REGIONAL DISTRIBUTION OF RIVERS AND STREAMS IN AUSTRALIA AND OCEANIA

V.I. Babkin
State Hydrological Institute, St. Petersburg, Russia

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Summary

Of the Earth's continents, Australia has the smallest land area, comprising 7615 million km^2. Much of Australia is very dry and the river network is very sparse. There are few rivers here compared to the other continents. The rivers of the western coast of Australia (Murchison, Gascoyne, Ashburton and others) flowing to the Indian Ocean do not have perpetual runoff. Their water resources are formed in semi-desert coastal plateaus. The largest rivers of the inner runoff area Coopers Creek, Georgina and Diamantina have a rainfall alimentation only after the short showers.

A vast area of the west Plateau is characterized by occasional runoff. Here, streams and chains of dry lakes are widespread. The most full-flowing rivers of Australia are the Burdekin, Fitzroy, Herbert, Clarence and Snowy. Their sources are located in the East Australian Mountains. In the north of Australia, the most full-flowing rivers are the

Daly, Victoria and Mitchell. The largest rivers of Australia are the Murray and Darling.

Oceania is in fact an independent region. It has a very high density of river network. Its area equals 1.27 million km^2. The rivers of Oceania are characterized by a large water content. On New Guinea Island, the largest and highest water rivers are the Sepik and Fly. The largest river on the North Island of New Zealand is the Waikato. The main rivers of the South Island of New Zealand are the Waitaki, Clutha and Waiau.

The water resources of Oceania are approximately seven times greater than those of Australia. The runoff of Australian rivers has a coefficient of variation of 1 or greater while Oceania is characterized by low variability, within 0.1 to 0.2.
The river runoff of Australia and Oceania is characterized by pronounced year-to-year change. The river runoff has a non-uniform distribution within the year in much of Australia but it is comparatively uniform in Oceania. The resources of river runoff in Australia are widely used in agriculture, industry and other economic sectors. In 1990, water consumption in Australia (including Tasmania) was 7.2% of total water resources. It is expected to increase to 10% by 2025. The use of runoff of rivers in Oceania is small at present and by 2025, it will be only 0.2% of their value.

1. Introduction

The Australia continent is situated in the southern hemisphere between 10^o and 30^{o}S and 113^o and 153^{o}E. Several continental islands including Tasmania, with an area of 68 400 km^2 belong to it. Australia is the smallest of the Earth's continents. Its area comprises only 7.615 millions km^2. Waters of the Pacific and Indian Oceans wash its shores. About 613 000 km^2 or 8% of the territory of Australia belongs to the Pacific Ocean Basin and 3 078 000 km^2 or 40.05% to the Indian Ocean Basin. Most of the continent area, 3 924 000 km^2 or 51.5%, belongs to the area of inner and occasional runoff.

North and east of Australia in the Pacific Ocean, there are large groups of islands combined under the common name of Oceania. The total area of these groups of islands is approximately equal to 1 270 000 km^2. The area of the three largest islands, New Guinea and North and South New Zealand, comprises 83% of the entire land area of Oceania.

The continent under consideration rises comparatively little above sea level. Its mean height is only 215 m. Of all the inhabited continents, Australia is the most sparsely populated. In 2000, 18.6 million people lived here. The population density comprises only 2.3 persons per km^2. The main portion of the population lives on the east and southeast coast where the largest cities are located.

The climatic conditions of Australia are primarily determined by its geographical location and the relief features. Dry and semi-dry land occupies about 5 million square kilometers of the area of Australia. Aridity is typical of much of the Indian Ocean basin territory, of the internal runoff area (basins of Lakes Eyre and Bulloo-Bancannia) and of the occasional runoff area (West Plateau). An insignificant quantity of precipitation falls over much of the continent, not just in desert areas but also in comparatively well

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populated regions.

The hydrographic network in the arid territories is poorly developed. It is represented by occasional saline lakes and short ephemeral rivers—creeks. Australia has small freshwater resources. Most of the lakes are saline. At present, about 400 water reservoirs with a total volume of about 100 km^3 have been constructed. The water resources in the river network of Australia and Oceania comprise about 30 km^3. The limited surface water resources have led to the need to use groundwater, including artesian sources. However, compared with the other continents, the groundwater supplies here are also small. Artesian water is used for pasture watering in Queensland and New South Wales. Due to the saline character of artesian water, it is little used for irrigation. Along with surface water, groundwater is used for irrigation and water supply. However, its share, compared to surface water is small.

Significant water supplies are centered on the islands of Oceania. The water supplies in the glaciers of New Zealand and New Guinea are assessed at approximately 107 km^3 and the lakes of New Zealand, as 154 km^3.

The peculiar climatic conditions and orography of Australia and Oceania, that govern the hydrographic network distribution, as well as the small population and specific features of industrial and agricultural production, contribute to the development of certain peculiarities in the use of water resources. The most accessible are waters of rivers and water streams. That is why, the hydrographic network and the river runoff distribution over the territory of the continent and the islands have a decisive importance for the development of industrial and agricultural production.

2. Physico-geographical characteristics. Factors determining the development of the hydrographic network and distribution of rivers

2.1. General physico-geographical information

Australia and Oceania have widely differing natural conditions. In respect of relief features, Australia can be conventionally subdivided into three parts: western, eastern and central. The western part of the continent is occupied by a plateau and the eastern one consists of highlands and mountains along the eastern margin of Australia and the associated coastal plain. The highest top of this Range (Mount Kosciusko) is 2230 m above sea level. The central part of Australia extending from the Gulf of Carpentaria to the Great Australian Bight is represented by vast lowlands.

The islands of Oceania contain mountain territories. The highest point of Oceania above sea level belongs to Mount Jaya located on New Guinea Island. Its height is 5029 m above sea level. By geographical and ethnographical features, the islands of Oceania are divided into three groups: Melanesia, Polynesia and Micronesia. Melanesia is comprised of the islands of the southwestern part of Oceania. The largest among them are New Guinea, the Solomon Islands, New Hebrides, New Caledonia and Fiji. The total area of Melanesia comprises about 970 000 km^2, i.e. 76% of the land area of the entire Oceania. Polynesia includes the islands of eastern Oceania, Hawaii, Samoa, Tonga, the Marquesas and others, and the North and South Islands of New Zealand. The total area

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of all islands of Polynesia comprises 292 000 km^2. Micronesia occupies the northwestern portion of Oceania. It includes the Marianas, Caroline and Marshall Islands and more than 1500 small islands with a total area of about 2000 km^2. By origin, the islands of Oceania can be divided into land and oceanic. The oceanic islands are in turn subdivided into volcanic and coral. The large islands of Melanesia located in the Western Pacific (New Guinea, New Zealand, New Caledonia, Bismarck, Louisade archipelago and others) belong to the class of land islands. They have a common origin with the mainland; they were connected to each other and to the mainland until the quaternary Period. The volcanic and coral islands of Polynesia and Micronesia located in the central and eastern parts of the Pacific belong to the class of oceanic islands. Islands of this type are also found around larger islands in the Western Pacific Tectonic movements and vulcanism are strongly manifested in this region. There are 60 active volcanoes in Oceania, 51 ground volcanoes and 9 submerged volcanoes. The majority of these are situated in or near New Guinea, New Britain, the Solomon Islands, the New Hebrides and New Zealand.

2.2. Relief

The river network of Australia and Oceania is closely connected with climate, relief, geological terrain structure, soils and vegetation. The Australian continent presents a vast plateau. It is concave in its central part and has elevated margins. The most significant heights are observed in the east and southwest forming the chains of coastal mountains. The mountain uplifts occupy 5% of the continent surface whereas 95% of the land is extensive plains with a height of 300-340 m above sea level.

Along the eastern coast of the continent, there are the East Australian Mountains that are also called the Great Dividing Range. These mountains comprise a number of uplands and plateaus that are separated by troughs and depressions. The mountains have been heavily and are low, their heights varying from 800 to 1000 m. The East Australian Mountains sharply break towards the sea in the east. Only a narrow coastal plain separates them from the sea. The western slopes of the East Australian Mountains are gentle. In New South Wales and Victoria, there is the Australian Alps. Their highest tops—Mount Kosciusko and the Bogong massif—rise to more than 2200 m above the ocean level. The Australian Alps has preserved ancient glaciation traces. Snow in the form of individual patches is preserved year round in shaded ravines and glacial corries. In the extreme southeast of the continent, Tasmania continues the East Australian Mountain system. The island presents a mountain plateau broken by cracks into individual massifs.

The East Australian Mountains are a climatic boundary as they regulate the distribution of precipitation in the eastern part of the island. The air masses coming from the Pacific Ocean supply much water to their eastern slopes, which is why dense tropical and subtropical forests grow here. The Pacific Ocean air masses rise above the mountain elevations, but they already contain less moisture and they irrigate the western mountain slopes to a smaller extent. The East Australian Mountains are the main water divide of rivers flowing from their eastern and western slopes.

The extensive Western Plateau is located in the west of the mainland with an average

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height above ocean level of 300 500 m. Mounts Mcdonnell and Musgrave, that are heavily eroded and are composed of old crystalline rocks, lie in the eastern part of the plateau. Their height above the sea level is 1300 to 1500 m.

Vast desert territories are located north and south of these mountains. The Great Sandy Desert and the rocky Gibson Desert are located in the northern part, and the Great Victoria Desert in the southern part. In the extreme south of the Western Plateau, lies the dry, karst Nullarbor Plain. There are no rivers here. An enormous depression, the Central Lowland, is located in the central area of the continent with a width of up to 1000 km. This depression was covered by sea waters for a long period of geological time. The endorheic saline Lakes Eyre, Torrens, etc. are the remains of this sea. The central lowland is the driest region of Australia.

The relief of the large continental islands is mountainous. High pointed peaks of some mountains are covered with perennial snow and glaciers. Deep valleys dissect the mountain ridges. The New Zealand Alps reach a height of 3756 m above sea level (Mount Cook) and the New Guinea Alps, 5029 m (Mount Jaya). Lowland plains are located on the margins of continental islands.

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2.3. Climate

Australia is the only inhabited continent of our planet, which is completely situated within the Southern Hemisphere. The climatic conditions of Australia and the adjoining large islands of Oceania are determined by their position near the equator among the relatively warm seas and the oceans. Due to this, tropical and equatorial air masses dominate over much of the continent and only the extreme south of Australia and Tasmania and New Zealand are affected by the air masses of temperate latitudes. The arid territories of the continent are characterized by prolonged dry periods alternating with rain showers. Strong droughts occur on average every 10-15 years and last for 2-3 years successively.

Waters of the Pacific and Indian Oceans have an ameliorating influence on climate of Australia and Oceania. The South Trade-Wind Current carries waters to the shore of New Guinea with temperatures higher than 28 ^{o}C. A cold West-Australian current passes in the Indian Ocean, its water temperatures comprising 10 - 12 ^{o}C in winter and 13 - 15 ^{o}C in summer. The location of the high and low pressure centers play a large role in the moistening of Australia. During the cold season of the year (July-August), high air pressure is established above the continent and low air pressure during the warm period (December-February).

Monsoon climate is clearly pronounced in the north of Australia. The central part of the continent belongs by climatic conditions to semi-deserts and deserts. The climate of the continent, in spite of its small size and location in the ocean, is continental with a large number of solar days. The average total annual solar radiation is equivalent to 172 watts per square metre in the South of Australia and more than 239 watts per square metre in the northwest. The significant length of the continent from west to east and weak irregularity of the coastline contribute to intense heating of its central areas.

The radiation balance of the Earth's surface here comprises 92.8 watts per square metre. About 35%s of the heat is lost due to evaporation, while the remaining heat is lost due to the turbulent exchange of the Earth's surface with the atmosphere and to heating of the surface and the heat flux to soils.

Tasmania experiences the influence of the ambient water space. Cool and moist summers followed by cool winters are typical of Tasmania. There is occasional snowfall, but snow melts very quickly. Abundant precipitation brought by westerly cyclones is typical of all seasons of the year. On the western shore of Tasmania, more than 2500 mm of precipitation fall per year, contributing to the development of luxuriant vegetation. A significant portion of Tasmania is covered with evergreen forest and meadows.

South West Australia is characterized by a hot, dry summer and a warm, humid winter. Comparatively small air temperature variations are observed here through the year. Between 500 and 1000 mm of precipitation fall here throughout the year. Tropical climate is characteristic of a narrow coastal territory in the northern and northeastern areas of Australia. It is characterized by uniform air temperature variations and by the fall of a large amount of precipitation (between 1000 mm to 2000 mm and more). Precipitation is transported by the northwesterly monsoon and mainly falls in summer. Rains in winter are observed occasionally. At this time of the year, dry winds blow from the inland areas, sometimes causing drought.

The eastern part of Australia from Torres Strait in the north to Bass Strait in the south is in the zone of action of the southeast trade wind. In winter, the trade winds deviate northward, at which time the southern part of the coast is beyond the zone of their influence.

The area of coastal plains and eastern slopes of the Great Dividing Range has a mild warm climate. Around 1000 to 1500 mm and more of precipitation falls here over the year. In the area of the Snowy Mountains, around 2500 mm of precipitation fall out throughout the year. About 4000 mm of precipitation falls over the year on the northeastern coast of Queensland. The air masses of the southeast trade wind cross the East Australian Mountains losing a significant portion of their moisture. This is why the quantity of precipitation towards the center of the continent sharply decreases. Only on the western slopes of mountains and a narrow foothill band (250 to 300 km), is there 250 to 500 mm of precipitation. The exceptional dryness of the climate dictates the extent of vast desert space from the shore of the Indian Ocean to the foothills of the East Australian Mountains. The quantity of precipitation in the central and western mainland areas is very low, mostly around 250 to 300 mm a year and, in the vicinity of Lake Eyre, about 100 mm. Here, precipitation is not so regular. Sometimes, for several years in succession, rain does not fall at all. Irregular precipitation and the low total rainfall over much of the territory of Australia, as well as the peculiar temperature regime of the continent located predominantly on tropical and subtropical latitudes, along with the terrain regime, lead to weak development of the hydrographic network.

There is abundant precipitation on the largest islands of Oceania. At the southern slopes of the mountains of New Guinea, there is more than 5500 mm per year, and on the

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western slope of the South Island of New Zealand, more than 6500 mm.

2.4. Soils and vegetation

Soils and vegetation influence the redistribution of precipitation, the runoff and evaporation. In the center of the continent in the area of sandy and rocky-clayey deserts, there are grey soils. On grey soils in the border areas of the Central Plains where irrigated agriculture is developed, it is possible to grow vines, fruit trees and fodder grass. In the semi-desert and steppe areas that surround the central desert area, where there is a herbaceous and sometimes a shrub-arboreal cover, there are thin grey-brown steppe soils. The zone of afforested steppes has red-brown and brown soils. The main wheat crops are located within the area of red-brown soils. The tropical and sub-tropical podzol soils are developed on the wettest eastern slopes of the Great Dividing Range and in the coastal plains. This soil type is also widespread in the southwestern afforested part of Australia. On the western slopes of the East Australian Mountains, red-brown forest soils are developed. These are characterized by good water permeability and the presence of humus. The distribution of the vegetation cover over the continent corresponds to that of soil cover, climate and terrain relief.

Eucalyptus is the most widespread tree on the continent. It is encountered in the form of shrubs and as giant trees up to 150 m high. In addition to eucalyptus, there are several different types of wattle (*Acacia* spp.), horse-tail and tree-fern, as well as casuarinas. In desert mainland areas, one can see dense scrub of thorny undersized shrubs consisting mainly of eucalyptus and wattle. In wetter areas, there are evergreen sparse and light woods consisting predominantly of eucalyptus. In the zone of heavy moistening in the north and northeast, there are evergreen tropical forests. Subtropical evergreen forests grow in East and South East Australia. Many beeches grow in the forests of Tasmania. In the southwest of the continent, forests grow on the slopes of mountains and hills facing the ocean. For the last few centuries, the vegetation of Australia has experienced significant changes, particularly through the arrival of European fruit and forest trees, vines, cotton, rice, flax, wheat, vegetables and other crops.

Soils and vegetation in Australia have little influence on the hydrography of river basins, but soils do have a major influence on agricultural production. Some tree species are felled for industrial purposes.

2.5. Human activity

The development of irrigation and hydroenergetics in Australia and on the Oceania islands has led to construction of water reservoirs, dams, channels and pipelines. The total length of the service channels—an artificial hydrographic network—on the continent comprises several thousand kilometers. Many rivers of the continents are regulated in the upper reaches. By the mid 1980s, about 400 water reservoirs were used in Australia including 18 large ones (with a full volume of 1 to 10 km^3), 52 medium (with a volume of 0.1 to 1 km^3) and more than 300 small reservoirs. Many water reservoirs were created on the continent and on Tasmania by means of backwater to lakes with the transfer of river water from other basins. On Tasmania, of the created 43 water reservoirs, 33 are hydropower reservoirs. On South Island (New Zealand), there is

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an irrigation channel known as Rangitoto. There are 15 water reservoirs with a volume of greater than 100 millions m^3 in New Zealand. The other islands of Oceania are sufficiently watered and have significant hydropower resources, but there has been little need for an artificial hydrographic network.

A multipurpose system was constructed in Australia: to obtain additional power and supply water to the basin of the Murray River and its tributary the Murrumbidgee to expand the area of irrigated lands. This complex project, called the Snowy Mountain Scheme, was executed from 1949 to 1974 and is now fully operational. A water reservoir accumulates the runoff of the upper reaches of the Eucumbene River, and also receives and temporally redistributes the runoff of the upper reaches of the Murrumbidgee and Snowy Rivers. The additional volumes of water coming to the Murrumbidgee and Murray Rivers, 1.39 km^3 a year and 0.99 km^3 a year respectively, allow a significant increase of the water supply of the adjoining areas. The water complex under consideration includes 16 large dams, 7 hydropower stations, 5 water reservoirs, 2 pumping stations, about 80 kilometers of pipelines and 140 tunnels.

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Biographical Sketch

Vladimir Ivanovitch Babkin was born in 1941. In 1965, he graduated from the Voronrzh State University. Since 1969 he has worked at the State Hydrological Institute. In 1970, Babkin defended a thesis for the degree of candidate of geographical sciences, and in 1984, a doctoral thesis of geography.

Since 1982, he has been the head of the laboratory "Water Resources and Water Balance" at the State Hydrological Institute, St. Petersburg.

V.I. Babkin is the author of 130 scientific papers including seven monographs on hydrology, hydrophysics, and water balance and water resources. Most of his studies deal with hydrological cycle processes (evaporation, runoff, precipitation, and infiltration), developing methods for their estimation, as well as discovering global mechanisms of land moisturizing on the continents.

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