane is expected to predominate in future years.

Dawson Valley Irrigation Area. A scheme for the development of the Dawson Valley providing for the irrigation of 70,000 acres was inaugurated in 1923, but work was discontinued after three weirs had been built in this area. Their total storage is 10,280 acre feet, covering about sixty-one farms (4,894 acres) in production. Dairy products and cotton account for the major part of the production from irrigated areas. Further development of the scheme is dependent on the provision of additional storage works.

St. George Irrigation Area. This area comprises nineteen farms, of which a maximum of 3,275 acres can be irrigated from a weir on the Balonne River (8,200 acre feet). Fat lambs, wool, and fodder and cotton crops are the main products.

Several additional projects have recently been completed and work is in progress on others. Moogerah Dam (Warrill Valley Project) on Reynolds Creek (73,000 acre feet) is capable of serving some 11,000 acres of the Warrill Valley, and will provide water for the thermal power station now under construction at Swanbank, near Ipswich. Borumba Dam (Mary Valley Project) on Yabba Creek (34,500 acre feet) makes water available to maintain the town water supply for Gympie and allows extension of the area irrigated from the Mary River to about 18,000 acres. Callide Dam (37,800 acre feet) on Callide Creek, 9 miles upstream from Biloela, will provide cooling water for the Calcap power station and compensation water for maintenance of underground supplies along Callide Creek; provision has been made to increase the storage capacity to 87,000 acre feet. Leslie Dam (Upper Condamine Project), nearing completion on Sandy Creek, will have an initial capacity of 38,500 acre feet, with provision for later increase to 87,000 acre feet. Water from the dam will be available for irrigation of sections of the Darling Downs downstream the Condamine River as far as Cecil Plains and for a supply to the city of Warwick. A 61,000 acre feet dam under construction at Coolmunda (Macintyre Brook Project) will allow irrigation of up to 8,000 acres. Wuruma Dam (Upper Burnett Project), under construction on the Nogo River, will have a storage capacity of 157,000 acre feet for irrigation of 11,000 acres along 100 miles of the Burnett River. The Eungella Dam (Bowen-Broken Project), under construction on the Broken River, will have a storage capacity of 104,000 acre feet. It will provide cooling water for the Collinsville power station and irrigation water along the Bowen and Lower Burdekin rivers. The development of rivers constituting portion of the Queensland-New South Wales border, under the authority of the Dumaresq-Barwon Border Rivers Commission, is described on pages 166–7.

Underground water—Great Artesian Basin and other sources

The use of underground water supplies has been a very important factor in agricultural and pastoral development in Queensland. The Great Artesian Basin is the major source of stock water supplies over more than half the State. Elsewhere, supplies obtained at shallower depths, in porous, fractured or fissured rocks, are extensively used for domestic and stock purposes. Underground water also supports more than half the irrigated area in the State, supplies being obtained chiefly from alluvial formations along river valleys, and from river deltas, the most conspicuous example of which is the Burdekin River (*see* page 178).

Great Artesian Basin

Western Queensland, beyond the 20 inch rainfall belt, is predominantly pastoral and is mainly dependent for water supplies on artesian and sub-artesian bores and, where surface storage is not readily available, on excavated tanks. The Great Artesian Basin in Queensland corresponds approximately with the area lying west and south of the Great Dividing Range, excluding the Cloncurry mineral field and the Barkly Tableland. It comprises 421,000 square miles or nearly two-thirds of the total State area of 667,000 square miles.

Artesian water. Although the number of bores has gradually increased over the years, the total flow of all bores has declined from the peak flow of 351 million gallons a day. A report on the nature and structure of the Great Artesian Basin, presented in 1954, indicated that the output would continue its decline during the next sixty years, at which stage the flow from the remaining flowing bores would be of the order of 110 million gallons a day. The discharge from windmills, springs and other leakages, together with the underflow past the Queensland borders, would then be about 20 million gallons a day. It was further expected that the total discharge, of the order of 130 million gallons a day, would be in equilibrium with the recharge of the basin. It was anticipated that numbers of bores on higher ground would cease to flow during the next sixty years and the area served by the flowing bores would contract by perhaps twenty per cent.

Up to 30 June 1965, 2,899 artesian bores had been drilled, of which 1,893 were still flowing. The total depth drilled amounted to 4,049,041 feet and the estimated daily flow was 199 million gallons. Although very few bores exceed 2,000 feet in depth (the average depth is 1,397 feet) and a new bore greater than 4,000 feet deep is exceptional, the deepest bore recorded was sunk to 7,009 feet. Some bores which had been classified as 'ceased' have been inspected and found to be still flowing, while other ceased bores have responded to deepening and have recommenced flowing. Both the pressure and flow of artesian bores are steadily diminishing, the rate of decrease varying widely throughout the basin. Present average rates of diminution are: pressure, 1–2 feet of head; total flow, 2–3 per cent. per annum. The greater part of the artesian discharge is distributed by some 15,500 miles of open earth channels, from which a large proportion of water is lost by soakage and evaporation, less than 10 per cent being actually used by stock.

Although artesian beds underlie a large area of the State, only 79,000 square miles are primarily watered by bore drains. The remaining area is watered by artesian bores (with small or no flow and limited drains), sub-artesian bores, excavated tanks, dams and natural waterholes. In many districts artesian bores do not provide economical watering facilities because of depth, limited area to be watered, and difficult terrain for distribution of water by drains. The quality of artesian water from the greater part of the basin is not suited for prolonged use for irrigation on most soils, nor are the supplies sufficient for both large scale irrigation and stock-watering. Practically the whole of the final steady-rate discharge from flowing bores will be needed for the watering of stock.

Shallower supplies, which come from beds unconnected with artesian beds, are of variable quality and volume. These supplies are available at depths of less than 1,000 feet over a large area of the basin. Some 11,651 sub-artesian bores within the Great Artesian Basin have been registered in Queensland. An important practical consideration is that the main artesian beds are continuous and the sub-artesian beds are not continuous.

Bore Water Areas. The constitution of Bore Water Areas was inaugurated in 1913 to aid pastoral settlement in districts where large flows were available at a cost beyond individual capacity, and to conserve artesian supplies by fully utilizing flows from the existing bores on the land resumed for closer settlement. Bores and drains are constructed from loan funds repayable over a period of years. The areas are administered by local boards or by the Commissioner of Irrigation and Water Supply, acting as a board. Rates are levied to meet interest, redemption, maintenance and administration costs. Statistics for the year 1964–65 are: areas constituted, 74; administered by the Commissioner, 55; administered by local boards, 6; number abolished, 13; area benefited, 4,086,056 acres; average rate per acre, 1.64d. (1.37c); number of flowing bores, 56; total flow, 24,821,000 gallons a day; drains served, 2,510 miles.

Other underground sources

Outside the Great Artesian Basin, ground water supplies can conveniently be divided into two broad groupings, (*a*) those obtained in porous, weathered, fissured or fractured rocks, and (*b*) those obtained in unconsolidated sediments of Cainozoic age. In the first group, supplies, often within short distances, are widely variable both in quantity and quality, but are normally sufficient only for stock-watering purposes. Because storage is generally small, seasonal fluctuation of water level tends to be high, and this can have a significant effect on the supply available during dry seasons. Small to moderate irrigation supplies (up to a few thousand gallons an hour) are sometimes obtained and, in exceptional cases, particularly with basalts and limestones, supplies may be as much as 10,000 gallons an hour. The second group comprises the main irrigation supplies and, although a wide range may be found in the supply normally available from individual bores in any area, pumping rates as high as 10,000 gallons an hour are common. The availability of underground water has been investigated in a considerable number of alluvial valleys in south eastern Queensland and in a number of coastal areas, particularly in the vicinity of the estuaries of the Burnett, Pioneer and Burdekin Rivers, where underground water is the main source for irrigation of sugar cane.

Reference has already been made to the importance of underground water for irrigation in the Lockyer Valley (*see* page 178), and other areas in which irrigation supplies from alluvial formations have been extensively utilized include the Callide Valley, the Monto area, parts of Barker and Barambah Creeks, Warrill Creek, Cressbrook Creek, the Upper Logan River, and parts of the Condamine River and its tributaries. Government authorities do not normally undertake private drilling for landholders, but assistance is given in the location and development of ground water supplies through the provisions of '*The Farm Water Supplies Assistance Acts*, 1958 *to* 1965 (*see* page 181). This assistance has considerably accelerated the use of underground water for irrigation, and there is no doubt that there are many areas with a large potential for future expansion.

Stock watering

A predominant interest in the field of water conservation has been the provision of stock and domestic water supplies in Queensland's great pastoral areas, which contain more than a third of the Commonwealth's cattle and about a seventh of the sheep. In addition to the stabilization of water supplies in the pastoral areas, the provision of water along stock routes for travelling stock has received much attention in recent years.

Main stock routes. The Queensland Irrigation and Water Supply Commission acts as consultant and constructing authority to the Stock Routes Co-ordinating Board for watering facilities on stock routes. On completion, facilities are vested in local authorities for control and maintenance. From 1935, when the scheme was inaugurated, to 30 June 1965, 635 facilities had been completed, and at 30 June 1965, 33 facilities were under construction or investigation. A State-wide investigation is being carried out by the two authorities mentioned above to ascertain the general movement of stock, determine primary and secondary routes, register existing water facilities, and formulate a co-ordinated plan in regard to the provision of new watering facilities.

Channel Country stock routes. Under the *State Grants (Encouragement of Meat Production) Act* 1949–1954 the Commonwealth Government agreed to meet half the cost of providing additional watering facilities in stock routes leading into, along, and out of, the Channel country and on the route from Camooweal to Mount Isa. These routes connect with the main far-western route included in the State scheme inaugurated in 1935. This scheme was completed during 1962–63. The total number of watering facilities constructed since the commencement of the scheme was 37, at a total cost of $599,184.

Technical and financial assistance to farmers

'*The Farm Water Supply Assistance Acts, 1958 to 1965*' are designed to improve the standard of water supply installations on individual holdings, encourage greater development of individual irrigation schemes, provide greater stability of production, and avoid losses in time of drought as well as generally increase production. To achieve this purpose, the Acts authorize the provision of technical and financial assistance to landowners for the investigation, design and installation of approved works of farm water supply. All projects for which finance is provided under the Acts are carried out under Commission supervision, and for the payment of a small charge the Commission will supervise the construction of works designed by its staff, but for which the landowners do not require financial assistance under the Acts.

During 1964–65, 1,013 requests (665 for technical assistance only, and 348 for technical and financial assistance) were dealt with in addition to advice on a further 475 requests on ground-water supplies. An amount of $1,041,390 was approved for advances under the Acts in 1964–65, and the amount advanced was $783,612.

South Australia

Brief particulars of the climatic conditions in South Australia are given on page 1129 of Year Book No. 37. (*See also* the chapter Physical Geography and Meteorology of this issue.)

Administration

Water supplies, other than irrigation works, are under the control of the Engineering and Water Supply Department, which administers the Waterworks Act, 1886 governing the supply of water through mains in water districts for townships and farm lands. The Water Conservation Act, 1886 provides for the construction of storages in non-reticulated areas, and authorizes the Minister concerned to 'divert and impound the water from any streams or springs or alter their courses, and take water therefrom, or any other waters as may be found in, under, or on, any land entered upon for the purpose of supplying water to the inhabitants of any water district'.

Early in the history of the State, the rights to all running streams, springs and soaks were vested in the Crown. The Water Conservation Act was passed in 1886 and, up to 30 June 1965, more than 550 dams, tanks and rainsheds, together with 460 wells and 340 bores, had been built or acquired by the State at a total cost of $3,721,800. The rainsheds are timber frameworks roofed with galvanized iron to collect rainfall, which is delivered to storage tanks and is available for surrounding settlers and travellers. Rainshed catchments vary from a few hundred square feet to four acres in extent. Over most of the State extraordinary precautions are taken to counteract evaporation, and pipelines in preference to open channels and covered storages are used for this purpose. Meters are attached to practically all services to check usage by individual consumers.

Irrigation

Australian irrigation originated in the upper Murray of South Australia and the Mildura area of Victoria. South Australian irrigation commenced with an agreement between the Government and the Chaffey brothers in 1887 whereby an area of land at Renmark was made available for the establishment of certain irrigation works. In South Australia, irrigation is almost exclusively confined to the Murray Valley. Except for that held in various lock pools, no water from the Murray is stored in South Australia. Water is either pumped onto the land or gravitated from the river.

The two major authorities administering irrigation areas are the Department of Lands and the Renmark Irrigation Trust. The Trust is controlled by a local board of management consisting of seven members. This area differs from other South Australian irrigation areas in that the land is freehold instead of leasehold and is self-contained and self-controlled. Every settler is entitled to vote for the election of Trust members. The Trust maintains 100 miles of reticulation channels.

The following table shows particulars of the areas of crops and pastures irrigated in the various areas during 1964–65 and in South Australia as a whole during the seasons 1960–61 to 1964–65.

AREA OF LAND IRRIGATED: SOUTH AUSTRALIA, 1960-61 TO 1964-65

(Acres)

Season and authority	Vine fruits	Tree fruits	Citrus fruits	Other crops(a)	Pastures	Total
1960–61	26,071	22,706		34,198	19,048	102,023
1961–62	27,167	25,236		36,653	19,344	108,400
1962–63	27,384	26,876		36,745	21,808	112,813
1963–64	27,954	28,787		38,193	22,936	117,870
1964–65—						
Department of Lands Irrigation Areas—						
Orchard land—						
Berri	4,774	1,335	1,656	..	..	7,765
Cadell	508	230	197	..	..	935
Waikerie	1,654	805	1,437	..	..	3,896
Cobdogla	4,304	273	344	..	..	4,921
Moorook	264	145	263	..	..	672
Kingston	176	85	299	..	..	560
Mypolonga	..	312	468	..	..	780
Chaffey–Ral Ral Division	801	238	23	..	..	1,062
Cooltong Division	2	20	3	..	..	25
War service land settlement—						
Chaffey–Cooltong Division	392	37	549	..	..	978
Loxton	3,269	918	2,191	..	..	6,378
Cobdogla–Loveday Division	248	39	40	..	..	327
Reclaimed swamp land—						
Monteith	..	..	..	..	992	992
Mypolonga	..	..	..	..	1,306	1,306
Wall	..	..	..	..	517	517
Murray Bridge–Burdett Division	..	..	..	..	106	106
Mobilong Division	..	..	..	..	429	429
Long Flat	..	..	..	..	338	338
Neeta	..	..	..	..	561	561
Pompoota	..	..	..	..	425	425
Cowirra	..	..	..	..	571	571
Jervois	..	..	..	..	3,639	3,639
Total, Irrigation Areas	*16,392*	*4,437*	*7,470*	..	*8,884*	*37,183*
Renmark Irrigation Trust	5,402	1,896	1,650	352	..	9,300
Private landowners	6,492	14,641		28,443	27,080	76,656
Total, 1964-65	**28,286**	**30,094**		**28,795**	**35,964**	**123,139**

(a) Includes fodder and fallow land.

Water supply schemes

Adelaide Metropolitan Water Supply. Adelaide derives its water from six reservoirs in the nearby Mount Lofty Ranges, and by means of pumping stations and a pipeline from the Murray River at Mannum. The reservoirs have a storage capacity of 87,400 acre feet and the pipeline has a capacity of 74,000 acre feet a year.

To the north, the city of Elizabeth receives water from South Para Reservoir in the Barossa system and from the metropolitan storages. The consumption for the whole area for the year 1964–65 was 95,000 acre feet, equivalent to a consumption of 101 imperial gallons per head per day. The capital cost to 30 June 1965 was $97,705,528.

Country reticulated supplies. Areas extending to a distance of 90 miles north of Adelaide are supplied from the Warren, Barossa, and South Para Reservoirs (50,350 acre feet) in the Barossa Ranges. Agricultural towns and areas further north are supplied from Beetaloo,

Bundaleer and Baroota Reservoirs, and the Morgan–Whyalla Pipeline. There is a supplementary supply from the Mannum–Adelaide pipeline through the Warren Reservoir. The 223-mile pipeline from Morgan to Whyalla can carry up to 14,500 acre feet of water a year from the Murray River. Work is well advanced on a second main of more than double that capacity. A large part of Eyre Peninsula is supplied, through the 240-mile, Tod River Main and the 104-mile East Coast Main, with water from the Tod River Reservoir (9,160 acre feet), the sand beds of the Uley-Wanilla Basin, the Lincoln Basin, and the newly developed Polda Basin. Along the Murray River all towns are supplied from the river. Water from the river is also reticulated through adjacent farmlands for up to 30 miles. Surface and underground resources have been developed to supply most rural centres not covered by the larger schemes. Water conservation and distribution works in country districts to 30 June 1965 have cost $109,905,574 (exclusive of river control and irrigation works on the Murray River) and contain 7,770 miles of water mains.

Underground water

Surveys of groundwater resources are undertaken continually by geologists of the Department of Mines, the results being published in various bulletins and reports. The *Groundwater Handbook* published in 1959 by the Department provides a comprehensive and detailed review of the State's groundwater resources.

The occupied portion of South Australia is, on the whole, well endowed with underground water, and the extent of the several artesian basins is reasonably well known. There are also considerable areas in which groundwater occurs, notably in the south-east of the State where, in the Keppoch district, supplies exceeding 100,000 gallons an hour are not uncommon. Quality varies widely, but a great deal is at least useful for watering stock, and this is its major use.

The deepest portion of the Great Artesian Basin (in the north-east) is not extensively developed because development costs are high in proportion to the carrying capacity of the arid land. Deep boreholes have been drilled by the Government to provide watering places along stock routes, and pressure waters have been developed around the basin margin. These waters occur at comparatively shallow depth, as at Marree township, where the deepest flowing bore is 575 feet. In addition to the pressure waters, the non-pressure aquifers of the subsidiary basins provide pastoralists with stock water supplies which can be readily and economically developed. The use of the waters of the Murray Basin is essential to settlement in the Murray-Mallee country and in the south-east of the State, especially for farms and township supplies. Mount Gambier draws its water from Blue Lake, which is fed from the Basin. Bores supply a number of towns in this Basin, the deepest bore being 1,805 feet. The Lincoln Basin is now fully developed and is yielding up to 20 million gallons a week, which provide a water supply for the town of Port Lincoln on Eyre Peninsula. The Polda Basin near the township of Lock was brought into operation late in 1962. Investigations in the Basin are almost complete, and yields of 20,000 to 40,000 gallons per hour have been obtained from single large diameter boreholes. The present pumping plant has a capacity of seven million gallons a week. The water is reticulated to townships and farming properties on the upper Eyre Peninsula. Investigations are currently proceeding for the further development of this basin.

Pastoralists, farmers, market gardeners and others have been assisted with expert advice on drilling, and the Government maintains and operates twenty-five drilling plants, which to date have developed an underground water supply potential in excess of 150 million gallons of water a day throughout the State. The whole of the Murray River Basin has been examined critically to ascertain the extent of land which could be used for lucerne, and considerable tracts of previously undeveloped country in the upper south-east and Yorke Peninsula have been found to have usable water and are now being opened up. On Eyre Peninsula the Uley Basin has been in use as a source of groundwater since 1948. The water level has dropped below the critical point, however, and no groundwater has been taken from the Uley Basin since 1963. Lincoln and Polda Basins have been supplementing the water supplies on the Peninsula since 1960 and 1962 respectively. Investigations are being made in the South Uley Basin, and yields of up to 80,000 gallons per hour have been proved from single boreholes.

Farm water schemes

The Department of Mines gives assistance to individual farmers in the provision of supplies from underground sources, and the Department of Agriculture provides an advisory service on water conservation and irrigation designs, on farms, and on the use and suitability of underground water for irrigation and stock purposes. In addition, a great part of the farming areas is supplied with water under pressure from the extensive distribution systems connected to various reservoirs on the Murray River.

South-eastern drainage

In the south-east of South Australia it has been necessary to construct drainage schemes to dispose of surplus water from areas where a series of valleys or flats is separated by low ranges,

parallel to the coastline, which prevent natural drainage. The Millicent Drainage System, completed in 1885, reclaimed 100,000 acres. The South-Eastern Drainage Area System, which is controlled by the South-Eastern Drainage Board, comprises drains constructed by the Government at national cost, plus those undertaken by the Government in co-operation with the landholders. The area is bounded on the east by the State boundary, and on the west by the sea coast. It extends from about 55 miles north of Kingston southerly to near Millicent and Kalangadoo. Up to 1948 about 430 miles of drains had been provided at a cost of $1,441,752. These were of a developmental nature intended more to promote the rapid removal of floodwaters than to provide a complete system of drainage. Since 1948 the complete drainage of the Biscuit, Reedy Creek, and Avenue Flats in the Western Division has been in progress. The southern section of 260,000 acres, which involved the excavation of 8,100,000 cubic yards and the provision of 343 miles of new or enlarged drains, has been completed. Work is in progress on the northern section of 140,000 acres, where 68 miles of drains, involving the excavation of 2,944,070 cubic yards of material, have been completed. In addition, work is in hand for the drainage of 727,000 acres of land in the Eastern Division of the south-east, situated east of Bakers Range, and extending from near Kalangadoo to north of Naracoorte. As part of the first stage of the work (which involves the construction of a main diversion drain from Beachport to Struan), an existing drain from Beachport to Legges Lane (a distance of over 24 miles) has been enlarged, and work is proceeding between Legges Lane and Struan (a distance of 33 miles). A total of 5,839,940 cubic yards of material has been excavated. The capital cost of drainage in the South-Eastern Drainage Area System to 30 June 1965 was $15,877,400, and the length of drains constructed was 791 miles. An extensive system of private drains (many of which are connected to the drains constructed under Government authority) also exists in the south-east of the State.

Murray River Irrigation District

Excess waters from the irrigation of orchards in the Murray River Irrigation Districts are building up a perched water table, which is rising to the levels of the tree root system. Investigations have proved that adequate drainage can be obtained in the underlying limestone aquifer. The building up of groundwater pressures due to drainage in these aquifers is being studied, as the outflow of saline waters into the Murray River surface waters must be prevented.

Western Australia

Brief particulars of the climatic conditions in Western Australia are giveon on page 1133 of Year Book No. 37. (*See also* the chapter Physical Geography and Meteorology of this issue.)

Administration

The Minister for Water Supply, Sewerage and Drainage administers the departmental irrigation schemes under the *Rights in Water and Irrigation Act, 1914–1964*. He is advised by an Irrigation Commission representing the local irrigationists and governmental, technical and financial branches. The Minister for Works administers, under the *Country Areas Water Supply Act, 1947–1964*, the water supplies to about 200 towns and 4,200,000 acres of reticulated farmland, and also controls minor non-revenue producing supplies to stock routes and a few mines and agricultural areas with their associated communities. Five town supplies are administered by local boards under the *Water Boards Act, 1904–1964*, which provides a large degree of autonomy with ultimate Ministerial control.

Irrigation

Irrigation schemes have been established by the Government on the coastal plain south of Perth in the Waroona, Harvey and Collie River Irrigation Districts between Waroona and Dardanup, the water being channelled from dams in the adjacent Darling Range.

Harvey Weir with a capacity of 8,372 acre feet and Stirling Dam (46,191 acre feet) supply the Harvey Irrigation District, the rated area of which is 13,290 acres. Additional supplies are provided by Logue Brook Dam with a capacity of 19,717 acre feet. The Harvey District is linked to the Waroona Irrigation District, served by the damming of Drakes Brook and Samson Brook (9,292 acre feet). Waroona Dam, under construction with a planned capacity of 11,900 acre feet, will also serve this district, the rated area of which is 3,060 acres. Wellington Dam on the Collie River with a capacity of 150,107 acre feet serves an area of 10,870 rated acres in the Collie River Irrigation District.

During the past thirty years a centre of tropical agriculture has been developed at Carnarvon, near the mouth of the Gascoyne River. Private pumping from sands of the Gascoyne River is the principal source of irrigation water. The Government is developing up-river sources and

delivers water by pipeline to twenty plantations in the district. Vegetables and fruit for the metropolitan market are grown. A tropical research station is maintained at Carnarvon by the Department of Agriculture.

A project has been embarked upon to provide water supplies for irrigation in the area traversed by the Ord River in the Kimberley Division. The project provides for the eventual development of an area of 175,000 acres of land agriculturally and topographically suitable for irrigation, and comprises four stages, the first being the construction of a diversion dam to supply water for an area of 30,000 acres. The other stages are the building of a main storage dam with a capacity of 3.5 million acre feet (equivalent to more than 950,000 million gallons), the progressive development of the remaining 145,000 acres, and the construction of a hydro-electric power station. The diversion dam, at Bandicoot Bar, sixty-five miles south-east of Wyndham, capacity 79,000 acre feet, was completed in 1963. Some forty farms are included in the first stage of the project, and are being released progressively. On the twenty-six farms allotted so far, cotton and rice are the principal crops grown. The Western Australian Government has presented a case to the Commonwealth Government for financial assistance towards meeting the cost of the remaining stages of the Ord Irrigation project, and this is under consideration.

On the Liveringa flood plain, water is diverted from the Fitzroy River through Uralla Creek to a natural storage of about 1,200 acre feet, which, together with a dam on Uralla Creek (4,600 acre feet), provides for irrigation at Camballin sixty-five miles south-east of Derby. During 1964–65, 8,674 acre feet of water were used in the irrigation of sorghum and rice. Further development in this area is envisaged.

AREA OF LAND IRRIGATED: WESTERN AUSTRALIA, 1960-61 TO 1964-65

(Acres)

Season	Vege-tables	Fruit	Vine-yards	Cotton	Other crops (*a*)	Pas-tures	Total
1960–61 . .	9,076	8,335	897	(*b*)	5,591	24,652	48,551
1961–62 . .	9,596	8,840	972	(*b*)	4,235	25,036	48,679
1962–63 . .	9,375	9,588	924	(*b*)	4,447	27,167	51,501
1963–64 . .	9,166	10.425	966	1,526	6,153	26,958	55,194
1964–65 . .	9,379	11,710	1,081	5,496	5,259	30,110	63,035

(*a*) Includes fodder and fallow land. (*b*) Not available for publication, included with Other crops.

Country water supplies controlled by Department of Public Works and Water Supply

Since 1947 enlargement and extensions of the Goldfields and Agriculture Water Supply and the development of the Great Southern Towns Water Supply have been carried out, mainly in accordance with a project known as the Modified Comprehensive Scheme. Under this scheme water has been supplied to towns and farms in an area of 4.1 million acres in mixed farming (cereal and sheep) districts of Western Australia. The modified scheme was completed in 1961 at a cost of $20.6 million, of which the Commonwealth contributed $10 million under the *Western Australia Grant (Water Supply) Act* 1948. A further request was made by the State Government in 1963 for a grant of £5.25 million ($10.5 million) representing half the estimated cost of proposed extensions which would increase by 3.7 million acres the area served by the scheme. The Commonwealth agreed to provide assistance in the form of an interest-bearing loan up to a maximum of the amount requested, advances to be made during a period of eight years commencing 1965–66. Legislative authority for the loan is given by the *Western Australia (South-west Region Water Supplies) Agreement Act* 1965.

Mundaring Reservoir on the Helena River, twenty-six miles from Perth, is the source of water supplied to the Eastern Goldfields. It has a capacity of 62,435 acre feet and is connected to Kalgoorlie by a pipeline with extensions to towns and agricultural areas. At 30 June 1965 the Goldfields and Agricultural Water Supply was serving eighty-nine towns, and water was being reticulated to farms in an area of 4.2 million acres. The total length of pipelines was 3,940 miles and the number of services was 24,208. Consumption during 1964–65, including supplies drawn from local schemes and from the Metropolitan Water Supply, was 2,798 million gallons.

The Great Southern Towns Water Supply pipes water from Wellington Dam to towns on the Great Southern Railway from Brookton to Katanning as well as a number of other towns. At 30 June 1965 the Supply was serving twenty-two towns, the total length of pipelines was 419 miles, and the number of sevices was 7,752. Consumption during 1964–65, including supplies drawn from local sources, was 518 million gallons.

Ninety-two local schemes supply water from stream flow, dams, tanks, wells and bores, mainly to country towns. At 30 June 1965 the total length of water mains was 679 miles and the number of services was 21,322. During 1964–65 consumption was 1,570 million gallons.

Other country water supplies

As well as the schemes controlled by the Department of Public Works and Water Supply, there are five local Water Boards which also draw supplies from stream flow, dams, tanks, wells and bores. In addition, some local authorities supply water within their boundaries. The Forests Department and sawmilling companies operate schemes to supply water to their mill towns. Railways of the Commonwealth and State Governments make independent provision for supplies of water for their own purposes, although considerable additional quantities are consumed by the railways from other sources, such as those controlled by the Department of Public Works and Water Supply and the Metropolitan Water Supply, Sewerage and Drainage Board.

Underground water

Considerable use is made of underground water by individual farmers, pastoralists, market gardeners, etc., and it is estimated that over 50,000 bores are in use in the State. The quality of the water varies from place to place and much of it is suitable only for stock. However, artesian aquifers are tapped to supply or augment the town supplies of Perth, Bunbury, Busselton, Eaton and Denham, and non-pressure water is used in the public supplies of thirty-seven other towns.

Considerable advances in the knowledge of aquifers and quality of water in the main sedimentary basins has been made as a result of extensive geological surveys by oil exploration companies in recent years.

The Public Works Department and the Metropolitan Water Supply, Sewerage and Drainage Department are responsible for all developmental works, and for the geological survey for all exploratory works, as well as for investigating and assessing the State's groundwater resources, advising local Government authorities, private industry and individuals on groundwater problems, and supervising departmental drilling.

Groundwater projects have recently been completed for Halls Creek, Boyanup, Carnarvon, Exmouth, Lancelin and Bremer Bay, and work is in progress on others for Geraldton, Mandurah, Morawa, Yerecoin, Esperance, Albany, Jurien Bay, Guilderton, Meekatharra, Port Hedland, and additional supplies for the Perth metropolitan area. In addition, a long-term systematic exploratory drilling programme on the Coastal Plain Basin is continuing.

Tasmania

Brief particulars of the rainfall pattern in Tasmania are given on page 1136 of Year Book No. 37. (*See also* the chapter Physical Geography and Meteorology of this issue.)

Main purposes of water conservation and utilization

Because of the generally more adequate rainfall in Tasmania, scarcity of water is not such a problem as it is in most mainland areas, though not all streams are permanently flowing. The only large scale conservation by reservoirs is for hydro-electric power generation, but there are some moderately sized dams built by mining and industrial interests and by municipal authorities for town water supplies.

Until a few years ago irrigated areas were negligible except for long established hop fields, but there is a rapidly extending use of spray irrigation on orchards and pastures, and to some extent on potatoes and beans. Up to the present there has been almost complete dependence on natural stream flows, but the need for some regulating storages is now apparent. A few farmers are constructing storages of their own, and the extension of this practice is foreseen as the logical solution in most areas, as valleys are narrow and steep sided. Single large reservoirs cannot economically serve large areas of suitable land, as nearly every valley is separated from others by pronounced hills, prohibiting the construction of cross-country channels.

Underground water suitable for stock, minor irrigation works, and limited domestic use is exploited in the south-east, the midlands and north-western Tasmania. Supplies are mainly derived from fractured rocks by means of shallow bores which yield between 200 and 400 gallons an hour. On King and Flinders Islands water of variable quality suitable for stock and limited domestic use is obtained from aeolian sands. The township of Currie on King Island obtains up to 200,000 gallons a day for domestic use from this source. Underground water investigations, and almost all of the water boring in Tasmania, are carried out by the Mines Department.

Administration

In 1962 a new authority, the Metropolitan Water Board, assumed overall control of water supplies to the cities of Hobart and Glenorchy and the municipalities of Kingborough and Clarence, all of which, however, retain primary responsibility for reticulation. Water supplies to other areas are primarily the responsibility of local councils, subject to approval of plans and finance by the Rivers and Water Supply Commission.

While the Commission does not own the waters of streams and lakes, it is empowered to take them, or issue licences, subject to pre-existing statute and common law rights. These include water reserved for specific industries, municipal requirements, and ordinary riparian rights. The Commission is also concerned with drainage trusts' operations, river improvement, including repairs after flood damage, and stream gauging.

Regional water schemes

Three regional water schemes are in operation. The first draws water from the east bank of the River Derwent at Lawitta to provide domestic and industrial supplies in five southern municipalities, and the second, which increases existing supplies to Hobart, pumps water from the west bank of the River Derwent at Lawitta. These two schemes are controlled by the Metropolitan Water Board. In addition, the State Government has constructed a regional water scheme to serve the aluminium refinery at Bell Bay on the River Tamar and to supply several municipalities with bulk water for domestic and industrial purposes.

Potential sources capable of greater development without storage exist on the Derwent, South Esk, Huon, Lake, Mersey and Forth Rivers. There is also a great reserve of untapped permanent streams in the western half of the State, which is largely unsettled. Diversion to the eastern half of the watersheds is not regarded as practicable.

Industrial water schemes

Three principal industrial water schemes have been installed privately—for a paper mill near Lawitta on the Derwent River, for a paper mill at Burnie using water from the Emu River, and for a factory at Heybridge reticulating water from Chasm Creek. The State Government has constructed some water schemes for use primarily for industrial purposes. These include the scheme serving the aluminium refinery at Bell Bay referred to above, a storage supplementing the summer flows of the Kermandie River for use by a wood-pulping plant at Geeveston, and the recently completed Prosser River Scheme which supplies water to a sodium alginate industry at Louisville near Orford and supplements the water supply of the township of Orford.

Irrigation

There are no State irrigation projects at present, but the Rivers and Water Supply Commission is investigating the possibility of establishing a scheme near Cressy. The *Water Act* 1957 provides for irrigation works to be undertaken by municipalities and by trusts constituted for the purpose, but no such works have been undertaken to date. With the exception of the Lawrenny estate at Ouse, which is the largest single area under irrigation in the State, and also the only formally constituted irrigation district, there are no extensive schemes utilizing one common source of water supply in Tasmania. The larger proportion of the area under irrigation is watered by pumping systems.

Details of the areas of crops and pastures irrigated in Tasmania in the seasons 1960–61 to 1964–65 are shown in the following table.

AREA OF LAND IRRIGATED: TASMANIA, 1960–61 TO 1964–65

(Acres)

Season	Vegetables	Fruit	Hops	Other crops(*a*)	Pastures	Total
1960–61 . . .	2,103	3,311	1,364	1,787	10,369	18,934
1961–62 . . .	3,388	3,930	1,447	2,711	11,713	23,189
1962–63 . . .	4,100	4,446	1,465	2,839	11,435	24,285
1963–64 . . .	6,319	5,933	1,463	4,162	15,693	33,570
1964–65 . . .	8,302	5,955	1,553	4,318	14,194	34,322

(*a*) Includes fodder and fallow land.

Northern Territory

Some particulars of the climate and main topographical features of the Northern Territory are given on page 1138 of Year Book No. 37, and in this issue information on climatic conditions will be found in the chapter Physical Geography and Meteorology, and a brief outline of contour and physical characteristics in the chapter The Territories of Australia.

Administration

Under the *Control of Waters Ordinance* 1938–1962 of the Northern Territory natural waters are vested in the Crown. Where a watercourse or lake forms a boundary of any land alienated by the Crown, the beds and banks are deemed to remain the property of the Crown (except in special cases) and the diversion of water is prohibited except under prescribed conditions. There is a Water Resources Branch of the Northern Territory Administration under the control of a Director. The functions of the branch include systematic stream gauging, collection of data on surface and underground water supplies, planning of water use for irrigation and town water supplies, and flood prevention and control.

Under the *Water Supplies Development Ordinance* 1960–1963 the Water Resources Branch gives financial assistance to landholders for the development and improvement of water supplies on agricultural and pastoral leases. Another function of the branch, which is increasing in importance as it builds up a body of technical data and information about the Territory's water resources, is the dissemination of this knowledge by the provision of advice and technical assistance to professional drillers and to landholders.

Underground water

The marked seasonal rainfall over the whole of the Northern Territory is one of the basic factors affecting the pastoral industry, which provides a large proportion of the Territory's income. Underground water supplies are of great importance in the Territory, where most of the cattle numbers are dependent on underground supplies for three to five months each year, because of the inadequacy of surface water during the dry season.

Rainfall is one of the factors controlling cattle numbers, but geological features, controlling both soils and the storage of underground water, are equally important. In the northern-most portion of the Territory, which receives from 25 to 60 inches of seasonal rainfall a year, surface water supplies are, in general, adequate for the pastoral industry. Despite this, however, the area has a comparatively low carrying capacity for cattle, and the pastoral industry is concentrated more in inland areas where feed retains more nutritive value in winter, despite dry conditions. South from this well-watered northern-most portion, the Territory becomes progressively drier, with an average annual rainfall of only five inches at the margins of the Simpson Desert in the south-east corner. In the lower rainfall areas the search for potable underground water becomes exacting, but in the Ord-Victoria region and the Barkly Tablelands the best pastures are generally in areas where sub-surface conditions are suitable for the storage of underground water.

In the Ord-Victoria region the best grass lands overlie volcanic rocks and extend over some 10,000 square miles. Outcrops of sandstone, limestone and shale also occur in this area and underlie the volcanic rocks in most places. In general, these sedimentary rocks dip gently to the east, and sub-artesian conditions prevail. Underground water in this region is obtained from sandstone aquifers which yield supplies ranging up to 4,000 gallons an hour. Most of the bores are required in areas where the sediments are overlain by basalts; selection of bore sites is usually difficult. Supplies of shallow groundwater from joints, cracks and faults in the basalt are insignificant, and virtually all the bores obtain water from the sub-basalt sandstone aquifers. Successful bores in this area have ranged in depth from 200 feet to more than 900 feet. There are also small basins of younger sedimentary rocks in the region, some of which yield sub-artesian, and in places artesian, water and provide areas of good pastures.

The Barkly Tablelands, which extend into Western Queensland, overlie flat-lying limestone, sandstone and shale of the Barkly Basin. In most places underground water is under pressure (sub-artesian), but no flowing bores are known. Sandstones and beds of limestone with fractures and solution cavities provide a number of aquifers within the Basin. The hydraulic surface (to which pressure water will rise in bores) ranges between 500 and 600 feet above sea level, and adequate supplies for the watering of stock are available at depths ranging from 150 to 400 feet from the surface. The water from over 90 per cent of the bores is suitable for stock and over 50 per cent of it is suitable for human consumption. Investigations by the Commonwealth Bureau of Mineral Resources indicate that underground water supplies will be more than sufficient for the future development of the pastoral industry on the Tablelands.

In the Alice Springs district valuable pastures occur on a great variety of rock types, and from some of these very little underground water is available. Many shallow bores obtain water from alluvium near stream channels. There are also many successful bores in porous sands and limestone in Mesozoic and Cainozoic sedimentary basins and in some Upper Proterozoic and

Palaeozoic limestones and sandstones. Small supplies of underground water are obtained from bores intersecting joint zones in metamorphic rocks and granite of Archaean age. However, except in areas close to recharge, the water quality varies from moderate to poor.

The Water Resources Branch of the Northern Territory Administration has intensified research aimed at increasing the water supplies for Alice Springs and Darwin. Bores into the Palaeozoic Mereenie sandstone, twelve miles south of Alice Springs, have intersected sub-artesian aquifers at depths between 500 and 1,000 feet, and water from these bores is now used to supplement the existing town supply from alluvial basins. High-yielding dolomite aquifers of Lower Proterozoic age in the area sixteen miles south of Darwin are being developed to augment the Darwin water supply. Tennant Creek now has a water supply pumped from Cabbage Gum Basin, a small basin of alluvium and deeply weathered Precambrian rocks nine miles south of the town. A continuous check on the hydrological results of such pumping is maintained in order to adjust future yields from the basin.

At 30 June 1965, 4,946 bores and wells were registered in the Territory. Of these, 3,385 were for pastoral use, 291 were for agricultural use, 310 served town and domestic water supplies, 32 were in use on mining fields, 405 were investigation bores, 392 were Government established stock route bores, and 131 were classified under other uses. Registered bores which have been abandoned total 1,244. These include successful bores which have collapsed, and bores which were unsuccessful owing to drilling difficulties, or to insufficient quantity or poor quality of underground water.

Irrigation

There are no large water conservation projects in the Territory with the exception of the Manton Dam (12,700 acre feet), which serves Darwin with a reticulated supply. Some water is drawn from the rising main between the Manton Dam and Darwin for irrigation purposes, but the trend is for properties in this area to develop their own water supplies, either by boring or by pumping from watercourses or lakes. Investigations for additional water to augment Darwin's water supply are proceeding on the Darwin River, at Berry Springs, and in the McMinns Lagoon area. In the McMinns area a production bore has been drilled and is expected to yield one million gallons per day. This bore will be connected to the rising main from Manton Dam.

Hydrological investigations are being carried out by the Water Resources Branch to determine the available water and the best method of control and use in the potential irrigation areas of the Northern Territory. Since the start of stream gauging activity in the Northern Territory the Water Resources Branch has established 221 gauging stations. At 30 June 1965, 164 stations were in operation. Of these, 136 measure the volume of discharge of flowing streams, twenty measure the level of free standing water, and eight record tide fluctuations. One of the latter records tides in the Darwin harbour and another the tides in Melville Bay near Gove Peninsula.

Agricultural activity in the Territory is not extensive, being confined to the Darwin, Adelaide River, Coomalie Creek, Daly River, Katherine River and Alice Springs areas, with only small acreages being utilized. In the Territory thirty-three licences to divert water from streams have been issued. The total licensed area is 2,003 acres, but the actual area irrigated is less than this. There are also a number of farms irrigated from bore supplies, particularly in the Alice Springs area. Purposes for which irrigation water is used include the growing of fruit, vegetables, crops and pastures, and also dairying and mixed farming. Some 300 acres of irrigated rice were grown commercially on the Adelaide River in the 1964–65 season in a pilot farm project.

The Northern Territory Administration and the Commonwealth Scientific and Industrial Research Organization are investigating the potentialities of the Katherine area for agricultural production. In this area there are twelve licensed stream diversions covering an area of 220 acres, and investigations are continuing into the possibility of using the Adelaide and Daly Rivers for irrigation. A dam site is under investigation at Adelaide River Township. The Daly River appears promising for irrigation purposes as it has a minimum dry season flow of 275 cusecs and a reliable annual flow, without regulation, of 300,000 acre feet.

Papua and New Guinea

Rainfall in Papua and New Guinea varies considerably from approximately 250 inches near Lindenhafen (New Britain) and 230 inches at Kikori (Papua) to about seventy inches near Marienburg (New Guinea) and forty inches at Port Moresby (Papua). For a general description of these territories *see* the chapter The Territories of Australia, of this Year Book. Irrigation has not been developed on any organized basis owing to the availability of high rainfall and the nature of agricultural development.

The Territory of Papua and New Guinea is well served with large rivers deriving their water from heavy tropical rains and high mountains which rise to over 14,000 feet, but complete data regarding water resources are not available. At 31 July 1965 there were thirty-eight stream gauging stations in existence, and it is planned to increase this number as part of the overall establishment

of a basic stream gauging network. However, the difficulty of the terrain and the inaccessibility of some regions gives rise to considerable difficulties in the installation and operation of such stations. The available stream gauging records up to the end of 1964 are being prepared for publication.

The largest rivers in the Territory include the Fly (700 miles long, situated in the western division of Papua), the Sepik (700 miles), the Ramu (450 miles), the Purari (300 miles), and the Markham (110 miles). The main water conservation interest in New Guinea at present is the hydro-electric potential, which is extensive. An outline of schemes at present in operation is given in the previous chapter.