CHAPTER 23

WATER RESOURCES

RESOURCES, UTILISATION 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.

An article on droughts in Australia appeared in Year Book No. 54, pages 991–6.

For further details on geographical and climatic features determining the Australian water pattern, *see* the chapter Climate and Physical Geography of Australia; on water supply and sewerage in metropolitan areas, cities and towns, the chapter Public Finance; 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 management

Geographic background

General. Water resources are determined by rainfall, evaporation and physical features including soil, vegetation and geology. Chapter 2, Climate and Physical Geography of Australia, contains a detailed description of the climatic features of the country and a brief description of the landforms. In assessing Australia's water resources, dependability and quantity of supply must be considered, as well as amount.

Topography. The major topographical feature affecting the rainfall and drainage patterns in Australia is the absence of high mountain ranges over most of the continent. The Main Divide along the eastern coast is composed of sloping tablelands and uplands which generally do not exceed 1200 metres in altitude, the highest point being Mount Kosciusko at only 2228 metres. The western half of the continent is mainly a great plateau between 300 and 600 metres in altitude, while the interior consists of plains below 200 metres with a marked depression descending to 15 metres below sea level in Lake Eyre. It has been estimated that over half the country's area has a slope of less than one in one hundred.

Drainage. Only one-third of the Australian land mass has direct external drainage to the ocean. This occurs mainly in the east on the coastal side of the Main Divide and inland with the Murray-Darling system which benefits from the better-watered southern highlands. In the west, small water-sheds are formed by the Darling Range and the Hamersley and Kimberley plateaux, while in the north the raised rim of the Georgina Basin separates the shorter rivers of the Gulf of Carpentaria coast from the interior drainage of the Barkly Tableland. With the exception of the Murray-Darling system, most rivers draining to the ocean are comparatively short because of the proximity of the highland areas to the coast and, for the same reason, these rivers account for the majority of the country's average annual discharge.

The remaining two-thirds of the country are interior lowlands which exhibit endoreic drainage patterns characteristic of a desert regime, i.e. disconnected ephemeral river systems and terminal salt lakes. In central Australia, each isolated upland has a radiating drainage system which dies out on the surrounding plains, while on the western plateaux, older stream systems have been disrupted by barriers of alluvium or aeolian sand. Surface drainage is totally absent from some arid areas of low relief and pervious cover such as the limestone Nullarbor Plain.

Climate. Australia has an area of almost 7.7 million square kilometres and a latitudinal range of about 3700 kilometres, resulting in climatic conditions ranging from the alpine to the tropical. But two-thirds of this area is arid or semi-arid, a result of its location approximately between latitudes 10°S and 40°S, a zone which contains most of the great deserts of the world. Generally, the northern part of the continent comes under the influence of the Australian-Asian monsoon which results in a summer wet season and a winter dry season, while southern Australia is subject in winter to the rain-producing influences of the great atmospheric depressions of the Southern Ocean. Consequently good rainfalls (over 800 mm annually) occur in the northern monsoonal belt and along the eastern and southern coastal highland areas, which total only 12 per cent of the country's area, while nearly 30 per cent of the land mass receives less than 200 mm per annum.

The effectiveness of the rainfall over most of Australia is greatly reduced by marked alternation of wet and dry seasons, unreliability from year to year, high temperatures and high potential evaporation. Average annual tank evaporation rates increase generally from about 1,000 mm in the temperate south-eastern and south-western coastal areas of mainland Australia to over 3,300 mm in the arid centre; for further details *see* pages 54–55. In a twenty-year period, on the north-eastern coast, Mackay averaged 1,400 mm of rain per annum, but experienced one year of only 900 mm and another of 3,200 mm, a pattern of variability which is common throughout Australia; *see* also page 35.

Settlement. The availability of water resources controls, to a large degree, the possibility and density of settlement; and these in turn influence, through production and disposal of waste, the quality of the water. Most early settlements were established on the basis of reliable surface water supplies and, as a result, Australia's population is concentrated along the coast, mainly in the comparatively fertile, well-watered east, south-east and far south-west. As early as 1795, the effect of settlement on water quality was shown when an order was issued forbidding the pollution of the Tank Stream, the only water supply for the infant settlement at Sydney Cove. Fouling of the stream became worse as settlement increased until it was finally abandoned as a source of water in 1826. Today, the major water pollution problems in Australia are associated with the cities, irrigated agriculture and mining activities.

As settlement spread into the dry inland grazing country last century, the value of reliable supplies of underground water was realised and in 1857 the earliest known official investigation of groundwater resources was reported to the Victorian Legislative Assembly. Subsequently, observations of the disappearance of large quantities of the rainfall precipitated on the coastal ranges of eastern Australia led to the hypothesis of the existence of the Great Artesian Basin. Boreholes drilled from 1879 at Killara homestead in north-western New South Wales, at Anna Creek in South Australia and in Queensland at Thuralgoonie and Barcaldine, substantiated this theory. Since then, the waters of the basin have been a major asset to the pastoral industry. Supplies of groundwater have also been essential to the development of the mining industry in remote areas. At Tennant Creek in the Northern Territory, almost all water is drawn from unconsolidated sediments; the Pilbara iron mines in Western Australia depend heavily on water from the alluvium of the Fortescue, de Grey and Yule Rivers; and near Townsville in northern Queensland, groundwater is being used in the treatment of nickel ore from Greenvale. Despite improved conservation and management, full utilisation of surface water resources is within sight in many areas and, as population and standards of living increase, there will be continued pressure to further develop groundwater resources and to improve efficiency through conjunctive use of both ground and surface water resources.

Surface supplies

Distribution and volume. Permanent rivers and streams run in only a small part of the continent and only two-thirds of Australia is regarded as contributing to stream flow. There is practically no flow from the Western Plateau drainage division or from arid parts of other divisions. The total average annual discharge of Australian rivers has been assessed at 345 x 10^9 cubic metres. This figure comprises 133 x 10^9 cubic metres measured discharge and 212 x 10^9 cubic metres estimated for areas where there are generally no gauging records, and is small in comparison with river flows on other continents. In addition, there is a pronounced concentration of runoff in the summer months in northern Australia, whereas the southern part of the continent has a distinct, if somewhat less marked, winter maximum.

Variability of flow. Seasonal conditions are such that large rivers in the north carrying in excess of 30,000 cubic metres per second in high flood may cease to flow altogether in the dry season. Highest recorded annual discharges in many rivers such as the Murray and Burdekin are as much as 300 times the lowest. Even in areas of high rainfall, large variability in flow means that, for local regional development, most streams must be regulated by surface storage. However, in many areas of Australia, evaporation is so great that storage costs are high in terms of yield. Extreme floods, which can be expected over much of Australia, also add greatly to the cost of water storages, since the provision of adequate spillway capacity to ensure safety of the dam is often a major cost item. In some cases, such as the Fitzroy River in north Queensland, flood discharge in one week can exceed the average annual discharge. Dam sites are seldom available to enable such large volumes to be stored, so that rarely can major floods be conserved or controlled to any degree.

Potential development. The total quantity of surface water used or which can be diverted for use from rivers in Australia is about 16×10^9 cubic metres a year. This figure represents about 5 per cent of the total Australian river discharge and does not include the quantity diverted for hydro-electric power generation and other purposes which do not affect the quantity of water available. However, there are many factors which limit potential development to a fairly small fraction of the total runoff, including the great variability of river discharge, high evaporation and lack of sites for storage on many catchments. In the more favourable and more intensively populated south-east, development of surface water in some areas has already reached about 60 per cent of the total resources, which is considered to be close to the feasible limit. On the other hand, there is considerable scope for greater efficiency in water use and, as the cost of obtaining additional supplies increases, it can be expected that more effective use will be made of existing diversions.

Major dams and reservoirs

The table below lists existing major dams and reservoirs (in descending order of size), together with those under construction and those projected, at June 1973. The list is confined to dams and reservoirs with a capacity of 100 mil. cubic metres or more.

MAJOR DAMS AND RESERVOIRS IN AUSTRALIA

Name and year of completion	*Location*	*Gross capacity (mil. cubic metres)(a)*	*Height of wall (metres) (b)*	*Remarks*
		EXISTING DAMS AND RESERVOIRS		
Ord (Lake Argyle)	Ord River, near Wyndham, Western Australia	5,679	99	For irrigation and flood mitigation (flood storage above spillway level 30,800 mil. cubic metres) and hydro-electric power generation at later stage.
Eucumbene (1958)	Eucumbene River, New South Wales	4,798	116	Part of Snowy Mountains Hydro-electric Scheme.
Eildon (1927, raised 1955)	Upper Goulburn River, Victoria	3,392	79	Storage for irrigation and hydro-electric power generation.
Hume (1936, raised 1961)	Murray River, near Albury, New South Wales	3,084	51	Part of Murray River Scheme: storage for domestic, stock and irrigation. Hydro-electric power station.
Miena (1967)	Great Lake, Tasmania	2,309	18	Storage for Poatina hydro-electric power station.
Warragamba (Burragorang Reservoir) (1960)	Warragamba River, New South Wales	2,092	137	For Sydney water supply and flood mitigation. Hydro-electric power station.
Menindee Lakes (1960)	Darling River, near Menindee, New South Wales	1,812	18	Part of Darling River water conservation Scheme.
Burrendong (1967)	Macquarie River, near Wellington, New South Wales	1,680	76	For conservation, flood mitigation, and rural water supplies.
Blowering (1968)	Tumut River, New South Wales	1,631	112	Regulates discharges from Snowy Mountains Hydro-electric Scheme stations for irrigation. Hydro-electric power station.
Fairbairn (1972)	Nogoa River, Central Queensland	1,444	49	Storage for Emerald Irrigation Area.
Wyangala (1936, raised 1971)	Lachlan River, New South Wales	1,220	85	Storage for domestic, stock and irrigation purposes. Hydro-electric power station.
Burrinjuck (1927, raised 1956)	Murrumbidgee River, New South Wales	1,032	79	Storage for irrigation. Hydro-electric power station.
Talbingo (1971)	Tumut River, New South Wales	921	162	Part of Snowy Mountains Hydro-electric Scheme.

For footnotes *see* end of table.

MAJOR DAMS AND RESERVOIRS IN AUSTRALIA—*continued*

Name and year of completion	*Location*	*Gross capacity (mil. cubic metres)(a)*	*Height of wall (metres) (b)*	*Remarks*
EXISTING DAMS AND RESERVOIRS—*continued*				
Somerset (1959)	Stanley River, Queensland	893	50	Brisbane–Ipswich water supply and flood mitigation. Hydro-electric power station.
Jindabyne (1967)	Snowy River, New South Wales	688	72	Part of Snowy Mountains Hydro-electric Scheme.
Lake Victoria (1928)	Murray River, near South Australian border in New South Wales	680	..	Improved natural off-river storage; conserves supplies for South Australia.
Lake Echo (1956)	Lake Echo, Tasmania	545	19	Storage for Lake Echo, Tungatinah, Liapootah, Wayatinah and Lower Derwent hydro-electric power stations.
Clark (Lake King William) (1949, raised 1966)	Derwent River, Tasmania	540	73	Storage for Tarraleah, Liapootah, Wayatinah and Lower Derwent hydro-electric power stations.
Keepit (1960)	Namoi River, near Gunnedah, N.S.W.	426	55	For conservation and irrigation. Hydro-electric power station.
Arthurs Lake (1965)	Source of Lake River, near Great Lake, Tasmania	423	17	Part of Great Lake hydro-electric power development.
Waranga (1910)	Swamp, near Rushworth, Victoria	411	12	Off-river storage in Goulburn Valley for irrigation.
Tinaroo Falls (1958)	Barron River, North Queensland	407	47	Storage for Mareeba–Dimbulah Irrigation Area. Hydro-electricity generation.
Mokoan (1971)	Winton Swamp, near Benalla, Victoria	365	10	Storage for irrigation.
Glenbawn (1958)	Hunter River, near Scone, New South Wales	361	78	For conservation, irrigation and flood mitigation.
Rocklands (1953)	Glenelg River, Victoria	336	28	Part of Wimmera–Mallee domestic and stock water supply system.
Eppalock (1964)	Campaspe River, near Heathcote, Victoria	312	45	For irrigation and to supplement supply to Bendigo.
Cardinia (1973)	Cardinia Creek, near Emerald, Victoria	287	79	Part of Melbourne water supply storage.
Darwin River (1972)	Darwin River, Northern Territory	259	31	Darwin water supply augmentation.
Tantangara (1960)	Murrumbidgee River, New South Wales	254	45	Part of Snowy Mountains Hydro-electric Scheme.
Devils Gate (Lake Barrington) (1969)	Forth River, near Devonport, Tasmania	235	84	Mersey–Forth power development.
Avon (1927)	Avon River, New South Wales	214	72	Part of Sydney water supply storage.
Upper Yarra (1957)	Yarra River, Victoria	207	89	Part of Melbourne water supply storage.
Wuruma (1968)	Nogo River, near Eidsvold, Queensland	194	46	Storage for irrigation.
Glenmaggie (1927, raised 1958)	Macalister River, Gippsland, Victoria	190	37	Storage for irrigation.
Lake St Clair (1938)	Central Plateau, Tasmania	190	3	Improved natural storage for eight Derwent River hydro-electric power stations.
Wellington (1933, raised 1944 and 1960)	Collie River, Western Australia	185	37	For irrigation and domestic water supply.
Koombooloomba (1961)	Tully River, North Queensland	180	52	For hydro-electric and irrigation purposes.
Serpentine (1961)	Serpentine River, Western Australia	178	55	For Perth water supply.
Lake Brewster (1951)	Lachlan River, near Hillston, New South Wales	153	..	Storage of rural water supplies for lower Lachlan Valley.
Grahamstown (1969)	Grahamstown River, near Newcastle, New South Wales	153	12	Part of storage system for Newcastle and district water supply.
Cairn Curran (1956)	Loddon River, Victoria	149	44	Storage for irrigation.
Liddell (1958)	Gardiners Creek, Muswellbrook, N.S.W.	148	43	Cooling water for Liddell power station.
Eungella (1968)	Broken River, North Queensland	131	49	For cooling water and water supply at Collinsville and irrigation.
Rowallan (1967)	Mersey River, North Tasmania	130	43	Mersey-Forth hydro-electric power development.
Yarrawonga Weir (1939)	Murray River at Yarrawonga, Victoria	117	22	Diversion weir for irrigation.
Cethana (1971)	Forth River, near Devonport, Tasmania	108	110	Mersey-Forth power development.
Beardmore (1972)	Balonne River, near St George, Queensland	101	15	Storage for irrigation.

For footnotes *see* end of table.

MAJOR DAMS AND RESERVOIRS IN AUSTRALIA—*continued*

Name	*Location*	*Gross capacity (mil. cubic metres)(a)*	*Height of wall (metres) (b)*	*Remarks*
DAMS AND RESERVOIRS UNDER CONSTRUCTION				
Lakes Gordon and Pedder	South-west Tasmania	11,728	140	Storage for Gordon River hydro-electric power development.
	Gordon River	..	38	
	Serpentine River, Upper Huon River, (Scotts Peak)	2,963	43	
	Lake Edgar		17	
Dartmouth	Mitta Mitta River, Victoria	3,700	180	Additional regulation under River Murray Agreement, hydro-electric power station.
Copeton	Gwydir River, New South Wales	1,358	113	Storage for irrigation.
Monduran	Kolan River, near Gin Gin, Queensland	586	52	Storage for irrigation.
Ross River	Near Townsville, Queensland	417	35	Flood mitigation and water supply to Townsville (first and second Stages).
Glenlyon	Pike Creek, near Stanthorpe, Queensland	261	46	Storage of irrigation waters for Border Rivers Scheme.
South Dandalup River	Near Mandurah, Western Australia	207	41	Storage for Perth water supply.
North Pine	North Pine River, near Petrie, Queensland	205	44	To supplement supply to north Brisbane area.
Tallowa (Lake Yarrunga)	Shoalhaven River and Kangaroo River Junction, New South Wales	123	43	Sydney water supply and pumped storage power development.
DAMS AND RESERVOIRS PROJECTED				
Thomson	Thomson River, near Erica, Victoria	1,110	160	For Melbourne water supply and irrigation storage.
Lake Mackintosh	Mackintosh River, Tullibardine River, near Queenstown, Tasmania	900	77 25	Storage for Pieman hydro-electric power development.
Lake Pieman	Pieman River, Tasmania	655	122	Storage for Pieman hydro-electric power development.
Windamere	Cudgegong River, near Mudgee, New South Wales	346	69	Storage for irrigation.
Rosebery	Pieman River, Tasmania	125	75	Storage for Pieman hydro-electric power development.
Julius	Leichhardt River, near Mount Isa, Queensland	123	35	Water supply to Mount Isa mines, city and other mining development.
Googong	Queanbeyan River, New South Wales	119	59	For Canberra water supply.

(*a*) Includes 'dead water', i.e., water below the operational outlet of the reservoir. (*b*) As a general rule, the figures shown for height of wall (metres) refer to the vertical distance measured from the lowest point of the general foundations to the 'crest' of the dam, i.e., the level of the roadway or walkway on the dam.

Irrigation

For some brief remarks on the history of irrigation in Australia *see* issues of the Year Book prior to No. 39. An article on the conservation and use of water in Australia appeared in Year Book No. 37, page 1096 and subsequent developments have been covered in later numbers of the Year Book.

Water resources research

Comprehensive programs 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 utilisation of irrigated pastures by stock; and growth problems affecting plants and trees and reduction of salinity in river systems.

The Commonwealth Scientific and Industrial Research Organization conducts a number of research stations and laboratories at locations throughout Australia. The Division of Irrigation Research at Griffith (New South Wales) is investigating ways of 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, maize, safflower, sorghum, sunflower and vegetables. This Division is also studying the effect on water quality of its use for irrigation, especially in regard to contamination by herbicides and fertiliser runoff. The Division of Environmental Mechanics at Canberra (Australian Capital Territory)

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studies the physics of infiltration and redistribution of water in soil, evaporation from field crops, water movement and water stress in plants, and riceland hydrology. The Division of Land Resources Management is looking at the effect of clearing on the salinity of water from catchments in the south-west of Western Australia. Much of the work of the Division of Horticultural Research at Merbein (Victoria) is concerned with the problems of perennial horticultural crops grown under irrigation. Among other projects salt resistant rootstocks for grapevines and citrus are being evaluated, and the effects of salinity on the photo-synthetic performance and water use efficiency of horticultural crops are under investigation. The Division of Tropical Agronomy conducts research on a number of irrigated crops including grain legumes, grain sorghum, rice, and irrigated pastures at the Kimberley Research Station (Western Australia). The Division of Applied Geomechanics is studying the engineering aspects of water movement through earth embankments and the design of underground water tunnels. Water and salt flow through a slowly permeable deep clay soil, in response to a variety of irrigation regimes, are being studied by the Division of Soils at a site near Griffith, the objective being to model hydrology and salinity relationships with a view to prediction for irrigated clay landscapes.

The Irrigation Research and Extension Committee plays an important part in the agricultural activity of the Murrumbidgee Irrigation areas and associated districts, and the Coleambally Irrigation Area. 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 Service of New South Wales, the Rice Marketing Board of New South Wales, the Wine Grapes Marketing Board of New South Wales, co-operative and secondary industries, and farmers' organisations. 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 organisation; 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.

Two other organisations with similar objectives are the Victorian Irrigation Research and Promotion Organisation which operates from Shepparton, and the Murray Research and Extension Committee centred at Deniliquin.

Preservation of catchments

Since water conservation commences on the catchments it is becoming increasingly recognised that anything which interferes with catchment efficiency affects the quantity of water available for all purposes. Active steps are being taken to counteract soil erosion, to conserve soil generally, and to minimise the effects of floods, overstocking, bush fires, and the destruction of vegetative cover. All States and the Australian Government have initiated forestry policies which provide for reafforestation 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. This is exemplified in the multi-objective approach to planning now being adopted by some Australian authorities.

Water quality

Although some Australian rivers are naturally saline, the quality of surface water is generally good. However, most types of water pollution experienced in advanced industrial countries also occur in Australia. The main problems relate to sewage, industrial effluents and increasing salinity caused by agricultural activities.

Throughout Australia untreated or inadequately-treated sewage and trade effluents are discharged into inland and coastal streams used for town water supplies. Mining activities cause pollution by the discharge of ore-processing wastes or underground water into streams or by leaching from waste dumps as in the Molonglo River in New South Wales where zinc is leached from tailings and slime dumps at Captains Flat. In this case, such leaching also affects groundwater quality.

Salinity affects two main areas of the country. In south-western Australia, clearing of the natural vegetation has been followed by a rise in watertable levels with consequent increase in discharge of groundwater to river flow. As the groundwater has a naturally high salt content, both the soil and surface water have been adversely affected. About four million hectares of land have been rendered sterile and difficult to till because of soil salinity, and the salt flow into surface storages for local urban water supplies is now a cause for concern.

In south-eastern Australia, salinity problems have caused concern over recent years in the Murray Valley where the salt content of the river is less than 30 milligrams per litre total dissolved solids in the upper reaches and increases progressively down-stream. At Waikerie in South Australia, it exceeded 600 milligrams per litre for much of the irrigation season during the 1967–68 drought. In the extensive irrigation areas of the middle reaches, continual additions to the groundwater from channel seepage and irrigation water cause the watertable to rise. As the sedimentary beds were laid down under a marine environment, the groundwater is saline and when drainage does return to the river, it carries large amounts of salt. It has been calculated that the Kerang area alone contributes, via Barr Creek, about 185,000 tonnes of salt per annum to the Murray, and all drainage in the upper sector of the river a total of 250,000 tonnes. An additional 500,000 tonnes of salt are estimated to enter the river annually as a result of groundwater inflow in the sector between the South Australian border and Morgan. Subsequent use of this water for irrigation has problems. Citrus growers in some areas have had to install under-tree sprinkler systems to prevent defoliation of trees caused by saline water from overhead sprinklers.

Groundwater supplies

Groundwater is more important than surface water in about 60 per cent of the country. Despite the lack of detailed knowledge of groundwater resources in some areas, and limitations on their usefulness because of their high salinity in many areas, they provide about 20 per cent of Australia's water supply.

There are three main sources of groundwater.

(i) *Shallow unconsolidated sediments* which are found in the principal river and lake systems and as coastal dunes, deltas and narrow shoreline deposits. Since 1957 use has been made of the good-quality groundwater resources of the inland drainage systems of New South Wales, such as the alluvium of the Lachlan, Macquarie and Murrumbidgee Valleys. In central and western Australia good-quality water in unconsolidated sediment is rare because of lower rainfall and higher evaporation rates.

The coastal superficial reserves occur mainly in the better rainfall areas of the eastern part of the continent and of Tasmania and contain good-quality water. Since 1939 the Tomago Sands have been a source of water supply for Newcastle, approximately 9 million cubic metres a year being extracted since 1970—about 15 per cent of the total amount of water supplied by the Hunter District Water Board. In Queensland, the sugar industry has drawn on the extensive groundwater resources of the Burdekin Delta to such an extent, that it has become necessary to use surface water to recharge the aquifers artificially. In 1970, when 33,800 hectares of cane were under irrigation, with an estimated demand for 3,200 million cubic metres of water, some 350 million cubic metres of river water were pumped to artificially recharge.

(ii) *Sedimentary basins* which contain at least one major aquifer system. The Great Artesian Basin is the largest, occupying about 23 percent of the area of the continent and extending into South Australia, the Northern Territory, Queensland and New South Wales. In any one aquifer, the dissolved solids content of the waters is remarkably uniform. However, the high ratio of sodium to calcium and magnesium ions in water from the Great Artesian Basin can have an adverse effect on soil structure, rendering it impervious and making such groundwater unsuitable for irrigation purposes. Bores provide watering points for stock and domestic supplies over much of the basin and some 30,000 holes have been drilled, about 6,000 of which are still flowing. Between 1870 and 1970 the average annual bore discharge has been estimated at 600 million cubic metres of low salinity groundwater.

Marked reductions in flow prompted a series of interstate conferences on artesian water between 1912 and 1928. These stressed the need for controlled development and management of artesian water resources and resulted in the systematic collection and interpretation of data on Australian artesian basins. It is now considered that while many bores will ultimately cease to flow, others will assume a steady rate of flow, corresponding with the average recharge from rainfall absorbed by permeable outcrops. Diminution in flows from artesian bores has emphasised the need to eliminate wastage as much as possible. Licences issued for the construction of new artesian bores prohibit the distribution of water through drains and channels as formerly. and the supplies must be confined to the borehead or piped to appropriate watering points.

Other sedimentary basins providing water for stock and domestic purposes are: the Murray Basin covering 320,000 square kilometres in south-eastern Australia; the Daly, Georgina and Wiso Basins in the Northern Territory and Queensland; and the sedimentary rocks of the Carpentaria Province. Smaller basins in Western Australia, notably the Perth Basin, provide important domestic supplies for the more heavily populated parts of the State. Many of the larger towns, including Albany, Bunbury and Geraldton, and some major industries, depend entirely upon groundwater for their supplies. In Perth eleven per cent of the water supplied by the Metropolitan Water Supply, Sewerage and Drainage Board comes from groundwater (160 million cubic metres a year) and this proportion is expected to increase to 30–40 percent in the next decade.

Urban supplies are also obtained from the Amadeus Basin for Alice Springs; from numerous small basins in South Australia for Adelaide and Port Lincoln; and from the Otway and Gippsland Basins in Victoria. Sandstones of the Sydney Basin contain useful aquifers, but most of these basin sediments have a low hydraulic conductivity and contain saline groundwater.

(iii) *Fractured rocks* which are an important source of water particularly in the highlands of the south-eastern mainland and in Tasmania, parts of South Australia, central Australia, shield areas of Western Australia and the Kimberley Block. These aquifers usually yield relatively small supplies and quality may change rapidly over short distances. Generally, groundwater quality is good in northern and eastern Australia but poor over much of South Australia, the southern portion of the Northern Territory and the south-western part of Western Australia, where the low rainfall and high evaporation, coupled with low permeability, account for the variability and poor quality of the groundwater.

The quality of groundwater varies considerably and sources are subject to pollution in much the same way as surface supplies. Locally, groundwater has also been polluted by poor drilling techniques which allow contamination of fresh or lower salinity waters by more highly saline waters, and also by the discharge of industrial wastes into underground drainage bores. The Port Phillip Basin has the problem of discharge of industrial and domestic waste underground, and in the Western Port Basin there has been control of groundwater withdrawal since 1968 to prevent overdraft and salt-water intrusion.

PRINCIPAL WATER-BEARING BASINS IN AUSTRALIA

Name	*State*	*Geological age of chief aquifers*	*Approximate area*	*Depth to pressure water*
			square kilometres	metres
Great Artesian	Queensland, New South Wales, South Australia and Northern Territory	Mesozoic	1,751,480	Up to 2,130
Canning	Western Australia	Mesozoic-Palaeozoic	388,500	30 to 550
Murray	Victoria, New South Wales and South Australia	Miocene-Eocene	320,000	30 to 400
Georgina (including Barkly and Daly)	Northern Territory, Queensland	Cretaceous, Ordovician, Cambrian, and Upper Proterozoic	279,720	45 to 305
Eucla	Western Australia, South Australia	Pliocene-Miocene	191,660	90 to 610
Carnarvon	Western Australia	Cretaceous, Permian	116,550	60 to 1,220
Perth	Western Australia	Recent, Jurassic	54,390	60 to 760
Western District (Otway)	Victoria	Pleistocene-Upper Cretaceous	33,670	30 to 1,370
Basins of Ord-Victoria region	Northern Territory, Western Australia	Mainly Cambrian, and Permian	31,080	60 to 305
Pirie-Torrens	South Australia	Recent, Pleistocene	23,310	Up to 180
East Gippsland	Victoria	Pleistocene-Eocene	9,060	60 to 1,070
Adelaide	South Australia	Recent, Oligocene	2,850	60 to 180

Conjunctive use of surface and groundwaters

Although utilisation of water resources in most areas of Australia has in the past tended to concentrate on either ground or surface water sources it is becoming increasingly necessary to use all the water resources of a region in conjunction, even in some cases importing water from outside the region. This is known as conjunctive use. Such an approach generally makes more water available for use than would be the case with independent use of the various sources as best use is made of the benefits of each type of resource.

Most conjunctive use schemes or proposals involve ground and surface water with a surface storage constructed on the stream and in some cases provision for artificial recharge of aquifers located beneath or near the area of demand, although in many cases natural recharge facilities are adequate. A comparison of some of the advantages of ground and surface supply facilities is given below.

Surface Storage	*Groundwater Storage*
small capacity	large capacity
quick response	slow response
high capital cost	low capital cost
low operating cost (gravity supply)	high operating cost (requires pumping)
high evaporation losses	low evaporation losses.

It can be seen from this comparison that an ideal plan of utilisation of water resources in a new area consists of first developing groundwater resources due to their low capital cost (the cost of drilling and installing pumps as opposed to the cost of a major dam) and the later construction of a dam to increase the amount of water available for recharge of the groundwater storage and where appropriate for alternative supply by pumping from the river. Alternatively the surface storage can be utilised in periods when plenty of water is available and the groundwater supplies drawn on when the surface supply is unable to meet the demand. When water is again available (following say rainfall and recommencement or an increase in streamflow) use can then revert partly or wholly to the surface supply which the groundwater supply has recharged.

The advantages and disadvantages of each type of source of supply can be described in economic terms both for development and operation. Given a basic objective, such as minimum annual cost, analysis techniques exist to develop operating strategies that will achieve this objective in the best way, given the constraints that may apply such as minimum level of supply or of reliability.

The conjunctive use concept may be applied over a period of some years to allow the cost of development to match the amount of return from the development, or to allow smoothing out of long-term fluctuations in the weather pattern, or it may be applied over an annual timespan where strongly seasonal conditions make surface water available for only a few months of the year and reliable and adequate groundwater supplies are required for the remainder of the year. In Australia to date, the level of development of water resources has been such as not to require the development of a conjunctive use approach, but as the degree of overall development proceeds and as the value of water rises there is increasing pressure for greater amounts of water to be supplied at higher levels of reliability. In the Pilbara region of Western Australia design is proceeding on a major conjunctive use scheme to supply water to several mining towns to meet both urban and industrial demands, both of which require a high level of reliability.

In this situation, with mean annual rainfall of 300 millimetres and annual potential reservoir evaporation of 3000 millimetres, a real advantage in using groundwater supplies is that of avoiding a large surface reservoir in which high evaporation rates would lead to concentration of salts in the water to make it too brackish for use. A small dam will allow utilisation of surface water in periods when the river is flowing together with recharge of aquifers and utilisation of groundwater for the remainder of the time. In the Namoi Valley in New South Wales and the Callide Valley in Queensland, irrigation from groundwater sources is causing falls in the water table and investigations are being made into conjunctive operation of the ground and surface storages to enable the current development of these areas to meet current demands.

Often concomitant with conjunctive use is the development and operation of facilities for artificial recharge of the groundwater aquifers. In the Burdekin Delta in Queensland the first major artificial recharge scheme in Australia is operating and research and investigation is being conducted into problems relating to this scheme. In this particular situation the limiting factor presently is the rate of recharge and although strongly seasonal there is still adequate unregulated flow in the lower Burdekin River to meet the requirements of the recharge scheme.

Because of the requirement of extremely high reliability of supply of water for urban demands a number of Australian towns and cities are using or considering using ground and surface supplies in conjunction. At present the Western Australian town of Bunbury draws all its water from underground. With future growth of the town it is likely that its water demand will exceed the mean annual recharge of aquifers in its immediate vicinity. Although the nearby Preston River has a very seasonal flow, dropping to almost zero in summer, adequate supplies could be drawn from run-of-river during the winter months. This would leave demand on the aquifer only during summer, allowing recharge to take place over winter. Similar conditions exist in a number of other towns and cities in Australia.

Water management

Australia's water resources are managed by about 800 irrigation authorities, metropolitan water boards, local government councils and private individuals. State authorities dominate the assessment and control of water resources as, under the Australian Constitution, primary responsibility for management of water rests with the individual State governments. The Australian Government participates indirectly through financial assistance or directly in the co-ordination or operation of interstate projects through bodies such as the River Murray Commission and the Snowy Mountains Hydro-electric Authority.

The water field is an area of major public sector activity because the storage and distribution of water must take place on a large scale which usually involves costly projects. Investment in water, sewerage and irrigation facilities over the last ten years has tended to consume about 20 per cent of gross fixed capital expenditure by public authorities. Of this total expenditure, 10 per cent has been devoted to irrigation investment. In most cases major storages are intended to be multi-purpose although the pattern of river flow in Australia often makes it difficult to reconcile requirements for irrigation, hydro-electricity and flood mitigation. Increasing problems are being encountered in the provision of adequate supplies for the major cities, and moves for the development of additional catchments tend to conflict with rural requirements.

The proper management of water resources is essential to the maintenance of both quantity and quality of supplies and the ecological balance of the environment in general. Since water is an agent of erosion and deposition, the consequences of its misuse appear sooner than with non-dynamic resources, and with more urgent impact. as in erosion, flooding, siltation and pollution. Conversely, land management practices can interfere with catchment efficiency through overstocking, bushfires and the destruction of vegetation cover. All States and the Australian Government have initiated forestry policies which reflect the strategic watershed location of the main Australian forest lands, upslope from urban centres and near areas of intensive agricultural land use.

Planning of land use on catchments can obviate or reduce siltation, runoff of agricultural materials and pesticides, and the discharge of industrial waste and the effluents of urban areas. Such land use control has been necessary in the Adelaide catchment area where the increased rate of subdivision and industrial development, intensive animal husbandry, intensive agriculture, quarrying and recreation are potential factors in water quality impairment. The catchments of the Snowy Mountains have been kept free of grazing and the associated practices of burning and pasture improvement, to provide for the Snowy Mountains Hydro-electric Scheme and the Kosciusko National Park. On the other hand, the failure of planners in the past to consider the long-term effect of reservoir-construction on streams has often affected the breeding places of inland fish and waterfowl with a consequent reduction of these native populations.

Consequently, in 1973 the Australian Government formulated a national approach to water resources management within the framework of overall economic, environmental and social planning and with the following objectives:

(*a*) the provision of water supplies, adequate in quantity and quality—
  - (i) to meet the needs of people throughout Australia, including the provision of satisfactory domestic and urban environments;
  - (ii) to meet the needs of, or to stimulate primary and secondary industry in such a way as to be compatible with projected market outlooks for the commodities concerned, and compatible with the resources and characteristics of the region concerned;

  In the rural sector there is likely to be emphasis on promoting stability and growth in established areas.

(*b*) the development and management of water resources so that where practicable, other purposes such as flood mitigation, power generation, recreation and improved wildlife habitat are achieved in parallel with the purposes referred to above;

(*c*) the development of waste water treatment facilities in conjunction with water supply systems and the encouragement of recycling and re-use;

(*d*) implementation of a program of public education and involvement aimed at ensuring on the one hand, a proper understanding of public responsibility in the use and management of water and, on the other hand, an acceptance by all relevant authorities that the public have a right to involvement, and a contribution to make, in the planning and management of water enterprises;

(*e*) the allocation of costs so that wherever feasible the user pays the full cost attributable to him, on the basis of appropriate cost allocation techniques. This should be phased in at a rate designed to avoid undue hardship;

(*f*) irrespective of the details of cost allocation, the adoption of water pricing policies which enable needs to be met at a fair and reasonable cost, but which provide an incentive to all water users to avoid wasteful or environmentally-harmful practices;

(*g*) the continued development of policies and practices, as far as possible consistent throughout Australia, aimed at achieving appropriate water quality objectives and the highest practicable level of pollution abatement;

(*h*) the inclusion in these policies of the general objective that direct costs, or costs related to loss of amenity, attributable to pollution should be borne by the polluter. Although the immediate and full adoption of this principle may not be feasible, it is nonetheless a goal to be pursued;

(*i*) the zoning of flood-prone land, with a view to its orderly management;

(*j*) the maintenance of an adequate sample of undisturbed aquatic environments as reference areas and the preservation of appropriate wetlands for the benefit of native wildlife.

National and interstate aspects

In terms of the Australian Constitution primary responsibility for control and conservation of water rests with the individual State governments. The Australian Government is responsible for matters relating to water in its Territories. However, because political boundaries sometimes intersect river valleys and underground water basins, co-operation between governments has been necessary to develop resources in certain cases. Specific examples of Federal-State and interstate co-operation and approach are given in the following paragraphs.

Australian Water Resources Council

A widening awareness of the need for a co-ordinated Australian approach to water utilisation led to the formation in 1962 of the Australian Water Resources Council by joint action of the Australian and State governments. The Council comprises the Australian and State Ministers primarily responsible for water resources, with the Australian Minister for the Environment and Conservation as Chairman, and is serviced by a Standing Committee consisting mainly of the heads of Departments responsible to these Ministers, and by three permanent technical committees with numerous supporting groups.

The primary objective of the council is the provision of a continuing comprehensive assessment of Australia's water resources, and the extension of measurement and research to provide a sound basis for the planning of future development. In terms of its objectives and functions, the council has dealt with a wide range of topics, making recommendations and stimulating action by appropriate bodies.

Following a recommendation by the council, the Australian and State governments in 1964 adopted an accelerated program of surface and groundwater investigations to establish a comprehensive network of stream gauging stations and to improve knowledge of underground water resources. Besides implementing its own accelerated program in the Northern Territory, the Australian Government has assisted State programs by making grants available over successive three-year periods. In 1973, $15.1 million was allocated to the States to assist in implementing programs over the next triennium.

Since 1968 the Australian Water Resources Council has administered a Water Research Fund for which the Australian Government has provided a total of $2.4 million. This research program is aimed at improving the efficiency of water management in Australia by complementing research already being undertaken by other agencies. Current research deals with such topics as: artificial recharge of groundwater, improvement of water sampling and analysis techniques, compilation of Australian water quality criteria and water use efficiency studies.

The Representative Basins Program, a joint Australian-State government venture, was initiated in 1965 as a co-ordinated study of the hydrology of 93 Australian catchments representative of the most typically-occurring complexes of climate, geology, landform, soils and vegetation in the Australian environment. Its aim is to collect and analyse data to improve our quantitative understanding of the water balance in Australian catchments with the following specific objectives:

(*a*) national water resources assessment, by improved interpolation between gauged catchments in the Australian stream gauging network;

(*b*) improved basis for design of engineering structures (dams and weirs, road and railway bridges and culverts) in ungauged catchments;

(*c*) prediction of the hydrologic effects of changes in land use and management; and

(*d*) provision of a bank of hydrological data which will be of fundamental importance to management, ecological and environmental studies.

In an attempt to collate available data on Australia's water resources, the following publications have been issued by the council.

A review of Australia's water resources (*Stream flow and underground resources*) 1963. *A review of Australia's water resources* (*monthly rainfall and evaporation*). (Bureau of Meteorology, 1969). *Water Resources Newsletter* (twice-a-year). *Hydrological Series* (listing results of Advisory Panel enquiries). *Technical Paper series* (listing results of research projects). *Inventory of water resources research in Australia* (published annually). *Stream gauging information* catalogue. *Groundwater resources of Australia.*

Murray River scheme

The Murray River and its tributaries form the largest river system in Australia. The catchment is approximately 1,057,000 square kilometres, 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 approximately one-fourteenth of South Australia. The Murray proper is 2,520 kilometres long. Its main tributaries are the Darling (1,390 kilometres) and the Upper Darling (1,140 kilometres, *see* page 27), the Murrumbidgee (about 1,550 kilometres), and the Goulburn (about 550 kilometres). The average annual flow of each of the chief contributory streams is as follows: Upper Murray, including the Mitta Mitta and Kiewa Rivers, 4,711.9 mil. cubic metres; Darling River, 3,478.4 mil. cubic metres; Goulburn River (including Broken River), 3,182.4 mil. cubic metres; Murrumbidgee River, 2,528.6 mil cubic metres; and Ovens River, 1,561.6 mil. cubic metres. 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 historical events leading up to the River Murray Agreement (1915) by the Governments of Australia, 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 58.0 mil. cubic metres a month in the winter months to 165.3 mil. cubic metres a month in the four summer months of maximum demand—the total amounting to 1,546.8 mil. cubic metres 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 542.7 mil. cubic metres per annum would be added to the Murray River (*see* Snowy Mountains Hydro-electric Scheme, page 875) 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 616.7 mil. cubic metres to approximately 3,083.7 mil. cubic metres. 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 Australia 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 6,167.4 mil. cubic metres capacity at Chowilla in South Australia was ratified by legislation in the Australian and State Parliaments and came into force on 30 April 1964. However, in view of the greatly increased costs by the time the project came to tender in 1967 and other significant factors (including water quality in the Lower Murray) which had arisen in the interim, the River Murray Commission resolved that, pending further investigations, construction of Chowilla Dam should be deferred. Further investigations then followed, including a re-assessment of the likely yield from both Chowilla and alternative storages on the Upper Murray and Mitta Mitta Rivers. Following careful consideration of this re-assessment, the River Murray Commission in February 1969 agreed that a 3,700.4 mil. cubic metres storage at Dartmouth on the Mitta Mitta River provided the greatest overall benefits in terms of cost and yield and should be the next development of the resources of the River Murray. The question of sharing the benefits could not be resolved by the Commission and was therefore referred to the respective Governments. Subsequently, Ministers representing the four Governments concerned met in March 1969 and agreed on conditions for the construction of the Dartmouth Project and for the sharing of the increased system yield between Victoria, New South Wales and South Australia. Among other things, the meeting of Ministers agreed to continue the Menindee Lakes Agreement in perpetuity.

The Australian Government has offered to assist the three States with financing the project by way of a loan to the extent of 50 per cent of each State's contribution. At the same time it will make its own quarter contribution of the cost of the project.

The Acts ratifying the amendments to the River Murray Waters Agreement were proclaimed by the four contracting Governments on 30 March 1972, and work commenced on the construction of Dartmouth Dam on 1 April 1972.

Inflows to the Murray system during the winter and spring of 1972 were well below average and by September it was apparent that the 1972–73 year was likely to be a severe drought year.

Irrigation diversions had begun earlier than usual and Hume Reservoir did not fill, a maximum of just over 2,467.0 mil. cubic metres, 81 per cent of the available storage, being reached early in September. Although a period of restriction was not formally declared, New South Wales and Victoria undertook to restrict their diversions from River Murray Commission resources to agreed amounts. Water accounting commenced on 1 October 1972 to ensure an equal sharing of available water between these two States.

In contrast to the 1971–72 year, the dry and stable weather conditions led to extensive periods of close river regulation until the onset of rain in late January, 1973. The drought was effectively broken by further general rains in March and April. Of the total flow of the River Murray and its tributaries in the year 1972–73, 3,944.7 mil. cubic metres were diverted and impounded by the State of New South Wales and 3,587.0 mil. cubic metres by Victoria, while 555.1 mil. cubic metres were diverted by South Australia. During the year 3,052.9 mil. cubic metres were passed to South Australia. The total diversion for irrigation, town water and other purposes from the River Murray itself by New South Wales was 1,715.8 mil. cubic metres and by Victoria 1,697.3 mil. cubic metres.

River Murray Works. Dartmouth Dam when completed in 1977 will store 3,700.4 mil. cubic metres of water and will be the largest reservoir in the River Murray system. It will complement Hume Reservoir, situated just below the junction of the Murray and Mitta Mitta Rivers, which has a storage of 3,059.0 mil. cubic metres and forms a lake 20,234 hectares in area.

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 71 cubic metres a second, serving 728,435 hectares of land in New South Wales. The Yarrawonga Channel, on the Victorian side, has an off-take capacity of 35 cubic metres a second, serving 121,406 hectares. Not all of this area is irrigated.

Adjoining the river in New South Wales, and 56 kilometres from the Murray–Darling junction, Lake Victoria storage, with a surface area of 11,198 hectares, 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 80 kilometres 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 24 kilometres.

In addition to the works carried out under the auspices of the Commission, the separate States have constructed thousands of kilometres of distribution channels and have provided a number of storages on the tributaries, thereby contributing materially to the large amount of irrigation development in the Murray Basin. The main storages are: New South Wales—Menindee Lakes Storage (Darling), Blowering (Tumut), Burrinjuck (Murrumbidgee), Copeton (Gwydir), Keepit (Namoi), Burrendong (Macquarie) and Wyangala (Lachlan); Victoria—Eildon (Goulburn), Waranga (Goulburn), Mokoan (Broken), 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.

New South Wales–Queensland Border Rivers Agreement

The catchments for the border streams of New South Wales and Queensland (5,180 square kilometres) extend to the granite areas in the vicinity of Tenterfield (New South Wales) and Stanthorpe (Queensland), and elevation rises to 914 metres. Average rainfall is 762 millimetres. 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 stabilise 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 provided 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 Border Rivers Commission 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 was also made for the construction of not more than four regulators in the effluents from the Border Rivers and for the taking over of the existing weirs on the MacIntyre and Barwon Rivers at Goondiwindi and Mungindi respectively. The cost of these works and of administration are to be borne by the States in equal shares. The Agreement further provided 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. Consequent upon these investigations an Amending Agreement was executed between the States of New South Wales and Queensland in November 1968, which included *inter alia* provision for the construction of storages on Pike Creek (Queensland) and the Mole River (New South Wales). The new agreement also provided for investigation and construction of works for the improvement of flow and of the distribution of flow in streams which intersect the New South Wales–Queensland border west of Mungindi.

Works completed under the original agreement include Bonshaw, Cunningham and Glenarbon Weirs on the Dumaresq River, a weir and regulator on the Barwon River at the off-take of the Boomi River. Until a dam has been constructed it is unlikely that any other weirs will be required.

Dam on Pike Creek. In December 1970 following a request by the two States, the Australian Government agreed to contribute one third of the cost of the dam on Pike Creek up to a maximum of $4.65 million, dependent upon a check by the Snowy Mountains Engineering Corporation of the cost estimate. Pending the outcome of the check the two States authorised expenditure to enable the preparation of plans and specifications for the dam to continue. In May 1972 the Australian Government advised the check of the estimates had been completed. The two States subsequently approved that the dam (subsequently called the Glenlyon Dam) be constructed to provide a gross storage capacity of 261.5 mil. cubic metres, at an estimated cost of $14 million and the time of its commencement be 1 July 1972. By 30 June 1973 detailed design was virtually complete and provision of access roads, township and construction services, buildings, facilities and land resumptions were in progress. Foundation stripping was well advanced and final clean up and grouting commenced. Expenditure on the project in 1972–73 totalled $1,999,656.

Improvement of distribution of flow—Rivers crossing the border. During 1971–72 the two States considered proposals for the better distribution of flows in the Balonne–Culgoa River System. The proposals provide for the construction of four regulating structures, one in each stream immediately downstream of the four main bifurcations, namely, the Culgoa/Balonne Minor, the Balonne Minor/Donnegri Creek, the Ballandool/Bokhara and the Bokhara/Birrie bifurcations. The works, estimated to cost $152,000, to be met equally by the two States, were approved for construction in November 1972. Expenditure to 30 June 1973 totalled $64,281.

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 Australian Government 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 Australian 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 was 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 Chapter 27, Electric Power Generation and Distribution.

The average total gain by diversion and regulation now that all storage works are completed is assessed at 1,381.5 million cubic metres per annum to the Murrumbidgee and 987 million cubic metres per annum to the Murray.

International aspects

International water organisations

Australia maintains contact with international bodies and United Nations agencies concerned with water resources and participates in their activities in various ways.

Organisation for Economic Co-operation and Development (*OECD*). Australian membership of the OECD since 1970 has involved participation in the work of the Water Management Sector Group. The group is composed of senior government officials responsible in their own country for the management of water and is responsible to the Environment Committee. It has the role of investigating and rationalising problems which are the subject of international concern and providing for strategies—economic, legal and technical—which might resolve them.

United Nations Educational, Scientific and Cultural Organization (*UNESCO*). The International Hydrological Decade (1965–1974) has been a period in which participating countries, including Australia, have implemented an international program designed to advance the science and practice of hydrology. More research and improvement of basic data acquisition has been encouraged as well as education and training, exchange of information and regional and global co-operation. Australia has been one of the 21 countries (later increased to 30) represented on the Co-ordinating Council for most of its annual sessions. The Australian UNESCO Committee for the International Hydrological Decade collaborated with Australian and State Government agencies, universities and other institutions concerned with hydrology on activities relevant to the IHD program. International seminars on hydrologic forecasting and on drought were conducted and a publication issued on *Australian Activities in Hydrology*. An international program in hydrology (IHP) will continue after the conclusion of the IHD. Intergovernmental Mid-Decade and End of Decade Conferences on the practical and scientific results were held at Paris in 1969 and in 1974, the latter co-inciding with the Tercentenary of hydrology celebration. The UNESCO publication *Nature and Resources* acts as a bi-monthly bulletin of the IHD and IHP.

World Meteorological Organization (*WMO*). Information on hydrology and meteorology is vital for water resources activities. WMO which has, *inter alia*, a Commission on Hydrology (formerly hydrometeorology) has recently strengthened its role in operational hydrology and its contact association with hydrological services. There is an Advisory Committee on Operational Hydrology on which Australia is represented indirectly through the WMO Regional Association V. WMO has made a notable contribution to the IHD program with its published reports on about twenty WMO/IHD projects and will participate in the IHP. The Director of Meteorology is the permanent Australian representative on the WMO which meets every four years in congress. In Australia, hydrological activities and meteorological activities relative to water resources are co-ordinated by the Australian Water Resources Council.

Economic and Social Commission for Asia and the Pacific (ESCAP). ESCAP (formerly ECAFE) is one of four regional economic commissions set up by the United Nations under the Economic and Social Council in 1947. The Commission through what is now called the Natural Resources Division of the ESCAP Secretariat has established a regular Regional Conference on Water Resources Development (now held every two years) which reviews and reports to the commission on a program of activities, largely of a technical nature but also including water policy issues. The program of activities is broadly concerned with the planning, management and development of water resources, including water resources planning of international rivers (e.g. the Mekong), measures for the mitigation of flood damage (so severe in this region) and the application of science and technology to the water field. By participation in this conference and in seminars arranged on selected topics, Australia contributes to, and benefits from, identification of the main problems of water resources management in a densely populated, developing region. A quarterly periodical, the *Water Resources Journal*, and a *Water Resources Series* publish the proceedings of conferences and seminars.

United Nations Environment Program (UNEP). A number of the recommendations of the UN Conference on the Human Environment held in Stockholm, June 1972 which forms part of the UNEP, relate to water (namely 51–55, 63 and 68). These involve Australian participation in a world registry of major rivers covering discharge and pollutants and of clean rivers so defined and in the development of methodology for analysis and planning of water resources management.

International Commission on Irrigation and Drainage (ICID). This commission was set up in India in 1950 so 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, drainage and flood control in their engineering, economic and social aspects. The commission consists of a National Committee from each participating country, and over sixty countries have so far been admitted to membership. Australia has been a member of ICID since 1952, and the National Committee consists of representatives of government departments, statutory authorities, firms and individuals actively interested in irrigation and drainage. Congresses of all member countries are held every three years.

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 Area. 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 stabilise 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

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* page 874 of this chapter.

Schemes summarised

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, by Burrendong Dam on the Macquarie 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. Copeton Dam on the Gwydir River is in the course of construction. 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 Area. The Areas are: The Murrumbidgee Irrigation Area, consisting of 182,620 hectares served with water through a channel system stemming from the river at Berembed Weir; the Coomealla Irrigation Area of 14,013 hectares, served by pumping from the Murray; the Curlwaa Irrigation Area of 4,204 hectares, supplied from the Murray by pumping; the Hay Irrigation Area of 2,772 hectares, supplied with water pumped from the Murrumbidgee; the Tullakool Irrigation Area of 7,287 hectares, supplied from the Edward River by diversion at Stevens Weir; the Buronga (3,537 hectares) and Mallee Cliffs (769 hectares) Irrigation Areas, served by pumping from the Murray; and the Coleambally Irrigation Area (94,954 hectares), served by diversion from the Murrumbidgee River. All these Areas are administered by the Commission.

The capacities of the main storages for irrigation in New South Wales (in million cubic metres) are:

Darling—Menindee Lakes Storages (1,811.6); Severn–Pindari Dam (37.4);

Murray—Half share of Hume Reservoir, weirs and locks to Wentworth (1,667); Paterson–Lostock Dam (20.2); Stevens Weir, Edward River (8.8);

Tumut (tributary of Murrumbidgee)—Blowering Dam (1,631.2); Iron Pot Creek (tributary of Richmond River)—Toonumbar Dam (11.1);

Macquarie—Burrendong Dam (1,189.3 irrigation storage; 489.4 flood mitigation storage);

Murrumbidgee—Burrinjuck Dam (1,032.4); Redbank Weir (9.1); Maude Weir (8.3);

Namoi—Keepit Dam (425.9);

Lachlan—Wyangala Dam (1,217.4); Lake Brewster (152.8); Lake Cargelligo (36.3);

Hunter—Glenbawn Dam (228.6 irrigation storage; 133.1 flood mitigation storage);

Belubula (tributary of Lachlan River)—Carcoar Dam (37.0).

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 8,490 kilometres. This comprises 5,772 kilometres of supply channels (including main canals), 2,607 kilometres of drains and scape channels, and 111 kilometres of pipe lines.

Irrigated culture

The following table shows details of the area of crops and pasture and the methods employed on land under irrigated culture during the 1972–73 season.

AREA OF LAND UNDER IRRIGATED CULTURE: NEW SOUTH WALES, 1972-73
(Hectares)

	Method of irrigation					
	Spray	*Furrow*	*Flood*	*Trickle*	*Multiple Methods*	*Total Area*
Crops—						
Cereals	15,688	19,565	152,388	..	918	188,559
Cotton	16	27,280	3,812	..	..	31,108
Fruit	6,702	5,960	581	633	172	14,048
Linseed	20	125	570	..	..	715
Safflower	6	12	253	..	..	271
Sunflower	208	1,558	6,171	..	..	7,937
Tobacco	803	64	31	..	..	898
Vegetables	10,994	2,534	605	32	71	14,236
Grapevines	835	6,464	632	1,270	215	9,416
Other crops (*a*)	2,597	3,680	8,448	8	73	14,806
Total crops	**37,869**	**67,242**	**173,491**	**1,943**	**1,449**	**281,994**
Lucerne	36,240	422	33,019	..	220	69,901
Pastures	38,998	4,605	318,285	..	1,393	363,281

(*a*) Includes fodder crops.

Irrigation areas

Murrumbidgee. This area, which consists of Yanco and Mirrool Irrigation Area, together with adjacent lands supplied under agreement, received 488.9 mil. cubic metres, nearly 14 per cent of the total water (4,068.0 mil. cubic metres) used within the State for stock, domestic and irrigation purposes. The area is served by the Burrinjuck Dam on the Murrumbidgee River and Blowering Dam on the Tumut River, which joins the Murrumbidgee River near Gundagai. The catchment of the Burrinjuck Dam is about 12,950 square kilometres and water storage in Blowering Dam is from the natural flow of the Tumut River and water released into that river from the Snowy-Tumut Development Section of the Snowy Mountains Hydro-electric Scheme. This includes water from the Eucumbene, Upper Murrumbidgee, Tooma and Upper Tumut Rivers. The dams also provide 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 dams for that purpose. For other areas and districts, however, water is stored during the winter, fed by melting snows and spring freshets, and is released during the September-May irrigation season. To supply the Yanco and Mirrool Areas, water is diverted by Berembed Weir into the main canal which has an off-take capacity of 45 cubic metres a second. The main canal has been completed to beyond Griffith, a distance of approximately 154 kilometres. These areas are served by approximately 1,283 kilometres of supply channels and pipes and 1,416 kilometres of drainage channels. In addition, approximately 715 kilometres of supply channel run through the Tabbita, Benerembah and Wah Wah Districts which are adjacent to the Areas.

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 1973 was 167,050 hectares including 11,877 hectares 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 1973 its population was approximately 31,500, that of Leeton Shire being 11,724 and that of Wade Shire 18,950. 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 in the M.I.A. 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 Area.

Other Irrigation Areas. The Coomealla, Tullakool, Buronga, Mallee Cliffs, Hay, Curlwaa, and Coleambally Irrigation Areas follow the same administrative pattern as the Murrumbidgee Area—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. The essential difference between an 'Area' and a 'District' is that in the case of the former, all the land to be included in the area is acquired by the Crown and then subdivided into such number of separate holdings as may be determined. Within the District, however, existing ownership of land is not disturbed other than to acquire land required for water distribution works.

Since the completion of the Hume Reservoir, several such districts have been established along the Murray to utilise the New South Wales share of the storage. Water is not available for the whole of the 2,023,430 hectares 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 hectare 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, 30 centimetres deep, as will cover an area of 0.4 hectares.

Water to serve Berriquin, Deniboota and Denimein Districts is diverted from the Murray River at Yarrawonga into the Mulwala Canal. 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. The total length of completed canals and channels in Berriquin District is 1,682 kilometres, comprising Mulwala Canal 121 kilometres, Berrigan Channel 35 kilometres, subsidiary channels 1,326 kilometres, escape channels 183 kilometres, and cross drainage channels 16 kilometres. Off-take capacity of the Mulwala Canal is 6.2 mil. cubic metres a day. Wakool, with 692 kilometres of channels, contains 328 holdings, and the area developed by irrigation includes about one hectare in six of the total area. Sheep raising and rice growing are the main industries. 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, wheat, and rice growing are the main industries.

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

The Water Act, 1912–1966 provides for the constitution of Trust Districts for domestic and stock water and irrigation, and empowers the Commission to construct, acquire or utilise 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 hectares of each district being shown in parenthesis): *Murray River*—Little Merran Creek (63,714), Bullatale Creek (27,648), Poon Boon (13,881), Minnie Bend Flood Prevention (886); *Murrumbidgee River*—Yanco, Colombo and Billabong Creeks (407,834); *Lachlan River*—Marrowie Creek (118,427), Torriganny, Muggabah and Merrimajeel Creeks (68,894), Micabil Weir (4,654), Condobolin West Weir (1,813); *Miscellaneous*—Great Anabranch of Darling River (388,168), Nidgery Weir (18,972), Algudgerie Creek (3,758), and Boomi River (105,230)—making in all a total area of 1,223,879 hectares. Twelve of these trusts have been formed for the provision of water for domestic and stock purposes and one for flood prevention.

Irrigation Trusts are established under the same Act and are administered by trustees in a similar way. There are seven of these trusts.

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 number 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 recognised as a means of stabilising production in dry months. There has also been a considerable increase along the Murrumbidgee, Lachlan, Namoi, and Macquarie Rivers.

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, and flood and spray irrigation systems.

Underground water

For information on underground water resources in New South Wales *see* Year Book No. 55 and earlier issues.

Future program

The program of development in hand includes the provision of additional dams and storages, weirs, and flood mitigation and river protection works in various parts of the State. Work is continuing at Copeton Dam site on the Gwydir River. Legislation has been passed authorising the construction of Windamere Dam on the Cudgegong River, a dam on the Brogo River and existing legislation authorises 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, incorporates 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. The strengthening and enlargement of Wyangala Dam, on the Lachlan River, has been completed and storage capacity has been increased to 1,217.6 mil. cubic metres following installation of radial gates in the spillway. Within the new Coleambally Irrigation Area further development of farms has been carried out and water is being supplied by the Coleambally Canal which off-takes from the Murrumbidgee River at Gogeldrie Weir. At 30 June 1973, 312 large area farms and 22 horticultural farms were occupied.

Victoria

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 916,923 hectares, rural waterworks and urban districts covering 4,867,295 hectares, flood protection districts covering 60,235 hectares and urban water supplies serving 312,600 people. It also supervises the activities of local urban water supply authorities supplying 708,720 people in 316 towns, as well as 113 local sewerage authorities and 32 river improvement and drainage authorities.

Works summarised

Since the State Rivers and Water Supply Commission began its operations in 1906 the capacity of storages under its control has been increased from 212.2 mil. cubic metres to 6,221.7 mil. cubic metres. In addition, Victoria has in effect a half share in River Murray Commission storages totalling 1,667.0 mil. cubic metres, bringing total capacity available to Victoria at 30 June 1974, to 7,888.8 mil. cubic metres. Most of the water used from these storages is for irrigation. The area irrigated in 1973–74 totalled 545,041 hectares (compared with 42,490 hectares in 1906). Irrigation deliveries in 1973–74 totalled 1,735.7 mil. cubic metres. The value of irrigation production in 1972–73 was estimated at $235,950,000. Irrigation deliveries for that year totalled 2,825.8 mil. cubic metres. Of the total irrigation production about one-quarter was from lands irrigated by 'private diverters', i.e. irrigators who are authorised to take water from streams, lakes, etc., but who do not come within the boundaries of an irrigation district.

Storages

Capacities of principal storages (in mil. cubic metres) and system totals at 30 June 1974 were as follows:

Goulburn System—Eildon, 3,390.1; Waranga, 411.2; total, 3,862.1.
Murray System—half share of Murray storages, 1,667.1; total, 1,667.1.
Broken River System—Nillahcootie, 39.8; Mokoan, 364.8; total, 404.6.
Ovens System—Lake Buffalo, 24.1; Lake William Hovell, 12.3; total, 36.4.
Loddon System—Cairn Curran, 148.8; Tullaroop, 74.1; Laanecoorie, 7.7; total, 230.7.
Campaspe-Coliban System—Eppalock, 311.9; Coliban storages, 80.1; total, 392.0.
Wimmera-Mallee Systems—Rocklands, 335.5; Toolondo, 106.6; Bellfield, 78.5; total, 775.1.
Maffra-Sale System—Glenmaggie, 190.3; total, 190.4.
Werribee-Bacchus Marsh—total, 60.2.
Mornington Peninsula—total, 59.3.

Irrigated culture

The following table shows details of the area of crops and pasture and the methods employed on land under irrigated culture during the 1972–1973 season.

AREA OF LAND UNDER IRRIGATED CULTURE: VICTORIA, 1972-73
(Hectares)

	Method of irrigation					
	Spray	*Furrow*	*Flood*	*Trickle*	*Multiple Methods*	*Total Area*
Crops—						
Cereals	1,732	328	18,593	..	66	20,719
Fruit	5,508	3,677	6,961	1,995	768	18,909
Vegetables	11,968	1,974	603	5	132	14,682
Grapevines	2,175	14,221	915	115	69	17,495
Other crops(*a*)	1,906	249	4,738	28	41	6,962
Total crops	**23,289**	**20,449**	**31,810**	**2,143**	**1,076**	**78,767**
Lucerne	7,310	484	16,891	..	173	24,858
Pastures	28,254	9,682	478,359	..	3,942	520,237

(*a*) Includes fodder crops.

Irrigation systems

Goulburn–Campaspe–Loddon. The principle storage for Goulburn waters is Lake Eildon, which was completed in 1956, submerging the original 377.5 mil. cubic metres 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 program of channel works which is still in progress. Deliveries of Goulburn–Campaspe–Loddon water during the 1954–55 Irrigation Season totalled 487.0 mil. cubic metres. This was near a record for annual deliveries at this time. The enlargement of Lake Eildon, and later storage and distribution developments, led to much higher delivery levels. Record deliveries of 1,310.7 mil. cubic metres were recorded in 1972–73. Deliveries during 1973–74 amounted to only 764.9 mil. cubic metres, owing to the fact that above average rains reduced demands.

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, with a capacity of 2.5 mil. cubic metres per day, supplies the area around Shepparton. Two channels, each of 3.7 mil. cubic metres per day capacity, to the west, convey water to the off-river Waranga Reservoir, and supply part of the Rodney area through off-takes on the way. From Waranga Reservoir there are two main outlets, one supplying the western part of the Rodney area and the other, of 2.9 mil. cubic metres per day capacity, supplying the Waranga Western Main Channel, which runs 370 kilometres west across the Campaspe and Loddon Valleys to beyond Birchip.

Flows in the Waranga Western Main Channel are augmented by the injection of Campaspe water through a pumping station of 0.5 mil. cubic metres per day 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 543,523 hectares. 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 121,952 hectares, devoted mainly to dairying, fat lambs and canning fruit. Holdings in the Torrumbarry system total 161,950 hectares, 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 5 districts supplied by pumping: the district of the First Mildura Irrigation Trust and the 4 Commission districts of Nyah, Robinvale, Red Cliffs and Merbein. These districts together serve 30,281 hectares, producing mainly dried vine friuts, with some citrus fruits and table and wine grapes.

Southern systems. The Maffra–Sale–Central Gippsland district, covering 52,800 hectares 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 District, supplied from storages in the Werribee River only 32 kilometres west of Melbourne, covers 6,420 hectares 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 25,000 square kilometres 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 10,600 kilometres of Commission channels and about 6,400 kilometres of private channels. Without this supply, occupation of the region would be extremely hazardous. Storage capacity has now been increased from 696.6 mil. cubic metres to 775.1 mil. cubic metres by construction of Lake Bellfield. Fifty towns, with a population of 46,000, receive their supply from the same system. Near Horsham and Murtoa, close to headworks in the south, a supply is maintained for the irrigation of an area of 3,030 hectares, 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 36,117 hectares 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 dollars 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, 32 such trusts have been formed (including the Dandenong Valley Authority). The importance of river improvement work is expected to continue to grow.

The Dandenong Valley Authority was created in 1963 by special legislation, with jurisdiction over the whole catchment of the Dandenong Creek (777 square kilometres) for purposes of arterial drainage, river improvement and flood protection. In June 1966 the Authority took over the Commission's Carrum Drainage District.

Finance

The net capital liability of the Commission at 30 June 1974 for works under its direct control was \$370.1 million. Eighty-four per cent of the cost of capital and interest repayments was borne by the State. Total expenditure on irrigation was \$192 million; \$33.6 million on rural, domestic and stock supplies; \$63.2 million on urban supplies and \$2.8 million on flood protection. A further \$34.8 million (relating mainly to irrigation) was expended on headworks but has not yet been allocated to the above. The remaining \$43.7 million was for expenditure on storages for private diversion and to supplement supplies to local authorities, and for items such as loan flotation expenses, miscellaneous surveys and investigations, and buildings, plant and stores.

Ten Year Program

The Victorian Water Commission's second ten year plan (for the period 1973–83), reflects a changing emphasis towards greater involvement with urban water supply, sewerage, environmental protection and water quality.

Two basic principles were adopted in formulating the program:

(i) That the environmental impact of new projects be taken into account with emphasis on *multi-objective planning.*

(ii) That each project should be economically sound and viable.

Major provisions of the 1973-83 program include:

the construction of new water supply trunk mains, reticulated services and water treatment plants at an estimated cost of $112 million (including $46 million for locally administered waterworks trusts);

the sewering of all towns with populations over 200 by the end of 1982 at an estimated cost of $37 million;

the expenditure of $15 million by river improvement, flood protection and drainage trusts to preserve flood waterways, protect valuable marginal land and safeguard the natural environment of streams in their catchment area;

expenditure of $7.5 million on rural waterworks districts, including the Millewa pipeline scheme (to be completed by 1975) and commencement of the pipelining of the extensive Mallee domestic and stock channel system;

construction or enlargement of ten major storages at a total cost of $47 million (including Victoria's share of the cost of the Dartmouth Dam project);

expenditure of $58 million on irrigation and drainage works within existing irrigation districts;

expenditure of $30 million to reduce water losses and control seepage in irrigation distribution systems;

provision of adequate drainage systems, including groundwater control in irrigation districts at an estimated cost of $15 million;

expenditure of $13 million on salinity control works to arrest the deterioration of highly productive irrigated lands and protect the River Murray from saline inflows from Victorian irrigation areas;

expenditure of $5.5 million as Victoria's share of capital works undertaken by the River Murray Commission (additional to the Dartmouth Dam Project);

expansion of Water Commission facilities and resources at an estimated cost of $12 million.

Queensland

Introduction

The important primary industries of Queensland are subject to relatively frequent and serious losses by drought and also to extensive flooding. There is therefore a definite and widespread need for the provision of works for water conservation for irrigation, for stock watering and for flood mitigation.

The average annual flow of all streams in Queensland of 133,216.1 mil. cubic metres, equivalent to 39.2 per cent of that for all Australian streams, gives ample scope for such works.

Water resources investigation

The Commissioner of Irrigation and Water Supply is required, under the *Land and Water Resources Development Acts* 1943 to 1946, to (a) prepare a complete description of the natural water resources of the State, both surface and underground, (b) undertake and carry out a survey of such resources, and (c) keep a record of all such natural water resources, surface and underground. For this purpose the Commission has installed and operates 558 stream gauging stations (491 of them being equipped with automatic water level recorders) and collects rainfall data from 103 stations in addition to the Bureau of Meteorology stations.

Licensing and control

As required under the Water Act, rights to underground and surface water are allocated and use controlled by a system of licensing of—(a) all artesian bores in the State; (b) all sub-artesian bores in areas proclaimed by the Governor in Council; the main purpose of proclaiming areas is to ensure the equitable distribution of available supplies and to obtain information on the quantity, quality, extent and use of those supplies; (c) all conservation and use (other than for stock and domestic supplies) of flow in watercourses.

The Commission is required to control use to share supplies as equitably as possible in periods of shortage of supply. At 30 June 1973, 13,977 waterworks licences were in existence, 10,499 being for pumps and 2,763 for dams and weirs and 715 for other works. Areas of sub-artesian water supply proclaimed in which all bores and wells require a license total about 1,410,000 square kilometres. A total of 29,429 bores (artesian and sub-artesian in proclaimed areas) were registered at 30 June 1973.

Development of water resources

The Commissioner of Irrigation and Water Supply is required to prepare a co-ordinated program of work for the conservation, utilisation and distribution of water resources, and to make recommendations to the Government regarding the carrying out of works in this program.

The Commissioner is principally responsible for water conservation and supply works for rural purposes, including irrigation, stock and domestic supply. However, in planning such works, particularly storages, economies to all users can accrue by providing where possible for dual or multi-purpose use of works for irrigation, rural, urban and industrial including power generation and mining purposes. As a result of this approach, 26 cities and towns now draw supplies from Commission storages or by diversion from regulated streams, four storages provide supply for power generation at three thermal stations (Swanbank, Calcap and Collinsville) and one hydro-electric station (Barron Falls), supply for mining operations is drawn from three other storages, and stock water supplies are or will be provided from two Commission and two private pipeline systems serving power stations or mining operations. Urgent water requirements of the expanding mining activities in Central, North and North West Queensland have brought out the need to further ensure the orderly and efficient development of the limited water resources in these areas, to provide for immediate and future needs for both urban, mineral and rural purposes.

Water conservation

At 30 June 1973, the Irrigation and Water Supply Commission controlled and operated 11 dams and 53 weirs with a total available storage capacity of 2633.5 mil. cubic metres. Two dams (Tinaroo Falls and Eungella) are located in North Queensland; two (Fairbairn and Callide) in Central Queensland; the other seven (Moogerah, Leslie, Borumba, Coolmunda, Wuruma, Atkinson and Beardmore) in South Queensland. Of the weirs 30 are in South, 12 in Central and 11 in North Queensland. Weir capacity ranges from 17.3 to less than 0.1 mil. cubic metres; 13 of them having a capacity of over 1.2 mil. cubic metres. Completion of Maroon, Monduran, Glenlyon and Julius Dams, Kolan Barrage and Chinchilla Weir now under construction will provide additional storage of 721.6 mil. cubic metres.

Irrigated culture and sources of supply

The total area under agriculture in Queensland in 1972–73 was 2,019,123 hectares. Of this area some 201,563 hectares were irrigated. In 1972–73 crops or pastures were irrigated on 10,048 holdings or 23.7 per cent of all rural holdings in the State. The area of crops (excluding lucerne and sown and native pastures) irrigated was 155,132 hectares, or 7.7 per cent of the total area under crop. In addition there were 20,569 hectares of lucerne irrigated and 25,862 hectares of other sown and native pastures. The average area irrigated per holding using irrigation was 20 hectares.

Unlike other States, the greater part of the area irrigated is by individual private pumping plants drawing supply from streams or underground sources, spread widely throughout the State, rather than in constituted irrigation areas where supply is provided by channel systems delivering water to farms.

The following table shows details of the sources of supply for the area of land under irrigated culture during 1972–73.

AREA OF LAND UNDER IRRIGATED CULTURE AND SOURCES OF SUPPLY: QUEENSLAND, 1972-73

Source of supply	*Area irrigated*		*Percentage of total area irrigated*	
	hectares	hectares	%	%
Underground supplies—				
Naturally replenished; Artificially replenished	..	116,268	..	57.7
Surface supplies—				
Irrigation areas	24,344		12.1	
Regulated streams; Unregulated streams	48,163		23.9	
Farm dams	12,560	85,067	6.2	42.2
Town water supplies		228		0.1
Total all sources		**201,563**		**100.0**

Because of the predominance of irrigation by private diversion pumping, most of the storages are used to release water downstream to maintain supplies for such diversion.

The following table shows details of the area of crops and pastures irrigated and the methods employed on land under irrigated culture during the 1972–73 season.

AREA OF LAND UNDER IRRIGATED CULTURE: QUEENSLAND, 1972–73
(Hectares)

	Method of irrigation					
	Spray	*Furrow*	*Flood*	*Trickle*	*Multiple Methods*	*Total Area*
Crops—						
Cereals	15,754	12,687	7,870	..	361	36,671
Sugar Cane	30,752	28,260	7,586	..	4,309	70,907
Tobacco	4,195	99	91	..	129	4,515
Cotton	75	6,040	229	..	69	6,411
Fruit	4,034	186	78	607	286	5,189
Vegetables	16,445	1,411	146	174	123	18,298
Other crops(*a*)	4,140	6,229	2,420	3	349	13,140
Total crops	**75,393**	**54,910**	**18,419**	**784**	**5,625**	**155,132**
Lucerne	20,268	36	215	..	50	20,569
Pastures	18,762	55	6,757	..	288	25,862

(*a*) Includes fodder crops.

Irrigation areas

About 9.5 per cent of the area under irrigation in the State is concentrated in the five established Irrigation Areas constituted under the *Irrigation Act*, 1922–1973, where the supply is generally reticulated by channel systems, by means of gravity or by pumping, from the storage. In addition some supply is also provided from streams regulated by the storage. Details of Irrigation Areas established and one under construction are set out below.

Dawson Valley Irrigation Area. The scheme is situated around the town of Theodore and the area is supplied by four weirs (with a capacity of 29.9 mil. cubic metres) on the Dawson River. Pumping stations deliver water through channel systems to 61 farms. Cotton and grain crops account for the major part of production from irrigated farms. In addition to irrigation demand the towns of Theodore and Moura and the Theiss Peabody Mitsui Mining Group obtain supplies from the storages.

Burdekin River Irrigation Area and Water Supply Scheme. This scheme is a complex system of water conservation, irrigation, industrial, urban and stock water supply. Storages are Eungella Dam on the Broken River, and Gorge and Blue Valley Weirs on the Burdekin River. From Eungella Dam, water is diverted directly by a privately owned 127 kilometre piped supply system to coal mining operations at Goonyella and Peak Downs and the town of Moranbah. Supplies for other purposes are maintained along the Bowen and lower 114 kilometres of the Burdekin River by release of water from the storages as required. These purposes and the arrangements for supply comprise (i) a pumping station on the Bowen River delivering supply through 34 kilometres of pipeline to the Collinsville Power Station, Collinsville Town and seven grazing holdings along the pipe line. (ii) Six pumping stations delivering water through channel systems to 152 individual irrigated holdings in Clare, Millaroo and Dalbeg sections of the Burdekin River Irrigation Area. Principal production crops from irrigated farms are sugar cane, rice and seed crops. (iii) private diversion by pumping for irrigation on individual holdings along the Bowen and Lower Burdekin Rivers.

Mareeba–Dimbulah Irrigation Area. This area is supplied by Tinaroo Falls Dam and weirs on the Barron and Walsh River systems. Water is delivered through channel systems and regulated streams to 563 farms on which the principal crop is tobacco. In addition, water is supplied to the towns of Mareeba, Dimbulah, Walkamin, Mutchilba and Tinarro Falls and to the Hydro-electric Generating Station at Barron Falls.

St George Irrigation Area. This area is located near the town of St George and the principal storages for this area are Beardmore Dam and Jack Taylor Weir on the Balonne River and two weirs on Thuraggi Watercourse. Water is supplied to 20 farms on which the principal crops are cotton, soya beans and cereals and to the town of St George. The construction of works to extend the area by some 16 farms is in progress.

Emerald Irrigation Area. This scheme, a joint Federal and State undertaking involved the construction of Fairbairn Dam (completed 1972) on the Nogoa River, some 19 kilometres upstream from Emerald. Water from this dam and associated irrigation, drainage and roadworks could ultimately serve 80 or more irrigation farms on which 13,000 hectares could be irrigated annually. In addition, supplies will be provided for coal mining and urban water supply in the Blackwater area.

Bundaberg Irrigation Scheme. This is a joint Federal and State undertaking, estimated to cost $58.48 million aimed at raising the efficiency and security of the established sugar industry in the region. Phase 1 of the Scheme now under construction involves the construction of Monduran Dam (capacity 585.9 mil. cubic metres) on the Kolan River, tidal barrages on the Kolan and Burnett Rivers, pumping stations and distribution works. The scheme will ultimately provide an assured water supply to 1,485 assignments with a gross area of 48,500 hectares and 6.2 mil. cubic metres annually to augment supplies to the city of Bundaberg.

Irrigation projects

These are schemes established under the *Water Act* 1926–1973 where water from storage is released downstream to maintain adequate supplies for private pumping under licence, to land adjacent to the watercourse. Details of existing Irrigation Projects are set out in the following table.

IRRIGATION PROJECTS: QUEENSLAND

Project	Storage	Number of licensed pumps	Annual water allocation	Water supplied 1972-73 Irrigation	Other purposes	
			('000 cu m)	('000 cu m)	('000 cu m)	
Warrill Valley	Moogerah Dam	305	10,608	9,921	11,656	Power generation and urban
Mary Valley	Borumba Dam	141	4,575	4,093	2,567	Urban
Upper Condamine	Leslie Dam	72	14,382	10,451	1,472	Urban
Macintyre Brook	Coolmunda Dam	94	4,629	4,999	334	Urban
Upper Burnett	Wuruma Dam	261	25,795	25,733	834	Urban
Lower Lockyer	Atkinson Dam	149	7,994	5,696	..	

Other projects currently under construction or approved are set out below.

Logan River Project. Maroon Dam, under construction on Burnett Creek, a tributary of the Logan River, is designed to permit expansion of irrigation from the present 1,406 hectares to 4,006 hectares along Burnett Creek and the Logan River for about 129 kilometres.

Border Rivers Project. The Dumaresq–Barwon Border Rivers Commission consisting of representatives of New South Wales and Queensland was created to control works on these rivers where they form the boundary between the two States, and to allocate the water. (For details *see* page 874).

Leichhardt River Project. This scheme, which involves the construction of Julius Dam on the Leichhardt River and a supply system to convey the water to the Mount Isa area is designed to provide water for the rapidly expanding needs of Mount Isa City and Mount Isa Mines Ltd and to maintain a reserve supply for possible other users in the foreseeable future. A contract was let in April 1973 for the construction of the dam. The Mount Isa Water Board was constituted in March 1973, to construct, own and operate the new supply works and to modify, operate and maintain the existing works for bulk supply to Mount Isa Mines Limited and the City.

Blackwater Water Supply. Construction of a supply system with a capacity of 4.6 mil. cubic metres per annum from Bedford Weir to Blackwater and a capacity of 2.2 mil. cubic metres from Blackwater to Leichhardt Mine has been approved and work commenced in December 1972. Initially to supply the Leichhardt Colliery and Town of Blackwater and stock water supplies to rural holdings along the pipe line, the works are estimated to cost $2.3 million.

Rural, stock and domestic supplies

Rural Water Supply Areas. Improvements to stock and domestic water supplies are assisted by the development of Rural Water Supply Schemes, where water from a central source is distributed through pipelines to individual farms and properties. Investigation and design of these schemes are carried out by the Irrigation and Water Supply Commission. The schemes attract a Government subsidy of 50 per cent of the capital cost, the balance being provided by way of Government guaranteed loans raised by the individual water boards. Operation and maintenance costs and capital charges are wholly met by rates levied on benefited properties. Fifteen schemes are in operation with a total benefited area of 110,933 hectares on 615 rural holdings.

Bore Water Supply Areas. Bore Water Supply Areas are constituted under the Water Act for the purpose of supplying water from artesian or sub-artesian bores to groups of adjoining properties for the watering of stock. The construction or acquisition of a bore and distribution system within an Area is financed by a Treasury loan, and rates calculated on the basis of area benefited are levied annually to meet loan repayments and maintenance and operating costs. Of the 60 Bore Water Supply Areas currently operating in the State, 54 are administered by the Commission and six by local boards elected by the ratepayers within the areas. A total daily flow of 0.1 million cubic metres was distributed through some 3,679 kilometres of drains to serve a benefited area of 1,846,402 hectares on 375 holdings.

River improvement trusts

These trusts are virtually autonomous bodies whose responsibility is to carry out and maintain works to improve stream channels, to increase their flood carrying capacity, to prevent or repair bank erosion and to mitigate flooding. Fifteen trusts are constituted throughout the State.

Drainage areas

Eight drainage areas—five in irrigation areas and three administered by autonomous drainage boards—have been constituted. These Areas served 296 holdings by 265 kilometres of drain; a total area of 24,822 hectares being drained.

Underground water supplies

The availability of underground water in Queensland has played a very big part in the development of the pastoral industry, and of irrigation on individual farms, particularly along the coastal fringe. Underground water is also used very widely for irrigation, stock, and domestic purposes outside the Artesian Basin. Over half the area irrigated in Queensland receives its supplies from underground sources, and in accordance with the requirements of The *Land and Water Resources Development Acts*, 1943 to 1946, the investigation of availability of underground water is being pursued by geological mapping, investigation drilling and hydro-geological assessment. The most important areas where water from this source is used for irrigation are in the following river basins; the Lower Burdekin, the Don (Bowen), the Pioneer, the Callide Valley, the Lower Burnett, many parts of the Brisbane Basin, including the Lockyer, and parts of the Upper Condamine Basin.

Burdekin Delta recharge. For the first time in Australia, the artificial replenishment of underground water supplies has been implemented in the Burdekin Delta. The North and South Burdekin Water Boards divert unregulated supplies of water from the Burdekin River for the purpose of artificially recharging the underground supplies from which some 28,328 hectares of sugar cane and 682 hectares of rice are irrigated and supplies for stock and domestic purposes, including the towns of Ayr and Home Hill are drawn.

Artesian water. The Great Artesian Basin in Queensland consists approximately of the area lying west of the Great Dividing Range, excluding the Cloncurry Mineral Field and the Barkly Tablelands. It comprises about 1,124,000 square kilometres, or about two thirds of the total State area. This part of the State is predominantly pastoral and is mainly dependent for water supplies on artesian and sub-artesian bores, and, where normal surface storage is not readily available, on excavated tanks. At 30 June 1973, a total of 3,275 artesian bores had been drilled in the Great Artesian Basin, of which 2,199 continue to flow, providing a supply of 0.9 million cubic metres per day. Although this supply will continue to diminish for a further 30 to 40 years, after that time a steady and continuous flow of some 0.6 million cubic metres per day is expected to be maintained.

Stock route watering

In 1935 the Trunk Stock Route System was inaugurated and from then on the construction of watering facilities on stock routes was greatly expanded. The Irrigation and Water Supply Commission acts as a constructing authority for the Stock Routes Co-ordinating Board in these matters, and had to 30 June 1973, completed 638 facilities with a further 10 under construction and 7 under investigation. The two authorities mentioned above carry out continuous investigation to ascertain general stock movements so that new facilities may be provided as required.

Farm Water supplies

Under The *Farm Water Supplies Assistance Acts* 1958 to 1965, technical assistance is available to landholders throughout the State on all matters relating to water conservation and utilisation for domestic, stock and irrigation purposes, on individual holdings or groups of holdings, covering construction of farm dams, irrigation bores and stock bores, and pumping and distribution systems. In addition, the Government provides finance to farmers by way of special Agricultural Bank loans, and technical advice on construction and installation. During 1972–73, 899 applications were received for assistance under these Acts, and $411,578 was paid in advances by the bank, bringing advances over the 15 years of operation of the Acts to $8,869,310.

South Australia

Administration

All major water resources and most public water supply schemes in South Australia are administered by the Engineering and Water Supply Department under the various statutes mentioned below.

The Waterworks Act, 1932–1974 empowers the Minister of Works to impound or divert the water from any lake, watercourse or underground source for the purpose of establishing and maintaining public water supply schemes to serve proclaimed water districts throughout the State. The Engineering and Water Supply Department administers and operates the great majority of water supplies in South Australia. A feature of these supplies is the extensive networks of pipelines transporting water over long distances from major resources to cities, towns and farmlands as well as numerous separate town and farmland schemes. A few domestic water supply schemes in Government irrigation areas along the Murray Valley in South Australia are administered by the Department of Lands. The Electricity Trust of South Australia administers and operates the water supply of Leigh Creek town and coalfield.

The Water Conservation Act, 1936–1972, relates to the provision of small dams, wells, bores and other waterworks to assist development in the more remote areas of the State or to provide water for travellers and travelling stock in such areas.

Under the *River Murray Waters Act* 1935–1971, which ratifies the River Murray Waters Agreement, the Engineering and Water Supply Department operates and maintains Lake Victoria Storage, nine weirs and locks downstream of Wentworth, N.S.W., and barrages at the River mouth.

The Control of Water Act, 1919–1925 vests the waters of the South Australian section of the River Murray in the Crown and provides the powers to control diversion of water and to take necessary steps for abatement of pollution.

The Underground Waters Preservation Act, 1969–1973 controls the sinking of wells and extraction of underground waters in proclaimed areas to prevent depletion and pollution of these resources. The Act has so far been applied in respect of important water bearing areas in the Adelaide Plains, the South-Eastern region of the State and Eyre Peninsula.

Irrigation

Australian irrigation originated in the upper Murray in South Australia and the Mildura area of Victoria. South Australian irrigation commenced with an agreement between the Chaffey brothers in 1887 whereby an area was made available for the establishment of certain irrigation works at Renmark. From this start government, co-operative and private irrigation areas totalling more than 42,000 hectares have been developed in the South Australian section of the Murray Valley.

The major authorities controlling River Murray irrigation are the Department of Lands which administers government controlled areas totalling 17,000 hectares (under provisions of the Irrigation Act, 1930–1971 and other statutes), and the Renmark Irrigation Trust (founded on the Chaffey brothers' venture) which administers distribution works supplying 4,000 hectares of irrigated land (under provisions of the Renmark Irrigation Act, 1936–1969). In addition some 21,000 hectares of irrigated lands are controlled by smaller co-operatives, development companies and private owners.

In the Government irrigation areas land is leasehold, whereas in the areas controlled by the Renmark Irrigation Trust and other co-operatives with local boards of management the land is freehold.

The irrigation areas comprise high land areas to which water is pumped from the River, and reclaimed swamp lands along the lower section of the River which are watered through sluices in the protecting levees. Considerable importance is placed on adequate drainage of both high lands and reclaimed swamp lands.

The principal high land crops comprise citrus and stone fruits and vines. The reclaimed swamps are used almost exclusively for pasture and fodder crops. However, vegetable crops of various kinds are also important in both types of irrigated lands.

Except for quantities held in various lock pools and natural lakes, no water from the Murray is stored within South Australia for irrigation purposes. Usage of the River is therefore planned on the basis of the minimum monthly flows to which South Australia is entitled under the River Murray Waters Agreement. This factor, plus the need to reserve water for city, town and rural water supply system, has resulted in the expansion of irrigation from the River being rigidly controlled by the government.

Divisions of water for irrigation of areas in excess of 0.4 hectares are made under licence issued under the Control of Waters Act, 1919–1925. Irrigation offtakes are metered but no charge is made for water taken unless licensed quotas are exceeded. However, block holders in government and trust operated irrigation schemes are rated or charged by measure by the administering authorities to recoup pumping and distribution costs.

In addition to irrigation from the River Murray there are considerable areas irrigated from underground sources by individual landholders in South Australia. The most important of these areas comprise 2,500 hectares of market gardens on the northern Adelaide plains and 4,000 hectares of pastures, fodder and seed crops, and vines in the Padthaway district of the south-eastern region.

Irrigated culture

The following table shows details of the area of crops and pasture and the methods employed on land under irrigated culture during the 1972–73 season.

AREA OF LAND UNDER IRRIGATED CULTURE: SOUTH AUSTRALIA, 1972-73
(Hectares)

	Method of irrigation					
	Spray	*Furrow*	*Flood*	*Trickle*	*Multiple methods*	*Total area*
Crops—						
Cereals	616	..	217	..	..	833
Fruit	9,169	3,069	115	603	171	13,127
Vegetables	5,506	612	72	23	36	6,249
Grapevines	4,530	10,368	532	1,429	301	17,160
Other crops(*a*)	766	11	412	1	4	1,194
Total crops	**20,587**	**14,060**	**1,348**	**2,056**	**512**	**38,563**
Lucerne	13,708	..	3,513	..	1	17,222
Pastures	9,852	..	17,468	..	45	27,365

(*a*) Includes fodder crops.

Water supply schemes

Adelaide Metropolitan Water Supply. Adelaide and surrounding areas of urban and rural development extending 80 kilometres to the south and 80 kilometres to the east and north receive water from nine reservoirs in the nearby Mount Lofty Ranges and by means of two pipelines pumping from the River Murray at Mannum and Murray Bridge.

The principal sources of supply for the reservoirs are the Rivers Torrens, Onkaparinga, South Para and Myponga. These have been developed to provide a total storage capacity of 188.7 mil. cubic metres in the nine reservoirs. A tenth reservoir to provide a storage of 18.0 mil. cubic metres on the Little Para River is under construction.

The pipeline from Mannum has a nominal annual capacity of 118.0 mil. cubic metres and the one from Murray Bridge an annual capacity of 163.0 mil. cubic metres. Actual quantities pumped however, depend upon intakes of reservoirs and consumption as influenced by climatic and demand factors. On the average the Adelaide water supply system currently depends upon the River Murray for about 40 per cent of its supply, with the percentage rising with urban and industrial development.

Water consumption for the whole area in 1972–73 was 155.1 mil. cubic metres, the amount pumped from the Murray through the two pipelines being 51.6 mil. cubic metres.

Capital works are financed principally from State loan funds. The net loan funds invested at 30 June 1973 in the Adelaide metropolitan water supply system was $145,156,000. New works in progress include the Little Para dam estimated to cost $23,000,000 and a ten year program to provide water treatment works for all sources of supply at an estimated cost of $73,000,000. Australian Government financial assistance is being provided for the latter program.

Country reticulation supplies. Areas extending to a distance 145 kilometres north of Adelaide are supplied from the Warren, Barossa and South Para Reservoirs (61.2 mil. cubic metres) in the Barossa Ranges. Supplies to these areas are supplemented by River Murray water delivered into the Warren Trunk Main by a pipeline extending from Swan Reach to a point near Stockwell. This pipeline has a nominal capacity of 24.9 mil. cubic metres per year. Areas further north are supplied from Beetaloo, Bundaleer and Baroota Reservoirs (capacity 16.2 mil. cubic metres) and the duplicate Morgan–Whyalla Pipeline system which can supply up to 65.7 mil. cubic metres per year from the River Murray. A large part of Eyre Peninsula is supplied through the 386 kilometres Tod Trunk Main and branch mains which distributes water from the Tod Reservoir (11.3 mil. cubic metres) and the Uley–Wannilla, Lincoln and Polda underground basins. Along the River Murray all towns are supplied from the River with reticulation to surrounding farmlands up to 50 kilometres distant in some cases. A pipeline extended from Tailem Bend to Keith and a network of branch mains provide the means of conveying River Murray water to numerous towns and large areas of farmlands in the upper south-east.

Surface and underground resources have been developed to supply most country centres not covered by the larger schemes. Victor Harbor and adjoining south coast resort centres are supplied from reservoirs and the River Murray. A reservoir on Kangaroo Island supplies Kingscote and adjacent farmlands. Underground resources of the lower south-east supply all towns in the region, the city of Mount Gambier and nearby farmlands being reticulated from the well-known Blue Lake. At the far northern opal mining town of Coober Pedy a reverse osmosis desalination plant provides a potable supply from brackish groundwater. Other centres in the far north obtain supplies from the Great Artesian Basin.

Net loan funds invested in country water conservation and distribution works at 30 June 1973, amounted to $142,977,000 (exclusive of river control and irrigation works on the River Murray). The various water supply systems contain approximately 14,300 kilometres of water mains from which consumption in 1972–73 was 74.0 mil. cubic metres.

Works in progress include extension of reticulation works on central Eyre Peninsula, for which an Australian Government grant of $2,100,000 is being provided, development of Uley South Underground Basin on southern Eyre Peninsula to augment the supply at Port Lincoln, and upgrading of various other country systems to meet current demands.

Underground water

For information on underground water resources in South Australia *see* Year Book No. 55 and earlier issues.

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 suitability of surface and underground water for irrigation and stock purposes. In addition, a great part of the farming areas is supplied by the Engineering and Water Supply Department with water under pressure from extensive distributions systems connected to various reservoirs and 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 about 40,500 hectares. The South-eastern Drainage Area System, which is controlled by the South-eastern Drainage Board, comprises drains constructed by the State Government at public expense, 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 89 kilometres north of Kingston, southerly to near Millicent and Kalangadoo. Up to 1948 about 692 kilometres 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 carried out. The southern section of 105,200 hectares involved the excavation of 6,193,000 cubic metres in providing 552 kilometres of new or enlarged drains, whilst the northern area of 56,650 hectares required the excavation of 2,333,000 cubic metres in the construction of 159 kilometres of drain.

The drainage of 294,200 hectares in the Eastern Division of the south-east, situated east of Bakers Range and extending from near Kalangadoo to north of Naracoorte, was commenced, in 1960 and completed in 1970. The work required the construction of a main diversion drain (consisting of the enlargement of 39 kilometres of existing drain and the construction of 35 kilometres of new drain) from the sea at Beachport to the Naracoorte-Mount Gambier railway line near Struan. The provision of new branch drains and the enlargement and extension of existing branch drains completed the approved works. A total excavation of 5,581,000 cubic metres over a length of 189 kilometres of new or enlarged drains was involved.

The capital cost of drainage in the South-eastern Drainage Area System to 30 June 1973 was $18 million, and the length of drains constructed was 1,408 kilometres. An extensive system of private drains (many of which discharge into drains constructed under Government authority) also exists in the south-east of the State.

Murray River Irrigation Areas

Where irrigation water in excess of plant requirements has been applied, perched water tables develop. Rising to the level of tree roots, these cause the death of orchards from salination and water-logging. Most orchards and vineyards are now drained by plastic and tile drainage systems, thus restoring their health and productivity. Disposal of drainage water is achieved by pumping to basins on river flats where it evaporates, or is discharged into the river when it is in flood. It may also be discharged into underlying sand and limestone aquifers. The usefulness of these aquifers is declining as they are becoming fully charged with water.

Western Australia

Administration

The Minister for Water Supply, Sewerage and Drainage administers the departmental irrigation schemes under the *Rights in Water and Irrigation Act, 1914–1971*. He is advised by an Irrigation Commission representing the local irrigationists and government, technical and financial branches. He also administers, under the *Country Areas Water Supply Act, 1947–1964*, the water supplies to certain country towns and reticulated farmland. As Minister for Works he controls minor non-revenue producing supplies to stock routes and a few mines and agricultural areas with their associated communities. A small number of town supplies are administered by local boards under the *Water Boards Act, 1904–1969*, 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.

Logue Brook Dam with a capacity of 24.3 mil. cubic metres, Harvey Weir (8.0 mil. cubic metres) and Stirling Dam (57.0 mil. cubic metres) supply the Harvey Irrigation District, the rated area of which is 5,593 hectares. The Harvey District links up with the Waroona Irrigation District, which is served by Waroona Dam (15.0 mil. cubic metres), Drakes Brook Dam (2.3 mil. cubic metres) and Samson Brook Dam (9.2 mil. cubic metres) and comprises a rated area of 1,427 hectares. Wellington Dam on the Collie River with a capacity of 185.2 mil. cubic metres serves an area of 4,751 rated hectares in the Collie River Irrigation District. Pastures for cattle comprise 91.9 per cent of water usage in these districts. Glen Mervyn Dam (1.5 mil. cubic metres) stores water for regulated release down the Preston River for irrigation of orchards and crops when the natural summer stream flow is insufficient to meet the demand.

Since the mid 1930s, 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 for the 146 plantations. Because of the high risk of drawing in surrounding saline ground waters by over-pumping, the usage of water by the planters is controlled strictly by the Government. The Government is developing up-river sources and delivers water by pipeline to 65 plantations in the district. Bananas for the Perth market and fruit and vegetables for the Perth and Adelaide markets are the principal crops. 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 72,000 hectares of land agriculturally and topographically suitable for irrigation. Nearly one-third of the suitable land is within the Northern Territory.

The first stage, in which water was supplied to 30 farms averaging 270 hectares plus a 970-hectares pilot farm from the Kununurra Diversion Dam with a capacity of 98.7 mil. cubic metres, was completed in 1965. Cotton is the principal crop but grain sorghum and fodders for cattle fattening are also important. Completion in 1971 of the Ord River Dam which stores 5,674 mil. cubic metres in Lake Argyle has allowed expansion of the area to be irrigated into the second stage. Five farms averaging 388 hectares were allocated in 1973.

On the Liveringa flood plain, water is diverted from the Fitzroy River into a dam on Uralla Creek, which together with a natural storage of about 1.5 mil. cubic metres, provides for irrigation at Camballin, 105 kilometres south-east of Derby. Grain and fodder sorghums are grown in the area.

Irrigated culture

The following table shows details of the area of crops and pasture and the methods employed on land under irrigated culture during the 1972–73 season.

AREA OF LAND UNDER IRRIGATED CULTURE: WESTERN AUSTRALIA, 1972-73
(Hectares)

	Method of irrigation					
	Spray	*Furrow*	*Flood*	*Trickle*	*Multiple methods*	*Total area*
Crop—						
Cereals	51	1,138	2,038	..	1	3,228
Cotton	..	..	3,861	..	..	3,861
Fruit	3,269	258	141	1,093	272	5,033
Vegetables—						
Potatoes	1,745	14	2	4	24	1,789
Other	1,541	551	100	24	66	2,282
Grapevines	368	28	33	139	27	595
Other crops(*a*)	359	50	300	..	6	715
Total crops	**7,333**	**2,039**	**6,475**	**1,260**	**396**	**17,503**
Lucerne	741	2	35	..	3	781
Pastures	1,310	2,484	10,651	..	172	14,617

(*a*) Includes fodder crops.

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

Since 1947 enlargement and extensions of the Goldfields and Agricultural 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 1,700,000 hectares 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 Australian Government 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 $10.5 million representing half the estimated cost of proposed extensions which would increase by 1,500,000 hectares the area served by the scheme. The Australian Government 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, 42 kilometres from Perth, is the source of water supplied to the Eastern Goldfields. It has a capacity of 77.0 mil. cubic metres and is connected to Kalgoorlie by a pipeline with extensions to towns and agricultural areas. At 30 June 1973 the Goldfields and Agricultural Water Supply was serving 112 towns and localities, and water was being reticulated to farms in an area of 2,300,000 hectares. The total length of pipelines was 7,883 kilometres and the number of services was 27,002. Consumption during 1972–73 including supplies drawn from local schemes and from the Metropolitan Water Supply, was 17.7 mil. cubic metres.

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 1973 the Supply was serving 30 towns and water was being reticulated to 600,000 hectares of farmland. The total length of pipelines was 1,860 kilometres, and the number of services was 10,580. Consumption during 1972–73, including supplies drawn from local sources, was 4.1 mil. cubic metres.

One hundred and thirty-two local schemes supply water from stream flow, dams, tanks, wells, and bores, mainly to country towns. At 30 June 1973 the total length of water mains was 2,007 kilometres and the number of services was 36,232.

Other country water supplies

As well as the schemes controlled by the Department of Public Works and Water Supply, there are four local Water Boards which draw supplies from stream flow, dams, wells, and bores. In addition, some local authorities supply water within their boundaries. The Forests Department, sawmilling companies, and mining companies operate schemes to supply water to their towns and operations. Railways of the Australian 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

Extensive use is made of underground water for town water supplies, household gardens, market gardening, orchards, pastures and stock water. Artesian wells throughout the State and non-artesian wells within 'declared' areas must be licensed under the *Rights in Water and Irrigation Act, 1914–1971.*

Tasmania

Main purposes of water conservation and utilisation

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. 'Run of the river' schemes are quite adequate for assured supply in many municipalities. The main supply for Hobart and adjacent municipalities originates from a 'run of the river' scheme based on the Derwent River. The river is controlled in its upper reaches by eight dams, built for hydro-electric power generation, and these tend to stabilise river flow.

Until a few years ago irrigated areas were negligible except for long established hop fields, but there is a rapidly expanding use of spray irrigation on orchards, pastures, potatoes and beans. Until recent years there has been almost complete dependence on natural stream flows, but the need for some regulating storages has become apparent. Increasingly, 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 domestic use is exploited in the consolidated rocks of southern, midlands and north-western Tasmania. In the south and midlands nearly all groundwater is obtained from Permian and Triassic rocks. In the north-west, water is recovered from a variety of rocks ranging from Precambrian dolomites, quartzites and schists to Tertiary basalts and Quaternary sands. The highest yields are obtained from the dolomites and the basalts. In the central north and north-east unconsolidated Tertiary clays and gravels yield water of variable quality, and in some coastal areas, notably King and Flinders Islands, water is obtained from Aeolian sands.

The Mines Department is charged with the investigation of underground water resources. There is a great reserve of untapped permanent streams in the western half of the State, which is largely unsettled. The State's largest rivers discharge in the west, but diversion to the eastern half of the watersheds is not regarded as practicable.

Administration

In Tasmania, water supply was once exclusively the responsibility of local government authorities, but two statutory authorities, the Metropolitan Water Board and the Rivers and Water Supply Commission, now operate bulk supply schemes, piping water for distribution by the local government authorities in the Hobart and Launceston regions, and directly to certain industrial consumers.

Metropolitan Water Board. The overall control of the supply of water to the cities of Hobart and Glenorchy and the municipalities of Kingborough and Clarence is vested in the Metropolitan Water Board, the local government authorities retaining primary responsibility for reticulation and sales to consumers. Water is also supplied by the Board to urban areas in the Sorell, New Norfolk and Brighton municipalities. The principal source of water for urban Hobart is the Derwent River from which the Metropolitan Water Board operates two schemes. The West Derwent Water Supply supplies the cities of Hobart and Glenorchy and the Kingborough Municipality. Water for this scheme is drawn from the Derwent at the Bryn Estyn pumping station. The Southern Regional Water Supply scheme, originally constructed by the Rivers and Water Supply Commission to serve Clarence Municipality and other areas on the eastern shore of the Derwent, draws its water from the Derwent at Lawitta (almost directly opposite the intake for the West Derwent Water Supply Scheme). The responsibility for loan raising, debt servicing and extensions to the schemes rests with the Metropolitan Water Board.

Rivers and Water Supply Commission. The Commission is empowered by the *Water Act* 1957 to take water at streams and lakes, or to issue others with licences to do so; licensing covers supply to specific industries and municipalities as well as irrigation. The Commission is concerned with drainage trusts' operations, river improvements (including repairs after flood damage), stream gauging, its own regional water schemes, and with water supply, sewerage and drainage of towns. It operates in a similar manner to the Metropolitan Water Board in controlling the water schemes serving the East Tamar region (North Esk Regional Water Supply), the West Tamar area (West Tamar Water Supply) and the Prosser River Scheme, which was originally constructed to supply water to a sodium alginate industry at Louisville near Orford and to supplement the water supply of the township of Orford (in December 1973 the sodium alginate industry ceased production). The North Esk Regional Water Supply was constructed to meet industrial requirements of the alumina refinery and other industries at Bell Bay, and to provide bulk supplies to surrounding municipalities on the eastern bank of the River Tamar. The West Tamar Water Supply was constructed primarily to meet domestic requirements of urban areas in the Beaconsfield municipality. The local government authorities retain primary responsibility for reticulation and sale to consumers, except to certain industrial users.

In municipalities not serviced by the Metropolitan Water Board or the Rivers and Water Supply Commission, the supply of water is a function of the local municipal council. Where the construction of water and sewerage schemes is beyond the financial capacity of a local government authority, or if it requires assistance to pay for water supplied from regional schemes, the Commission may make recommendations to the Minister for payment of a subsidy.

Industrial water schemes

Four 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, for another at Wesley Vale using water from the Mersey 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 alumina refinery at Bell Bay referred to above, and a storage supplementing the summer flows of the Kermandie River for use by a wood-pulping plant at Geeveston.

Irrigation

The Cressy-Longford Irrigation Scheme was officially opened in March 1974 and services approximately 65 farms within the irrigation district. The farms are supplied with irrigation water by either flood or spray sprinkler systems. A further 30 farms, on the fringes of the irrigation district, will benefit from augmented river flows. This scheme, which was designed and is operated by the Rivers and Water Supply Commission, involves the diversion of water from the tailrace of the Poatina hydro-electric power station through some 97 kilometres of earthen channels to irrigate eventually some 8,094 hectares. At least half this area will be served by gravity and it is estimated that under maximum development 7.4 mil. cubic metres of water annually would be available to farmers both inside and outside the irrigation district.

With the exception of the Cressy-Longford Scheme and a privately owned scheme at the Lawrenny estate at Ouse there are no other extensive irrigation works utilising one common source of water supply in Tasmania. A large portion of the area under irrigation in the State is watered by private schemes pumping water from natural streams.

Irrigated culture

The following table shows details of the area of crops and pasture and the methods employed on land under irrigated culture during the 1972–73 season.

AREA OF LAND UNDER IRRIGATED CULTURE: TASMANIA, 1972-73
(Hectares)

	Method of irrigation					
	Spray	*Furrow*	*Flood*	*Trickle*	*Multiple methods*	*Total area*
Crops—						
Cereals	726	..	33	..	16	775
Fruit	2,904	37	137	80	143	3,301
Vegetables—						
Potatoes	2,290	8	..	2	13	2,313
Other	4,815	11	..	5	9	4,841
Other crops(*a*)	1,504	213	110	26	12	1,865
Total crops	**12,239**	**269**	**280**	**113**	**193**	**13,095**
Lucerne	1,343	24	43	..	4	1,414
Pastures	8,022	345	4,687	..	83	13,137

(*a*) Includes fodder crops.

Northern Territory

Information on climatic conditions will be found in the chapter Climate and Physical Geography of Australia, and a brief outline of contour and physical characteristics in Chapter 30, The Territories of Australia.

Administration

Under the *Control of Waters Ordinance* 1938–1971 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). The diversion of water is prohibited except under prescribed conditions. The Ordinance requires that drilling for ground-water be carried out only by drillers who are registered under the Ordinance. Registered drillers are required to provide the Government with information on bores drilled including the location, depth and size of bore, strata encountered and water produced. In particular areas, described as Water Control Districts, where stricter control is necessary the construction or use of a well or water bore without a permit can be prohibited.

Under the *Water Supplies Development Ordinance* 1960–1971 any landholder engaged in pastoral or agricultural production may seek information or advice from the Commissioner of Water Development who is appointed under the Ordinance. He may also apply for an advance towards the cost of work proposed to be carried out. The Ordinance also provides for a refund to the landholder of the cost of drilling an unsuccessful bore where the landholder had applied to the Commissioner for advice on its construction and has carried out all drilling operations in accordance with advice given.

There is a Water Resources Branch of the Department of the Northern Territory under the control of a Director. The Branch carries out systematic stream gauging, the collection of data relating to the quantity and quality of surface and groundwater, the planning of water use for industrial, irrigation and town water supplies, and flood prevention and control. It also provides a general advisory service to the public on water resources and water conservation by providing information on the geology of the Territory, the prospects of obtaining groundwater, the possible location of bore sites, the method of drilling and equipping bores, information on stream flows, surveys of dam sites, the design of water supply schemes and reticulation layouts, and on the chemical and bacteriological quality of water supplies. It is involved in water pollution studies and control, and carries out environmental assessments of water and related developments. The Branch administers the licence and permit provisions of the Control of Waters Ordinance.

Underground water

For information on underground water resources in the Northern Territory *see* Year Book No. 55 and earlier issues, and the Australian Water Resources Council's 1972 publication, *Groundwater Resources of Australia.*

At 30 June 1973, 8,522 bores and wells were registered in the Northern Territory. Of these 4,855 were for pastoral use, 430 for agricultural use, 682 served town domestic water supplies, 140 were in use on mining fields, 973 were investigation bores, 431 were Government established stock route bores and 741 were classified under other uses. 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.

Community water supplies

The largest water conservation projects in the Territory are the Darwin River Dam (259.0 million cubic metres) and the Manton Dam (15.7 million cubic metres) which both serve Darwin with a reticulated water supply. Groundwater from McMinns Lagoon area can be used to augment supply.

Most other towns and communities are supplied by groundwater. A few are supplied by both ground and surface waters depending on relative quality variations throughout the year.

Surface water measurement

The hydrological investigations required in the Northern Territory as part of the National Water Resources Assessment Programme are being carried out by the Water Resources Branch. The program for the Northern Territory includes establishment of base gauging stations and pluviograph rainfall recorders. In particular areas of development where water supply or irrigation proposals require special or extra surface water data, supplementary gauging stations are built to obtain this information. At 30 June 1973, the Northern Territory stream-gauging network comprised 274 operating stations; of these 209 were base gauging stations and 65 were supplementary gauging stations.

Irrigation for agricultural purposes in the Territory is not extensive, being confined to isolated areas near the Darwin, Adelaide River, Coomalie Creek, Daly River, Katherine River, Wickham River, Douglas River, Edith River and Alice Springs area, with only small acreages being utilised. In the Territory 91 licences to divert water from streams were current at 30 June 1973. The total licensed area for irrigation is 2,554 hectares, 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, fodder and pastures, and also dairying and mixed farming.

Both the Daly and Adelaide Rivers appear to offer considerable potential for irrigation development with regulation of the rivers. Extensive investigations are being conducted into possible dam sites and areas of land suitable for irrigation in the region, and there is a need for other associated studies. Irrigation trials are in progress using water from the high-production bores in the Daly Basin. Further exploratory drilling in this area is being carried out. There is an increasing demand for water resource assessment studies and assistance for relatively small irrigation projects.

Investigations are continuing into areas of the Northern Territory which may be suitable for irrigation from the main storage on the Ord River in Western Australia.

Australian Capital Territory

The climate of the Australian Capital Territory with its moderate rainfall and high evaporation over the growing season is such that water conservation and irrigation are practised.

Groundwater in the A.C.T. and environs occurs mainly in fractures, joints and weathered zones of crystalline rock such as porphyry, granite, limestone and metasediments. Alluvial aquifers are restricted to the Lake George basin and small areas along mature sections of the Molonglo and Murrumbidgee Rivers. Very minor perched aquifers occur. Recharge mainly takes place in the cooler months of the year.

Currently there are 103 bores for all purposes in the A.C.T.; 69 cater for domestic, stock and irrigation purposes, four are for industrial purposes and 30 are observation bores which the Bureau of Mineral Resources has progressively established over the past 12 years as part of its policy of assessing the groundwater resources of the region and gathering basic hydrogeological data. The yield from the bores ranges mainly from 0.45 to 8.18 cubic metres per hour.

In 1972-73 a total area of 386 hectares was under irrigated culture in the A.C.T. The crop areas were orchards, 7 hectares; vegetables, 45 hectares; nurseries, 3 hectares; lucerne, 180 hectares; and pastures accounted for 150 hectares. Of the total area irrigated, 329 hectares was irrigated from surface sources, 53 hectares from bores and 4 hectares from the reticulated water supply.

Control of irrigation and farm water supplies is exercised by the Conservation and Agriculture Branch of the Department of the Capital Territory. The Bureau of Mineral Resources of the Department of Minerals and Energy provides technical advice on groundwater, and occasionally on run-off, to landholders.

Water conservation on farm holdings was shown to be deficient in the severe 1965–68 drought when stock were moved to areas outside the A.C.T. Improvements by the provision of additional or larger farm dams and of bores have been made in recent years.

Papua New Guinea

Rainfall in Papua New Guinea varies considerably from approximately 6,100 millimetres near Lindenhafen (New Britain) and 5,840 millimetres at Kikori (Papua) to about 1,780 millimetres near Marienburg (New Guinea) and 1,020 millimetres at Port Moresby (Papua). For a general description of these territories *see* Chapter 30, The Territories of Australia of this Year Book. Irrigation has not been developed on any organised basis owing to the availability of high rainfall and the nature of agricultural development.

Papua New Guinea is well served with large rivers deriving their water from heavy tropical rains and high mountains which rise to over 4,250 metres, but complete data regarding water resources are not available. During 1972–73 the Government continued the development of a national network of stream-gauging stations which can be used in assessing the water resources of Papua New Guinea, while continuing to collect more detailed hydrological data for proposed hydro-electric projects.

The largest rivers in the Territory include the Fly (about 1,100 kilometres long, situated in the Western division of Papua), the Sepik (about 1,100 kilometres), the Ramu (about 725 kilometres), the Purari (about 485 kilometres), and the Markham (about 180 kilometres). 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 Chapter 30, The Territories of Australia.

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