PERENNIAL AND NON-PERENNIAL RIVERS IN SOUTH WEST AFRICA AND THEIR UTILIZATION FOR THE ECONOMY OF THE LAND

By H. W. Stengel

(With 5 maps, 17 diagrams, 9 photographs by the writer, 9 by Dr. O. Wipplinger, 2 by Prof. Dr. R. Lehmann, 1 by H.G. Rotter and 1 by F. Lempp. The article was for the first time printed in "Der Kreis", fifth year, Nr. 2/3, February/March, 1962.)

Contents: Perennial and non-perennial rivers in general - The topography of South West Africa with its natural drainage systems and the main rivers - The flow of non-perennial rivers and the system of observation at the water gauge stations - The utilization of river water - Development potential for large scale water conservation schemes in the future.

PERENNIAL AND NON-PERENNIAL RIVERS IN GENERAL

South West Africa belongs to the semi-arid zones. Its water courses only flow periodically, and in times of poor rainfall it can happen that a "river" "comes down" for only a few miles, or its bed can even remain quite dry. Only the Orange River on the southern boundary, the Cunene on the northern boundary, the Okavango with its tributary the Quito of similar size, the Kwando-Linyanti and the Zambesi, flow perennially. Perennial rivers are those that flow the whole year through. Of the non-perennial rivers, those that flow regularly every rainy season could be termed "seasonal rivers" and those like the Kuiseb which flow only occasionally can be called "periodic rivers".
The Orange, which forms the southern boundary between South West and the Republic will not be dealt with in this article.
While the seasonal and periodic rivers have well-developed dry beds with sand and gravel banks, the Omiramba (singular: Omuramba) are level meadow-like water courses with shallow valleys and poorly developed flood channels. Vleys often form in them, with deep ponds or pools, in which water collects after good rains and can stand for months until it percolates or evaporates. The vleys are important to the farmers for grazing, and so are the pans which occur mostly with limestone substrata in the Kalahari. Both vleys and pans, however, can only be used on a small scale locally for farming.
The underground water reserves of the country are limited. They can hardly withstand a greater strain, as consumption in the bigger centres has shown over the past decade. An exception is the water supply triangle Rooibank -

Walvis Bay - Swakopmund. As most of the underground water depends on the rainfall and consequently on the volume of water in the rivers, the greatest possible attention should be paid to both perennial and non-perennial rivers as they form the basis of economic development, now and even more so in the future.

THE TOPOGRAPHY OF SOUTH WEST AFRICA WITH ITS NATURAL DRAINAGE SYSTEMS AND THE LARGER PERENNIAL AND NON-PERENNIAL RIVERS

South West Africa is geologically and geographically a part of the subcontinent of Southern Africa. Steep mountain ranges and vast high plateaus follow the narrow coastal belt. The interior forms part of the Kalahari, a great basin, also ringed by mountains on the eastern sea-board, the Indian Ocean. There are many mountain ranges, some jutting sharply out of the sea, some rising in steps above precipitous cliffs as in the Drakensberg, and others with wide flat coastal plains opening below them as in Portuguese Mocambique. In the west the Cunene and the Orange have broken through the escarpment and in the east the Zambesi and the Limpopo.

The northwestern part of this sub-continent is South West Africa. Here steep massifs and high plateaus succeed the coastal plain of the Namib Desert, up to 90 miles wide. To the north lies the polymorphous mountain region of the Kaokoveld. In the interior are the massifs of the Brandberg, Erongo, Waterberg, Etjo, the Khomas Hochland and the Auas Mountains with plateaus between. The south is tableland with the mountain masses of the Naukluft and the Great and Little Karasberg. These north-south trending mountain zones give place in the east to the decline to the Kalahari Basin. Ovamboland in South West Africa is a northwesterly extension of the Kalahari.

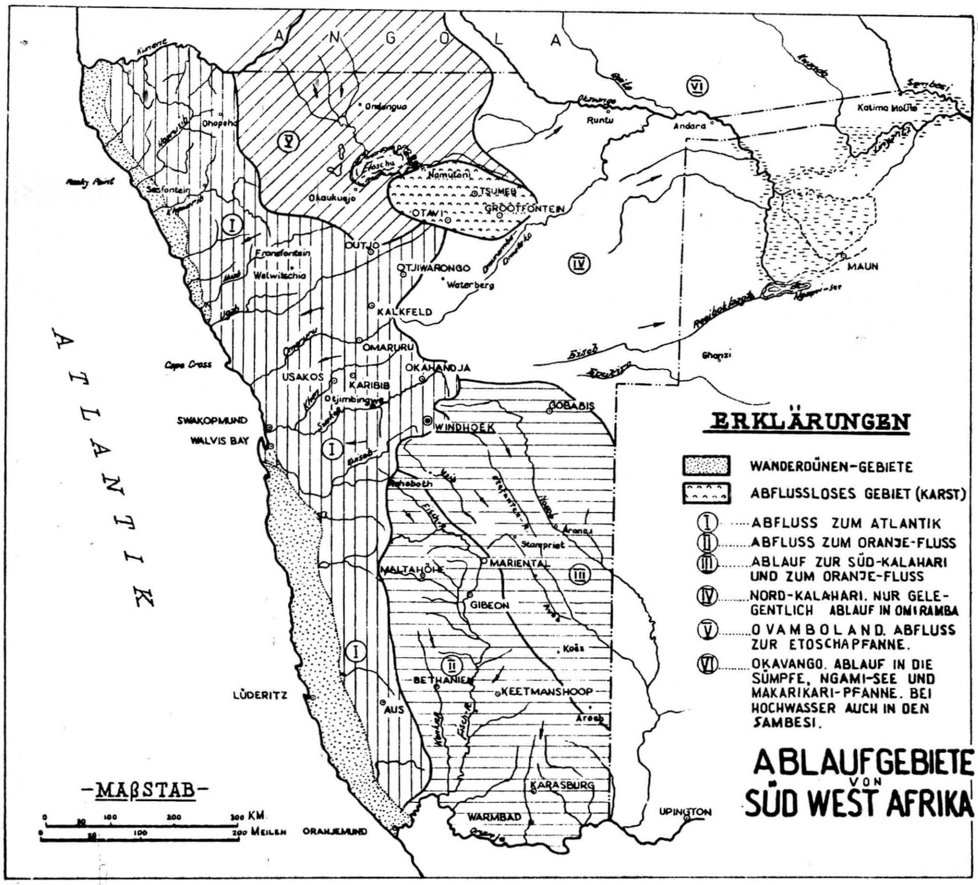
The structure of the land determines the hydrography. According to the direction of discharge, five drainage systems can be distinguished. These, with their principal rivers, are as follows:

1. Exoreic or direct drainage to the Atlantic Ocean
2. Run-off to the Orange
3. Run-off to the Kalahari
4. Endoreic or inland drainage system of the Okavango
5. Endoreic or inland drainage system of the Etosha Pan, and the two areic regions i.e. without surface drainage, of the Namib and the northern Karstveld.

In the Kaokoveld, the Hoanib, the Hoarusib, and other rivers discharge directly into the Atlantic. In the central coastal region, the Ugab, Omaruru, the Swakop with its tributary, the Khan, and the Kuiseb empty into the Atlantic. South of the Kuiseb no rivers reach the sea. The Tsondab river, for instance, flowing west from the Naukluft Mountains forms a great vley, the Sossus Vley, and then disappears into the shifting dunes of the Namib.

The rivers in the Kaokoveld are also sand basins, often no longer visible. Some of these watercourses can only be recognized by the fringes of trees and bushes along the banks.

The rivers of the central region, the Ugab, Omaruru, Swakop, and Kuiseb are the most important. In spite of comparatively low rainfall on the coastal slopes and the escarpment, they carry a relatively large volume of water as they have deeply dissected the plateau edge and thus developed an average gradient 1:150 to 1:250. The length of the rivers varies between 300 and



MAP OF THE DRAINAGE AREAS OF SOUTH WEST AFRICA. Key: [shaded box] shifting dunes; [dotted box] areic region of the Karstveld; (I) exoreic drainage to the Atlantic; (II) drainage to the Orange River; (III) run-off to the south Kalahari and to the Orange River; (IV) north Kalahari, only occasional flow in Omiramba; (V) Ovamboland, endoreic drainage to the Etosha Pan; (VI) Okavango, endoreic drainage to the Swamps, lake Ngami, and the Makarikari Pan, at high flood also to the Zambesi. Maszstab means "scale".

450 kilometres. The highest mountain mass in this drainage area is the Brandberg, 2586 m., which is at the same time the highest mountain in the territory. The mountains around Kalkfeld, Otjiwarongo, Okahandja, Windhoek and Rehoboth also belong to this drainage system of which the central part of the Khomas Hochland is up to 2,048 m. Moltkeblick in the Auas Mountains is 2,485 m.

The Ugab rises southwest of Otavi and flows a few miles to the south and southeast past Outjo. In the middle tract it has cut deeply into limestone terraces. It flows around the Brandberg and then west and southwest to the Atlantic. It is 450 km. long and its catchment basin, to the sea, is about 15,450 sq. km.

The Omaruru River, 296 km. long, is the shortest of these four rivers. It rises in a valley basin of the Etjo, flows through Omaruru, round the Erongo Mountains and discharges, in a broad sandy bed, into the sea. The catchment area, to the sea, is 14,000 sq. km.

The Swakop with its 31,000 sq. kilometres catchment basin is considered the most important river of this zone. Its catchment basin includes the following towns: Windhoek, Okahandja, Otjimbingwe, Karibib, Usakos and Swakopmund. It drains the western part of the Auas Mountains, the mountains of Ovitoto and the northern part of the Khomas Hochland. Its confluent, the Khan, 8,570 sq. kilometres rises in the hilly country between Okahandja and Omaruru, flows along the southern slopes of the Erongo and joins the Swakop between Usakos and Swakopmund.

The headwater basin of the Kuiseb consists of the Khomas Hochland, the wild Hakos Mountains to the south, and the Gamsberg. The catchment area of the Kuiseb up to Rooibank, 30 km. above Walvis Bay, is 16,200 sq. kilometres, of which 5,200 sq. km. fall within the Namib. The river is 375 km. long and on its delta lies one of the most important settlements in South West Africa, the harbour and fishing port of Walvis Bay. The lower reaches of the Kuiseb are unique: the broad sandy bed is densely overgrown with riparian trees, on the north bank are the glittering white desert plains and on the south a desolate world of shifting dunes extending to Luderitz.

On the appended table of drainage areas, river lengths and gradients, the great differences between these rivers are apparent.

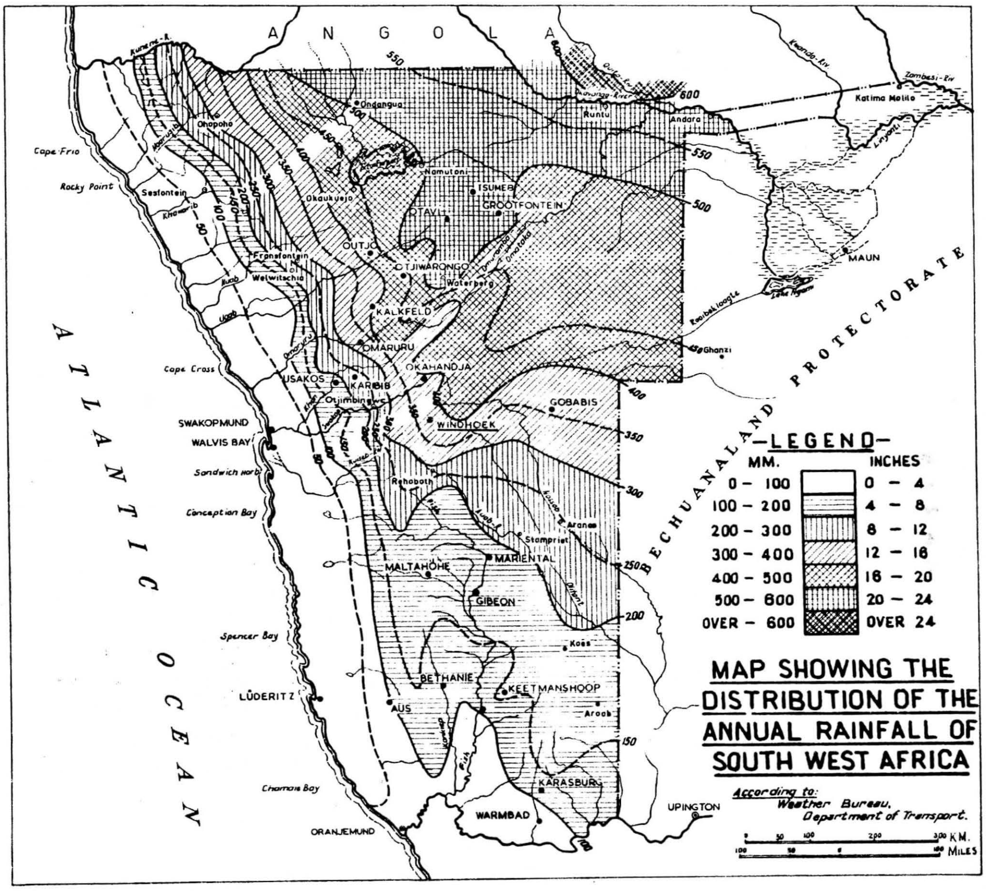
The boundary river Cunene also empties directly into the Atlantic. It drains an enormous area in southern Angola and its headwater basin is the plateau of Angola 1,700 m. The Benguela Railway runs along the watershed. From this plateau with its annual rainfall of 1,500 mm. a whole network of perennial affluents feed the upper reaches of the Cunene. The most important tributary, the Caculovar, flows perennially only in its upper reaches. Near to the watershed, the Serra Shella, lies Sà da Bandeira, capital of the Huila province. The confluence of the Cunene and the Caculovar is just below Forte Roçadas. The most important eastern tributary is the Chitanda, which however, also dries up in the winter months. The scenery on the Chitanda is unusually attractive: broad green meadows and forests flank the river bed even in the dry period. Flocks of herons inhabit the trees and the call of the screech eagle sounds across the forest. It was even more beautiful one early morning, when I saw it completely covered with frost which only disappeared after sunrise.

Below Naulila near Eriksson's Drift, the Cunene forms a series of waterfalls of which the last is the Rua Cana Falls. From here to the Atlantic, the middle tract of the river forms the boundary between South West Africa and Angola. At the Falls the annual rainfall is about 400 mm.

From the Rua Cana Falls, the Cunene flows through rocky valleys, between well-wooded banks where the palm-tree is very much in evidence. The Epupa Falls with a series of cataracts lies halfway to the sea. Here the water plunges into a rocky chasm only a few yards across and about 40 metres deep. Further down, the river winds in deep gorges through the Baynes Mountains and reaches open land again at its confluence with the dry Marien River, 90 km. from the Atlantic. At the turn of the century a railway line had been planned from the South West African side, which would cross the Cunene near its confluence with the Marien River and go on to Tiger Bay in Angola (Map survey by Dr. Hartmann and Tönessen 1899 - 1904).

Between the Marien River and the sea, high sand dunes tower over the south bank of the Cunene, while the Portuguese side consists of bare granite rocks and banks. During low flow the sea builds sandbanks in the mouth of the river, but these are washed out again at high flow.

The catchment area of the Cunene, up to the Rua Cana Falls is 87,800 sq.km. and from the Falls to the sea 30,800 sq.kilometres. The total length is 1,000 km. Direct run-off to the Orange River in the south is from the Fish River with its two large tributaries the Konkiep and the Löwen. The Fish River thus only contributes indirectly to the Atlantic.
Apart from the northern rivers of South West Africa and the Orange River itself, the basin of the Fish River is the most important in the land from the point of view of water conservation. It extends over four degrees of latitude and is more than 650 km. long. Its catchment area occupies the whole central part of the southern territory and this, together with the confluents Konkiep and Löwen, up to the Orange River is an area of 90,000 sq.kilom. or more than one tenth of the area of the whole territory. If the Namib, Kaokoveld, Ovamboland and the Okavango Basin are excluded as peripheral regions, then the Fish River Basin is even one eighth of the total area of South West Africa. The Fish River rises south of Rehoboth, and west of the foothills of the Naukluft. All the affluents of the east and north Black Rand, among them the Hudup, Huams and Leber Rivers, drain into the Fish River and more than half of the Rehoboth Gebiet is drained by the Kam or the Schlip to the Fish River. The Heinarichab River comes from the White Rand in the east.



MAP SHOWING THE DISTRIBUTION OF THE ANNUAL RAINFALL OF SOUTH WEST AFRICA

The two most important tributaries are, however, the Konkiep and the Löwen. The Konkiep has a catchment area of 18,300 sq. km. and the Löwen of 8,600 sq. kilometres. The Löwen River drains the Great Karas Mountains and flows west. Its confluence with the Fish River is south of Seeheim. The Konkiep drains the western part of the Black Rand and on it lie Bethanie and Konkiep. Kub, Mariental, Gibeon, and Seeheim are on the Fish River. Keetmanshoop is only 40 km. from the Löwen River.

The vast basin of the Fish River is an erosion valley which originated during the last pluvial period. The river mostly flows shallow over rocky outcrops, often forming deep pools which retain water even in the dry season. Owing to its rocky substrata which causes only shallow sand filling and gravelbanks, the river bed and its surroundings have little ground water. The only spring which can be used for agriculture is at Orab above Gibeon. For miles the river bed is fringed with trees and bushes. In many places it winds through tableland of sandstone and shale into which it has cut deeply. At the great canyon of the Fish River west of Holoog, the river has bitten into the rocky substrata and formed a mighty canyon 400 -700 metres deep and of considerable length. Below the canyon are the hot springs at Ai-ais.

Some of the rivers rising in the mountainous heart of the land - Windhoek - Rehoboth - Seeis - flow southeast towards the Kalahari. Originally they were tributaries of the Orange River, but in the dry period following the Pluvial, their beds became so silted up that to-day, even in the heaviest rainy seasons, they no longer reach the Orange. In 1934, for instance, the floods of both Nossob Rivers, together with these of the Molopo reached only to Abiquasputs where between the sand dunes they formed a lake which percolated and evaporated in a short time.

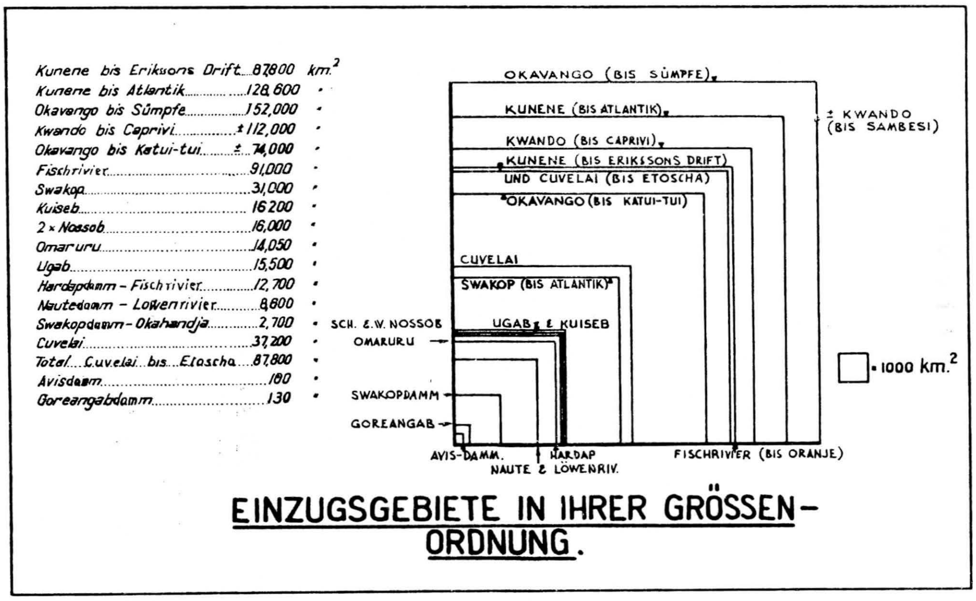
The rivers belonging to this drainage system in South West Africa are the Black Nossob and the White Nossob, which are known, after their confluence, as the Nossob. They both rise east of Windhoek. Gobabis lies on the Black Nossob, Witvlei on the White Nossob and Leonardville on the united Nossob. Across the border the Nossob disappears in the sand dunes, with the Molopo and Kuruman Rivers. The Seeis River rising on the northern slopes of the Auas Mountains, and the Bismarck Mountains, reaches the Elephant River in good rain years.

The Elephant, Schaf and Usib Rivers rise on the southern slopes of the Auas Mountains. The Schaf and the Usib are already obstructed by dunes at Wilderness. The Schaf flows into the Usib and not far from the confluence the river disappears in the sand. The Elephant flows into the Auob which joins the Nossob outside the border. The upper valley of the Auob is an artesian basin.

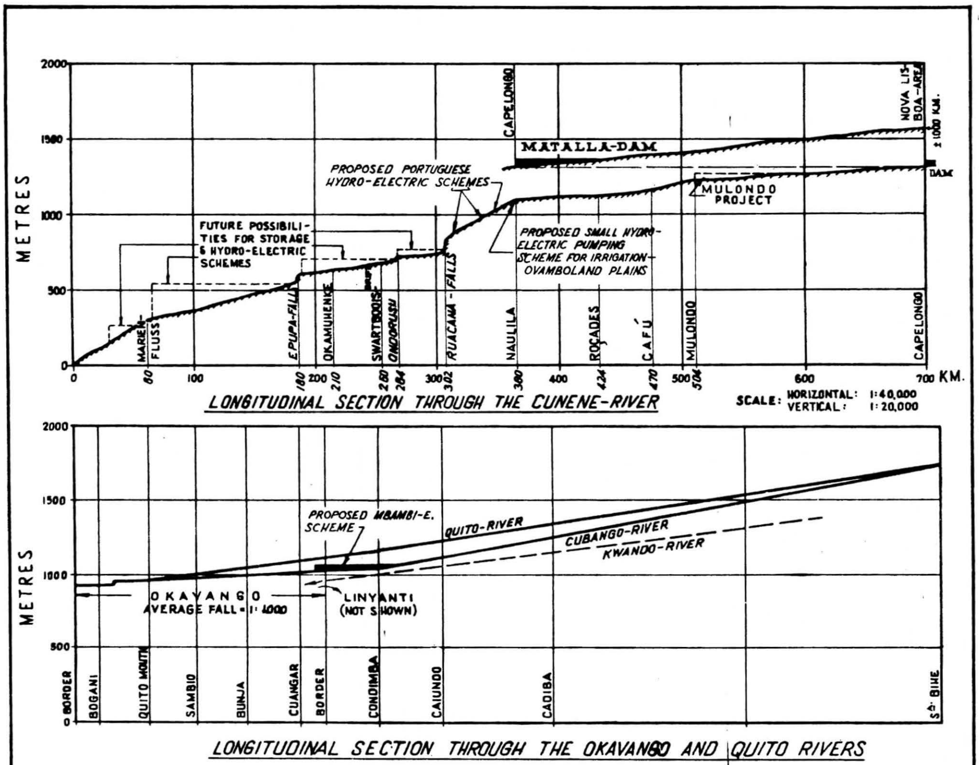
All the rivers flowing towards the Kalahari carry water only in their upper courses and even in unusually heavy rain years their floods never reach the Orange and therefore also not the Atlantic. The gradients and lengths of these rivers may be seen on the appended tables and longitudinal sections.

The Etosha Pan, with the Cuvelai, must be regarded as an unusual endoreic system. The Cuvelai rises in spurs of the plateau of Angola and on its way to the Etosha Pan receives several other tributaries. It is a seasonal river in spite of its headwater basin in the Serra Encoco having an annual rainfall of 1,000 mm. On the border between South West Africa and Angola it forms a widely ramifying delta-like network of water courses, the so-called oshanas. In South West Africa it is once again confined to a river-bed, the Ekuma which empties into the Etosha Pan. The delta region takes up a large part of Owambo-land on both sides of the boundary line. In good rain years the run-off from the upper Cuvelai and the oshana system is so considerable that a vast flood

known as the Efundja covers the whole area. The main tributaries of the Cuvelai are the Caundo which comes from the northeast and also rises in the Serra Encoco, and the Mui-Mui which runs parallel to the Cuvelai over a long stretch. The Oshana Etaka rises in South West Africa and joins the Cuvelai system in Lake Oussouk.
Contrary to the old idea, which still appears now and again even to-day, the Cunene does not flow into Ovamboland, even in flood time.
Up to a line Ondangua-Okatana-Oshikuku the catchment area of the Cuvelai is 37,200 sq. kilometres and its length up to this line is about 500 km. The delta area of the Cuvelai, Ovamboland, is the most densely populated agricultural area in South West Africa.
The river system of the Okavango is an enclosed endoreic basin the waters of which, only at high flood, flow down the bed of the Malewegana-Linyanti and reach the Zambesi which empties into the Indian Ocean.
The largest "water course" running from South West Africa to the Okavango is the Omuramba Omatako which rises in the Omatako Mountains as well as east of the Etjo. It is joined by the Great Waterberg Omuramba, coming from the Waterberg. At Kano Vley, even in exceptionally good rain years the Omuramba Omatako seeps away. From Karakuwisa to its confluence with the Okavango, however, its bed is once more well defined, but it contributes nothing to the well-watered Okavango. The two other eastward flowing Omiramba, the Epukiro and the Eisib, also lose themselves in the Kalahari.
The Okavango, like the Cunene, also rises in the plateau of Angola directly south of the Benguela Railway line. Up to the border of South West Africa it flows through a well-defined, thickly forested valley, on the terraces of which the natives have laid out their fields. From Katuitui onwards, the middle tract of the river forms the border between South West Africa and



Opvanggebiede van die vernaamste riviere in verhouding tot hul groottes - River catchment areas in order of magnitude.



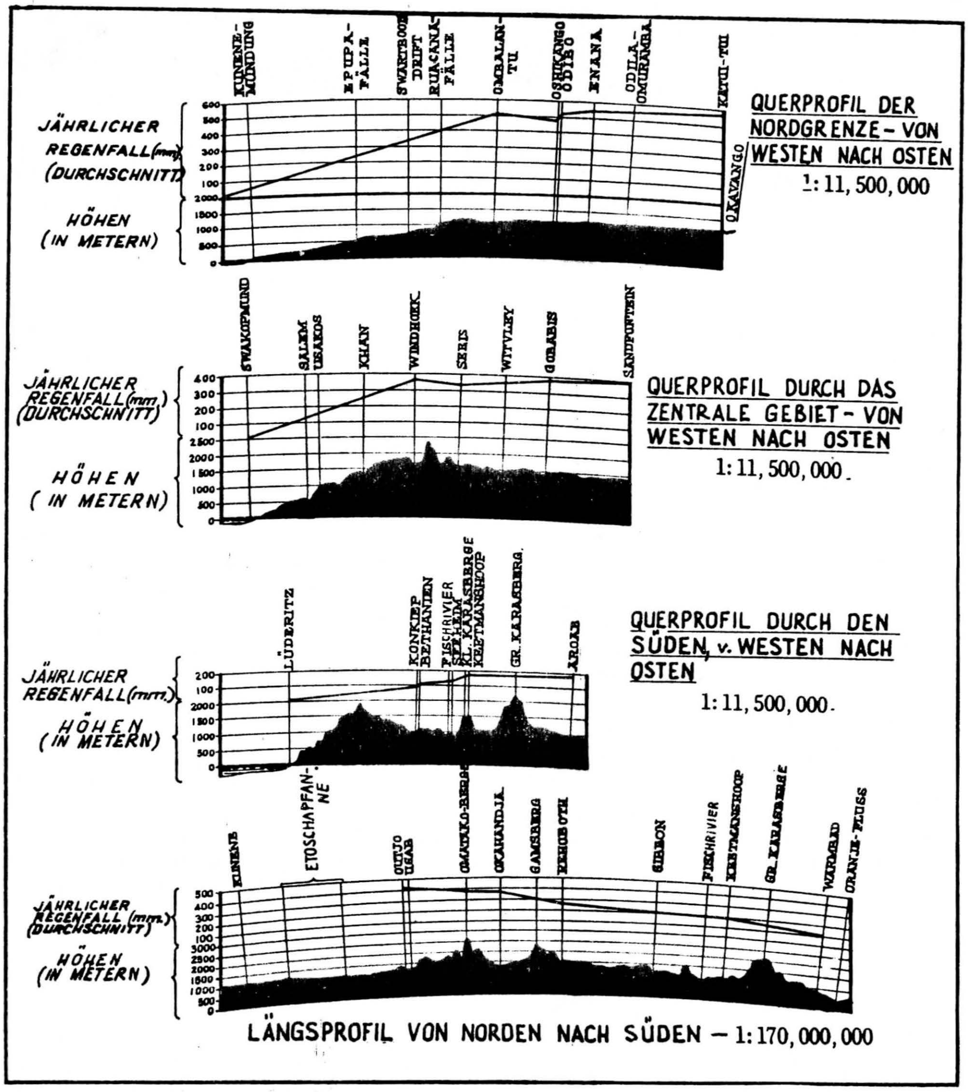
LONGITUDINAL SECTIONS THROUGH THE CUNENE, OKAVANGO AND QUITO RIVERS.

Angola. For only a few miles, ridges border the river, then it widens out to the Popa Falls and from there on branches delta-like to the swamps. The river border with Angola is about 400 kilom. long. A number of rapids interrupt the flow of the river, which has here a gradient of 1:3,000. The most important of these rapids are the 6 m. high Popa Falls below Andara where for about 55 kilom. both river banks are in South West territory. This is the beginning of the Caprivi Strip which extends 300 kilom. east towards the world-famous Victoria Falls on the Zambesi.

The tributary Quito is of the same size as the Okavango. The upper Okavango region is about 74,000 sq. kilom. to which must be added the catchment area of the Quito 73,000 sq. kilom. making the whole catchment area of the Okavango up to the swamps 152,000 sq. kilometres.

The basin of the Kwando is of the same extent. This river also rises in Angola, flows through the middle of the Caprivi Strip, and up to the Zambesi forms the border between the Caprivi Strip and Bechuanaland. There it is known as the Linyanti.

The Zambesi flows next to the border of South West Africa for over 160 kilom. and has a much greater catchment area and water flow than either the Okavango or the Cunene. The large marsh and flood area of the eastern Caprivi Strip,



Opskrifte links beteken: Gemiddelde jaarlikse reënval in millimeters; hoogtes in meters. Regs: van bo na onder: Dwarssnit deur die noordgrens van wes na oos; dwarssnit deur die sentrale gedeelte van wes na oos; dwarssnit deur die suide van wes na oos; langssnit von noord na suid.

Translations. Left: Mean annual rainfall in mm; heights in metres. Right, from top to bottom: Cross section of the northern boundary from west to east; cross section through the central region from west to east; cross section through the south from west to east; longitudinal section from north to south.

enclosed by the Kwando-Linyanti and the Zambesi, is sparsely populated and backward.

The two areic regions of South West Africa are the coastal strip of the Namib, particularly south of the Kuiseb, and the Karstveld of Outjo, Otavi, Tsumeb and Grootfontein.

The Karstveld is formed of limestone and dolomites of the Otavi formation, and surface limestone layers. Rivers are non-existent, though there are some open lakes such as Otjikoto and Guinas. Because of the low rainfall the Karstveld is not as deeply eroded as similar regions in southeastern Europe. In a number of crevices ground water is found but the water table falls towards the Kalahari. In this area the rain seeps into the ground and there are a number of springs of which the strongest is the one at Otavi with a yield of 40 litres per second. The fan palms on the Grootfontein plain indicate that there is ground water quite near the surface.

Within the scope of this article it is impossible to go into the morphology of the various river basins in detail. Only the general trends and the most important points can be dealt with. The zoning of South West Africa used here concurs with that of Professor Dr. J. H. Schultze-Jena, to a large extent. The map of Professor F. Jäger "Oberflaechen- und Grundwasser in Deutsch-Suedwestafrika" ("Surface and underground water in German South West Africa") was also referred to.

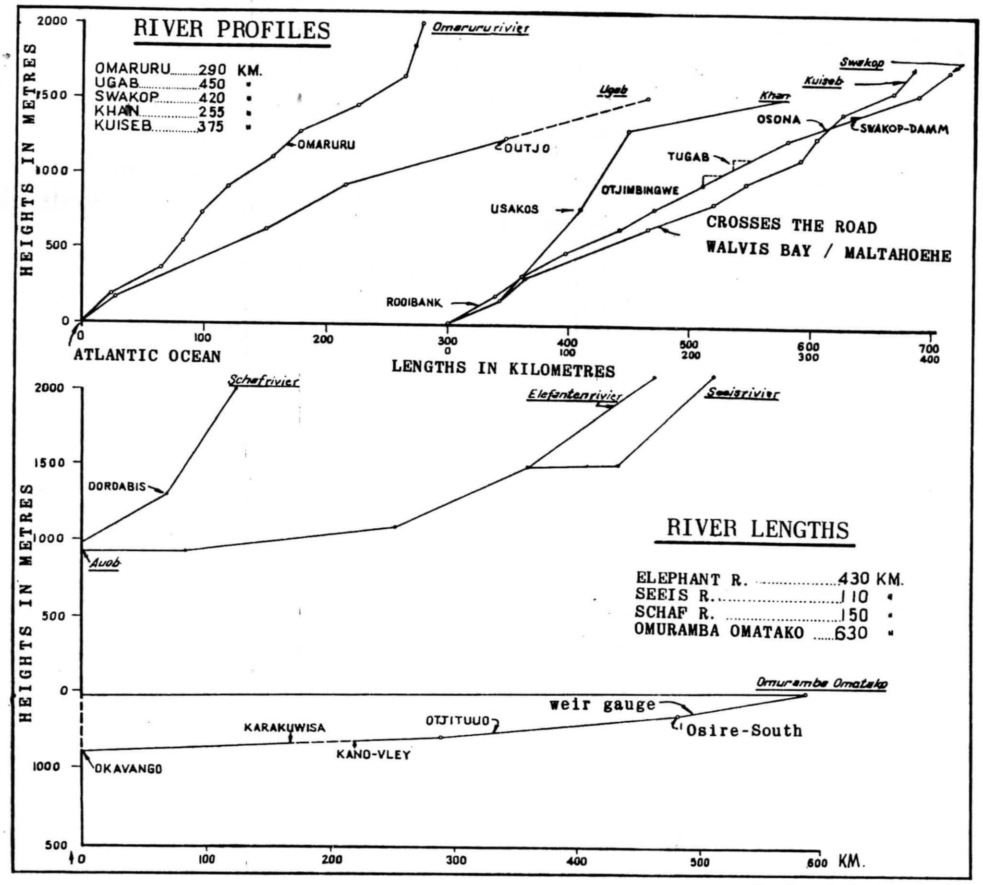
THE FLOW OF THE NON-PERENNIAL RIVERS AND THE OBSERVATION SYSTEM AT THE WATER GAUGE STATIONS

The flow of the perennial and non-perennial rivers depends on the altitude and geological formation of the river basins concerned and most especially on climatic factors, of which the amount of rainfall, its duration and intensity are the most important.

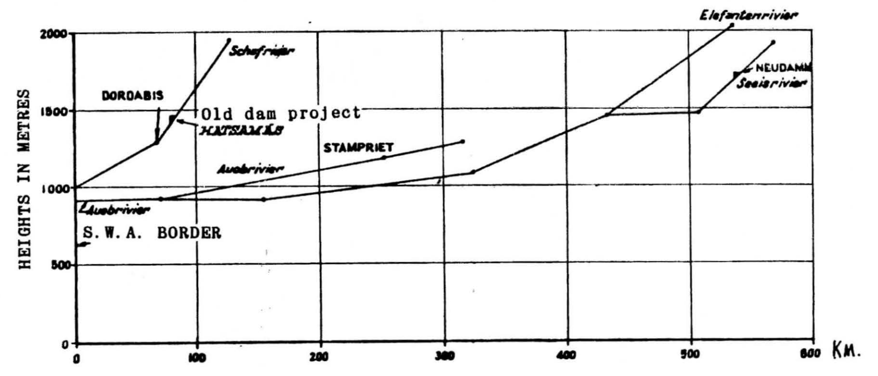
The steady increase in rainfall from west to east and from south to north can clearly be seen from the appended diagrams of cross sections and from the curve of average rainfall drawn above and also from the rain chart which was recently completed by the Windhoek Weather Bureau and based on all existing measurements and observations. For our purpose, the rainfall as such is not of much interest, but the run-off which causes the seasonal flow of our rivers is. In South West, 1,000 mm. of annual rainfall are needed to produce perennial rivers. The headwater basins of the Cunene, Okavango and Kwando on the plateau of Angola, 1,700 m., have an annual rainfall of over 1,500 mm. The streams there, are consequently perennial, but in dry months the volume of water in the rivers may be considerably reduced. It is estimated that the Cunene carries 6,000 cbm/s in exceptionally high floods, and only a few cbm/s at unusually low flow.

When the periodic rivers carry water for only a short period they are said to "come down". The "come down" may be limited to a few miles depending on the magnitude of the catchment area receiving rain. A very heavy rain period is needed to put a periodic river in spate from source to sea. The come down of the rivers is uncertain owing to the irregularity of the rain periods and amounts of precipitation. The quantity of water coming down cannot be deduced from an isolated shower, because not only the duration of precipitation and its intensity but also the type of plant cover and the topography are determining factors.

The surest method of registering the volume of water in a river is by a system of observation stations measuring the duration and height of the "come down".

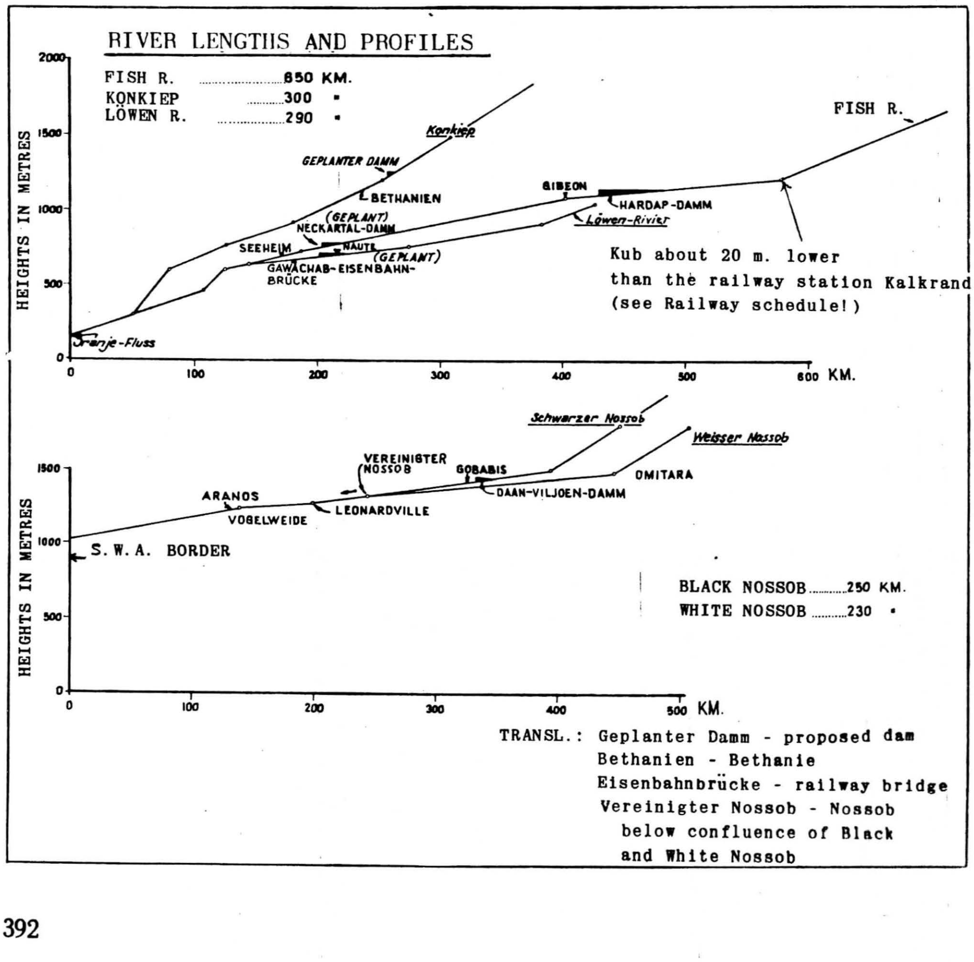


Read: rivier = river!



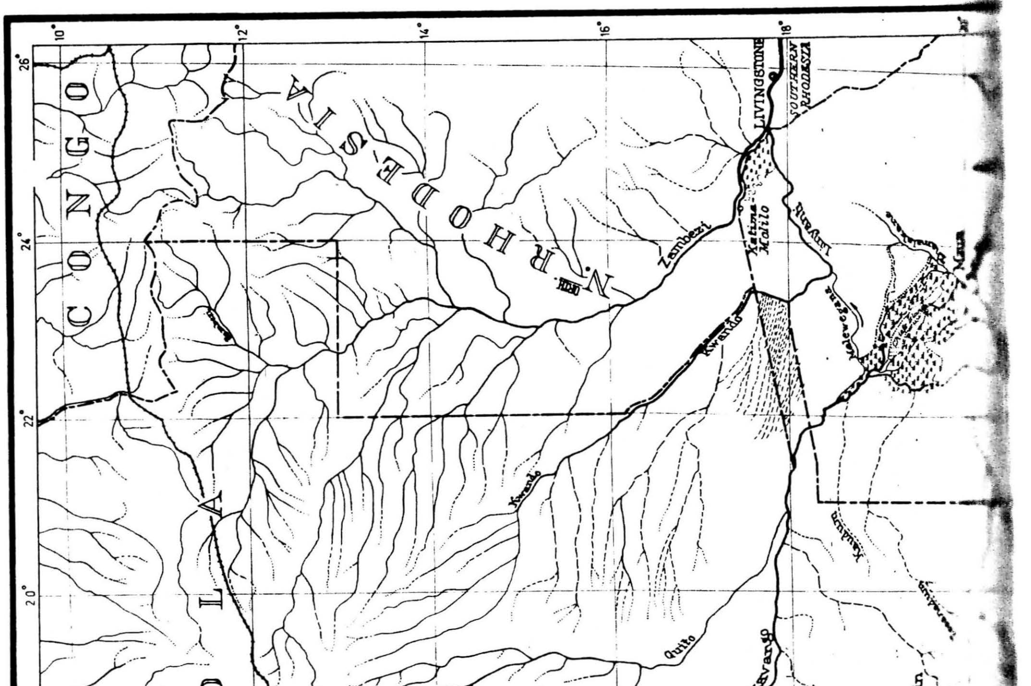
LENGTHS AND PROFILES OF THE ELEPHANT, SEEIS, AND SCHAF RIVERS

Different instruments are used from the simple lath gauge, to float gauge and air pressure gauge. The credit for this goes to Dr.Otto Wipplinger, Director of Water Affairs Branch of the South West African Administration, who started the hydrological service in 1940. This service has recently been enlarged and will be still further developed in the future.
Mr.Erich Zelle, who ran the Windhoek Weather Station between the two World Wars, began already in 1931 with automatic rain recorders and measurements at the Dam on the Farm Nubuamis near Windhoek. These rain gauges are still used today to record intensity and duration of rainfall.
Without accurate information on the volume of water carried by the rivers, greater projects for the economic development of the country cannot be planned, executed or worked.
Every river, perennial, seasonal or periodic, has its own regimen, and a thorough knowledge of this is required to make the best use of the waters. This entails observations of the volume of discharge over several years and it is also essential to know the loss of water through evaporation, percolation - or any other loss of water - in canals and furrows and the quantity that would be needed for future projects in agriculture and industry. Evaporation and rate of silting in dams are very important factors in the planning of great water schemes.

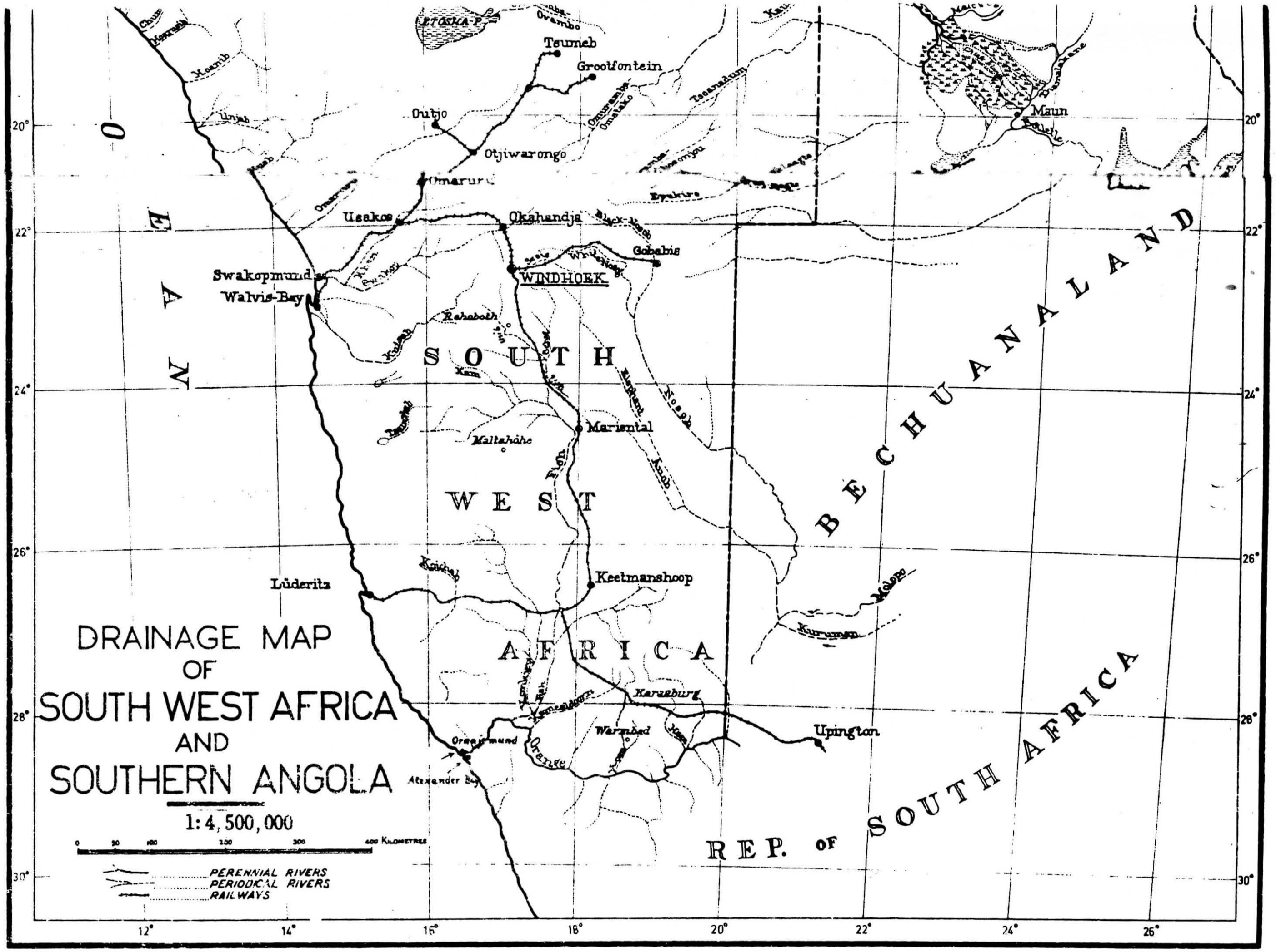


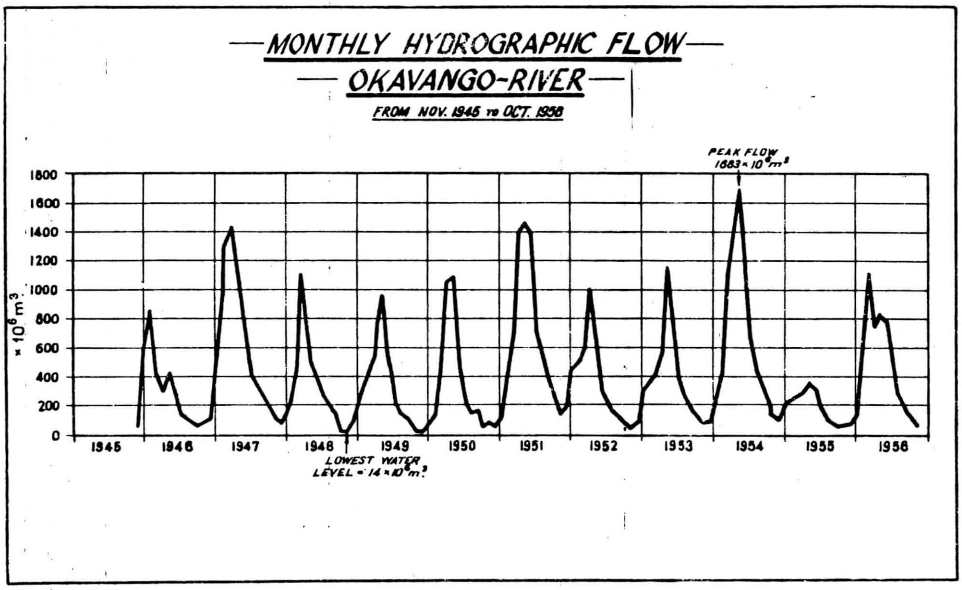
Tables of the flow of some South West seasonal and periodic rivers, and the corresponding graphs, are appended to this article. The Fish River is exceptional with its great volume of water and its almost yearly "come down". It has also the greatest run-off per square mile of its catchment area.
A special department for hydrographic research is being formed within the Water Affairs Branch of the Administration. During the rainy season a continuous service must be maintained at the gauging stations, and the long distances to the outlying stations necessitates an extensive organization. Some of the stations are massive constructions with weirs, but those in remote and isolated

RIVER SYSTEMS AND GAUGING STATIONS FOR HYDROLOGICAL RESEARCH, SOUTH WEST AFRICA. Scale: Kilometres and miles - Key: ▲ Existing Gauges: (erected 1961) 1., 2., 3. Gammams Gauge (1942), 4. Nubuamis (1931), 5. Ugab (1960), 6. Omaruru (1943), 7., 8., 9. Swakop upper course (1945), middle course (1960), lower course (1960), 11., 12. Kuiseb, middle course (1960), lower course (1960), 13., 14. Fish, middle course (1941), lower course (1949), 15. Loewen River (1959), 16. Omuramba Omatako (1960), 17. Cunene (1961), 18. Daan Viljoen Dam (1958), 19. Van Rhijn Dam (1952), 20. Neudam (1957), 21. Omatjenne (1933), 22. Avis Dam (1933), 23. Hatsamas (1947), 24. Cuvelai (Okatana) (1957), 25. Usakos (Khan River) (1952), 26. Runtu (Okavango River), △ Proposed Gauges: 27. Ugab, 28. Omuramba Omatako, 29. Kuiseb, 30. Konkiep, 31. Hardap (Fish), 32. Marien River at the Cunene, 33. Andara (Okavango).



CONGO
N. RHODESIA
ANGOLA
ATLANTIC
LIVINGSTONE
SOUTHERN RHODESIA
Zambezi
Katima Mulilo
Kwando
Quito
Okavango
Rio Cubango
Vila Silva Porto
NOVA LISBOA
Lobito
Benguela
Sá da Bandeira
Moçamedes
Porto Alexandre
Chibemba
Vila Pereira de Eça
Cuvelai
Rocadas
Cunene
Grootfontein
Tsumeb
Maun


DRAINAGE MAP
OF
SOUTH WEST AFRICA
AND
SOUTHERN ANGOLA
1: 4, 500, 000
PERENNIAL RIVERS
PERIODICAL RIVERS
RAILWAYS
SOUTH
WEST
AFRICA
BECHUANALAND
REP. OF SOUTH AFRICA
Tsumeb
Grootfontein
Outjo
Otjiwarongo
Omaruru
Usakos
Okahandja
Gobabis
WINDHOEK
Swakopmund
Walvis-Bay
Rehoboth
Mariental
Maltahöhe
Keetmanshoop
Lüderitz
Karasburg
Warmbad
Upington
Alexander Bay
Maun
Orange
Molopo
Kuruman
12°
14°
16°
18°
20°
22°
24°
26°
28°
30°



places are usually selected so as not to require any building work. At the beginning, lath and float gauges were used and are still in use to some extent to-day although air pressure gauges are now favoured because they are simpler to install. The height of the constantly changing water level above the crown of the weir or river-bed is recorded, according to the type of gauge, by means of a pen, on a reduced scale and then transferred onto a drum which is turned by a clock which runs for 35 days. The figures for height and duration of flood are recorded on a paper strip on the roll. Before the volume of discharge can be determined the velocity of the stream must be measured with the Woltmann-Fluegel apparatus, at different water levels and also at different positions on weir crown or river bed.

Naturally it takes years to obtain the key curve of a non-perennial river i.e. the curve from which a particular discharge can be read at different heights of the water level. These observations are made not only on rivers but also at dams. Every inflow increases the volume of water in a dam and from a capacity curve or table the amount of water can be estimated. At dams subject to silting or bogging the capacity curve must be adjusted from time to time to allow for this.

On the map of the river systems and the gauging stations the positions of the stations are marked. To estimate the flow of a seasonal or periodic river it is essential to have gauges in upper, middle and lower tracts of the river, so as to include water which only flows in certain sections.

The Hydrographic Service of the Water Affairs Branch to-day has 26 gauging stations, some looked after by municipalities and farmers. The results are sent directly to the Water Affairs Branch or made known on request. With

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REMARKS: x) Erection of Goreangab Dam; xx) no observations; xxx) no accurate figures as the river dug itself a new bed; it 'came down', however, during all three years - 1958/59 low, 1959/60 low, 1960/61 very low.

RUN-OFF VOLUMES, PER SQ. KM., OF SIX OF THE LARGER RIVERS

Rivers Gauging Stations	Annual volumes in mill. of cub. m.	Run-off area in sq. km.	Annual run-off per sq. km.	Observation period
Okavango near Runtu	4800.00	74,000	65,000	1946/56
Fish River near Kranzplatz	292.00	13,815	21,200	1942/60
Omaruru River near Omaruru	50.00	3,000	16,600	1943/60
Gammams River near Goreangab	1.48	130	10,600	1942/60
Swakop River near Okahandja	13.20	2,700	4,900	1945/60
Schaf River near Hatsamas	2.01	1,020	1,940	1947/60

RUN-OFF IN MILL. OF CUBIC METRES

Period	Oka-vango	Fish River	Omaruru River	Swakop near Oka-handja	Swakop near Swa-kopmund	Gammams River I	Gammams River II	Gammams River III	Schaf River	Khan
1941/42		600								
1942/43		135				2,30	2,65	3,05		
1943/44		480	144,00			4,55	4,60	5,90		
1944/45		1	0,15			0,09	0,09	0,09		
1945/46	3128	163	70,50	13,4		2,00	3,30	4,35		
1946/47	6780	162	106,40	31,0		2,85	4,40	5,90		
1947/48	3372	370	1,20	9,1		2,75	4,35	9,20	3,31	
1948/49	3113	320	100,50	29,1		3,30	6,90	14,20	3,85	
1949/50	4161	1070	320,00	21,0		4,30	8,90	14,10	6,20	
1950/51	7804	31	0,70	1,9		0,14	0,14	0,34	0,00	
1951/52	3930	274	0,40	3,7		0,29	0,49	1,21	0,17	
1952/53	4749	161	32,90	21,5		0,52	0,83	1,58	0,63	0,0
1953/54	8058	362	10,14	19,2	0,0	3,05	4,40	8,05	5,93	0,0
1954/55	2286	97	4,72	1,8	0,0	0,24	0,08	0,20	0,00	0,0
1955/56	5176	690	2,50	17,1	0,0	1,45	3,12	3,13	5,53	0,0
1956/57		147	2,70	2,8	0,0	0,51	0,53	0,99	0,43	0,0
1957/58		100	11,70	11,2	0,0	1,38	2,20	3,00	xx)	0,0
1958/59		30	3,02	6,2	xxx)	x)	0,30	0,40	0,63	0,0
1959/60		82	19,70	1,9	xxx)		0,01	0,02	0,40	0,0
1960/61			8,00		xxx)		0,30	1,90		

neighbouring rivers, where only one is gauged, the volume of flow of the second river may, in certain circumstances, be estimated. The rivers of the north merit special attention because of their great annual flow of water, in comparison with the periodic rivers of the interior.

Observations over many years are available for the Runtu gauge. The figures given below show the height readings at the gauge, the key curve for the water level, and the water volume curve, which is calculated from the first two. The average annual discharge of the Okavango up to Runtu is 4,800 million cubic metres and to Andara about 10,000 million cubic metres.

The flow of the Kwando-Linyanti is about the same as the Okavango but up till now it has not been possible to erect gauges on this remote river.

The Cunene is being gauged by South West Africa at the Rua Cana Falls. The Portuguese have measured its flow in the upper tract since the building of the dam at Matalla. The estimated annual flow is about 5,000 cbm. Its monthly flow in wet and dry years has repeatedly been observed and estimated, by Kanthak, Machado - a Portuguese - and Hudson Spence. After careful consideration, the following monthly volumes can be reckoned on (Dr. Wipplinger: Southern Angola). The table is for the estimated flow at Eriksson's Drift:

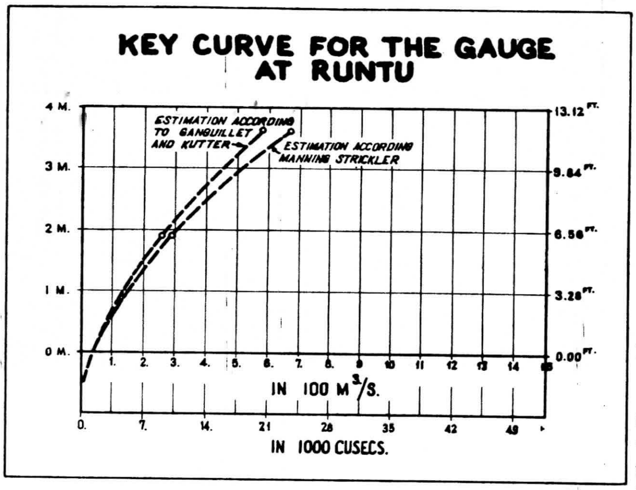
Estimated Flow in Millions of Cubic Metres

Month	Normal Year	Very dry Year
October	40	18
November	70	50
December	180	80
January	400	300
February	700	600
March	900	600
April	1200	500
May	900	210
June	400	106
July	160	32
August	80	26
September	50	18

According to a border treaty, half the volume of the river is at the disposal of South West Africa. An agreement between the territories concerned on the utilization of the river water is absolutely necessary if all border states are to obtain their water rights. South West Africa, Angola, Bechuanaland and both Rhodesias are concerned in theee northern rivers. The Zambesi has an annual discharge of 37,500 cbm. The European states of Germany, France, Switzerland and Austria show an exemplary international collaboration regarding water conservation on the Rhine, the Moselle and the Danube.

THE UTILIZATION OF NON-PERENNIAL RIVER WATER

All underground water supplies in South West Africa are more or less dependent on the rainfall. The most important reserves have, in many cases, originated from the flowing of the rivers and can be improved by the building of dams. Only a few underground water reserves, however, have sufficient water to supply large towns as well as industry and agriculture. These are mainly the artesian

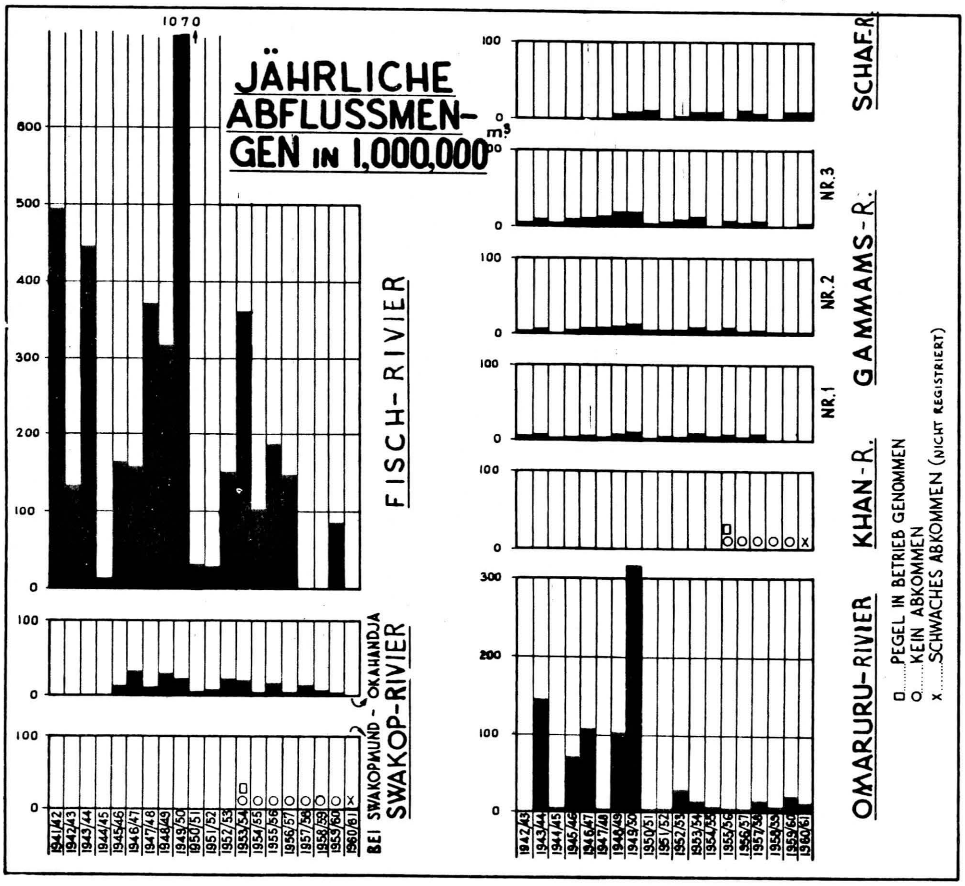


Oben: Schluesselkurve fuer den Wasserstand in Runtu. Das Diagramm zeigt zwei Kurven, die eine nach den Berechnungen von Ganguillet und Kutter, die andere nach Berechnungen von Manning Strickler. Die Hoehen des Wasserstandes sind links in Metern, rechts in Fuss, die Ablaufmengen in zwei Maszstaeben, naemlich in je 100 cbm/s und in je 1000 Kubikfuss/Sek. angegeben.

Bo: Sleutelkromme vir die watermeter te Runtu.

Onder: Jaarlikse afloophoeveelheid in 1,000,000 kub. meters. Die verduideliking lui: 1. Meetstasies in gebruik geneem. 2. Geen vloed. 3. Swak vloed (geen waarneming).

Bottom: Annual volume of discharge in million cubic metres. 1. Gauge put into operation. 2. No come down. 3. Weak come down (no registration).



'n jaarlikse waterhoeveelheid van 37,500 miljoen kub.m. 'n Voorbeeld van Internasionale samewerking ten opsigte van die ekonomiese benutting van gemeenskaplike riviere toon die Europese state Duitsland, Frankryk, Switserland en Oostenryk met betrekking tot die Rhein-, Mosel- en die Donau-rivier.

River and Gauging Station	Size of Run-off Area		Length of River		Run-off Area	Remarks
	sq. km.	sq. miles	km.	miles		
Fish River						
Hardap	12,700	4,900	170	106	Orange River	
Gibeon	13,815	5,320	245	153		
Neckartal	41,615	16,060	487	305		
Oranje	62,780	24,228	735	460		
Konkiep						
Bethanie	3,900	1,505	124	77,5	Orange River	
Confluence with Fish River	18,300	7,060	298	186		
Löwen River						
Naute	8,600	3,300	27	17	Orange River	
Confluence with Fish River	9,846	3,780	180	112,5		
Swart Nossob						
Gobabis	6,550	2,528	175	134	Kalahari	
Confluence with White Nossob	8,640	3,334	302	188		
Wit Nossob						
Kaukurus	4,670	1,800	200	125	Kalahari	
Confluence with Black Nossob	7,527	2,905	273	170		
Seeis River						
Neudamm	156	60	17	10	Kalahari	
Seeis	645	251	64	40		
Confluence with Elephant River	3,049	1,177	125	78		
Schaf River						
Hatsamas	1,020	397	58	36	Kalahari	
Dordabis	1,370	535	68	42		
Confluence with Usib	3,900	1,560	185	116		
Omuramba Omatako						
Ousema	2,500	961	96	60	Okavango	Belongs to the Okavango area, but does not contribute to the flow of the Okavango
Osire	4,280	1,646	129	80		
Kano-Vlei	19,990	7,688	460	287		

River and Gauging Station	Size of Run-off Area sq. km.	sq. miles	Length of River km.	miles	Run-off Area	Remarks
Kunene						
Eriksson's Drift	87,800	32,900	550	343	Atlantic	
Mouth	128,000	44,800	960	600		
Cuvelai						
Okatana-Oshikuku	37,200	14,150	500	315	Etosha Pan	
Etosha Pan	62,600	24,170	600	375		
Okavango						
Katuitui (Northern boundary)	74,000	28,461	356	222	Okavango	Including Kwito run-off area
Below Andara (South. boundary)	152,000	58,461	720	450		
Kwando						
North. boundary of Caprivi Strip	112,238	43,168	760	485	Indian Ocean	
Ugab	15,450	5,942	450	280	Atlantic	
Omaruru River						
Omburo	1,750	675	58	36	Atlantic	
Omaruru	2,940	1,135	85	53		
Okombahe	7,365	2,843	142	88		
Mouth	14,050	5,425	296	185		
Swakop						
Okahandja Dam Site	2,700	1,060	85	53	Atlantic	
Tugab	8,181	3,146	140	81		
Lievenberg	11,650	4,496	174	107		
Khan Mouth	21,970	8,480	340	212		
Mouth	31,000	12,000	380	237		
Khan	8,570	3,308	280	175	Atlantic	
Kuiseb						
Begin of Namib Desert	11,000	4,230	178	111	Atlantic	
Rooibank	16,200	6,230	375	240		

areas of Auob and Maltahöhe, the latter only recently developed. The artesian districts are subject to strict government control and boreholes may be sunk only with the permission of the Water Affairs Branch.

In the north, the Karstveld, with Grootfontein, Tsumeb, Otavi, and Outjo, has sufficient water for the foreseeable future. In Otavi there is a strong natural spring.

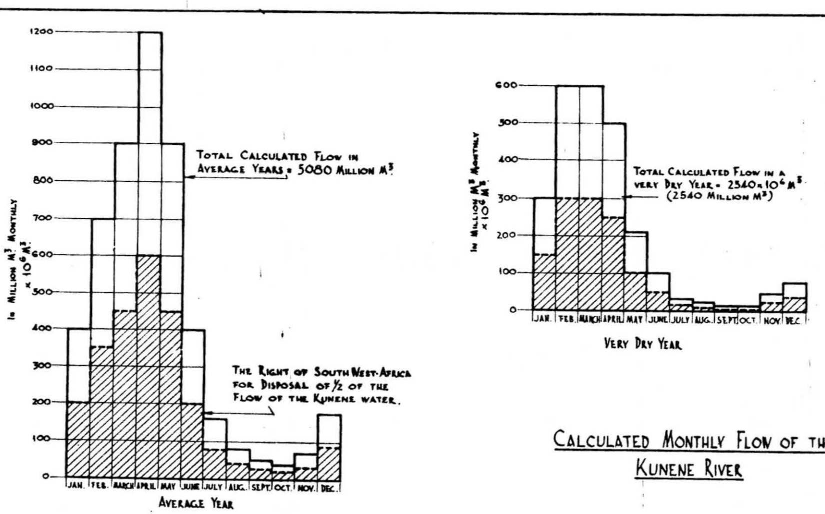
There are many examples of boreholes deteriorating or even drying up with only temporary usage, and this indicates how important it is to develop the rivers for big enterprise and towns. The difficulties which towns in South West Africa have experienced in recent years with their water supplies, clearly show the need for such a development.

The five towns of Windhoek, Keetmanshoop, Karasburg, Otjiwarongo, and Gobabis could no longer augment their water supplies with local borings and were forced to build dams, which in turn feed and replenish the underground water reserves. How important it is to build dams can be seen for example from the economic development of Keetmanshoop:

In the German times an artesian borehole supplied the growing settlement adequately, but as the town grew additional borings could no longer meet its needs and there was not enough water for the railways. The problem was solved by building the Van Rhyn Dam on the Aub River, and after the dam was filled it fed a number of boreholes by percolation. With the further expansion of Keetmanshoop the water consumption has increased so much that a supply from the Löwen River is planned for the near future.

The privately owned Voigtsgrund Dam is one of the oldest in the country, one of those with the largest capacity: 6.8 million cbm, with which originally 260 hectares could be irrigated. Even if the dam did not suffice for the whole area, year in and year out, irrigation had not to be given up completely, but merely suspended, at the most for one year until the Tsub River again brought down sufficient water.

The largest dam in South West is the Hardap Dam near Mariental, which is at the same time one of the biggest dam constructions in southern Africa. It is modern in design and serves more than one purpose:



Calculated Monthly Flow of the Kunene River

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1. The irrigation of 2,500 hectares of land, divided into 140 holdings of 15 - 20 hectares.
2. Water supply for Mariental and for the Railways.
3. For flood protection. By means of sluice gates on the spillway, the volume of water coming down can always be regulated so as to leave sufficient room in the dam basin to intercept a wave of high water and break it.
4. Power production for installations on the dam itself, and for the farms.
5. Bathing, rowing, sailing, and fishing for trippers and holidaymakers.

The dam is nearly finished and may be brought into operation, in stages, as soon as the first section of the canal system at present under construction, is ready for irrigation.

The proposed Swakop Dam, which will supply mainly drinking water to Windhoek and Okahandja, will, however, at the same time increase the ground water for the agricultural settlements and gardens at Osona further downstream. The Windhoek water supply shows the same tendencies as that of Keetmanshoop. In Windhoek in the twenties and thirties the springs overflowed the streets while to-day boreholes must be sunk to a depth of 200 m. to be successful and the water table is constantly falling. In the following table twelve dams are shown; all except Voigtsgrund Dam supply water to towns and villages with hospitals and industry, as well as to the outlying agricultural colleges.

The advantage to farming, of the smaller periodic rivers for dams of all types and sizes, is incalculable. Numerous dams have been built with great success. In the earliest stages of European colonization, the building of dams was already of the utmost importance for the development of farming. The first dams were built in the 1890's in the south of the land, only a few years after the Germans had occupied it.

Without the dams on the periodic rivers, large areas in South West, notably in the central regions, would be completely unworkable. To-day new methods are being tried for a systematic development of water supplies on the farms. The precious supply of water is much too exposed to losses by evaporation in the large shallow open dams, the dam capacity is steadily reduced by rapid silting, and the basin acquires a thick layer of silt through which no more water can pass to the underground reserves.

Sand dams are formed by the systematic construction of dams in stages on sand-bearing rivers. The filling up of the basin with masses of sand forms a permanent ground water feeder which is always replenished when the river comes down. The water supply can also be maintained and economically distributed by means of deeply excavated dams and pump storage plants which reduce evaporation and, if properly constructed, prevent stoppage and silting almost entirely.

The well defined water systems of the land, allow still further development of water supplies for farming, towns and industry in the future.

DEVELOPMENT POSSIBILITIES FOR LARGE SCALE WATER CONSERVATION IN THE FUTURE

The possibilities for further large water conservation schemes are limited in South West Africa. The observations and measurements of the water in periodic rivers will be of decisive importance for future planning. The development of water supplies on the farms poses new problems which open up a limitless field to the water engineer.

Plans must be made for the further development of the periodic river basins and the extent to which they can be used and the costs involved must be

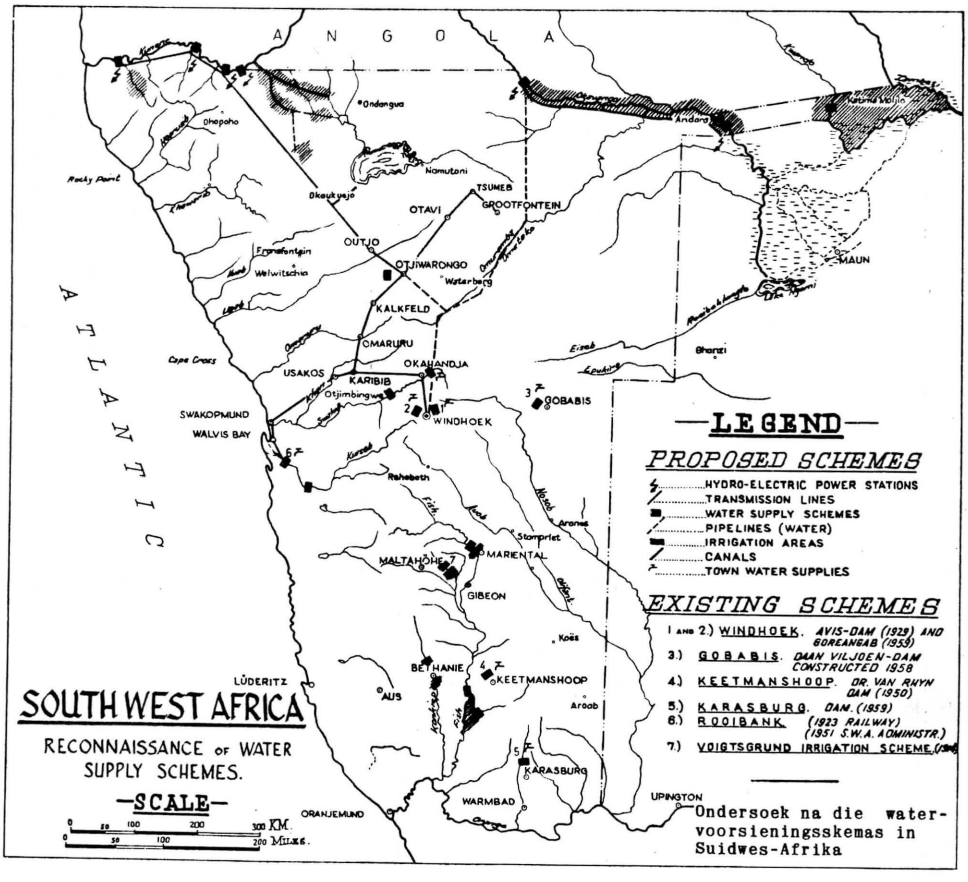
REVIEW OF EXISTING DAMS

Name and year of construction	Town or district	River	Catchment area in sq. kilometers (sq. miles)	Capacity in mill. cbm	De[illegible] i[illegible] met[illegible]	co[illegible]
Voigtsgrund-dam, 1914	Gibeon	Tsub	330 (124)	6,8	9,[illegible]	earth
Avis Dam 1933	Windhoek	Avis	104 (40)	3,5	16,[illegible]	earth
Omatjenne Dam 1933	Govt. farm near Otjiwarongo	Otjitasu	1,300 (500)	7,2	6,[illegible]	earth
Otjitasu	Otjiwarongo	Otjitasu	200 (78)	0,38	6,[illegible]	earth
Van Rhijn Dam 1951/52	Keetmanshoop	Aub	312 (120)	2,6	9,[illegible]	earth
Bondels Dam 1959/60	Karasburg	Tributary of the Homs	265 (102)	1,3	4,[illegible]	earth concr[illegible] way
Daan Viljoen Dam 1956/57	Gobabis	Black Nossob	5,200 (2000)	0,345	8,[illegible]	concr[illegible]
Goreangab Dam 1958/59	Windhoek	Gammans	135 (52)	4,7	18,[illegible]	concr[illegible]
Neudam 1956/57	Govt. farm and Agricultural College	Seeis	156 (61)	0,37	8,[illegible]	[illegible] concr[illegible]
Hardap Dam 1960/62	Mariental	Fish River	13,600 (5312)	252,0	36,[illegible]	[illegible]
proposed Swakop Dam	Okahandja, Windhoek	Swakop	2,700 (1055)	60,0	33,[illegible]	[illegible]
Okatana 1956/57	Ovamboland	Cuvelai	37,200 (14531)	3,25	10,[illegible]	earth

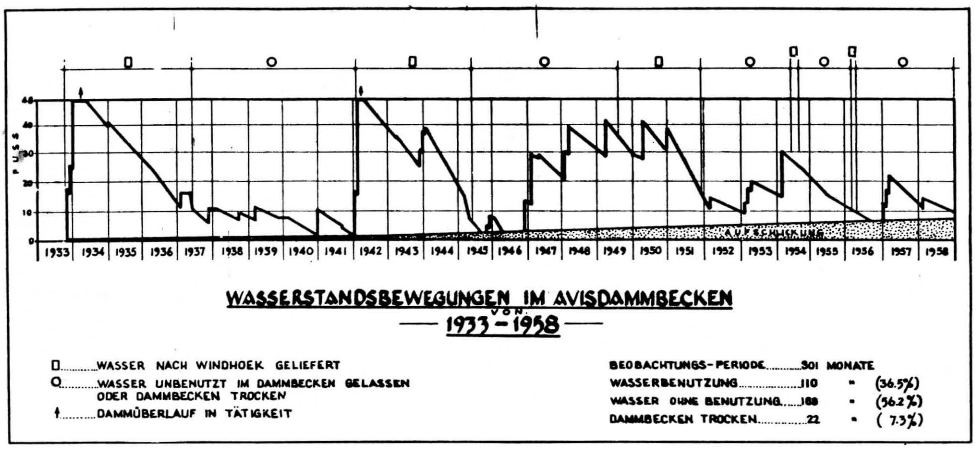
rs	Capacity in mill. cbm	Dept in meter	Type of construction	Use	Remarks
1)	6,8	9,(	earth dam	irrigation	Fish River basin
))	3,5	16,(	earth dam	town supply	Swakop head water basin
))	7,2	6,(	earth dam	irrigation; formation of ground water	Ugab head water basin
3)	0,38	6,(	earth dam	town supply; formation of ground water	Ugab head water basin
))	2,6	9,(	earth dam	town supply; formation of ground water	Fish River basin
2)	1,3	4,!	earth dam with concrete spillway	town supply; formation of ground water	Orange affluent
)0)	0,345	8,;	Concrete (S)	town supply; formation of ground water	only catchment area above Gobabis
52)	4,7	18,;	Concrete (S)	town water supply	southern part of upper Swakop
51)	0,37	8,(	twice earth and concrete (Bo)	irrigation, formation of groundwater	
12)	252,0	35,(	stone and gravel with bitumen cover; concrete spillway (S)	irrigation, town-supply, flood protection holiday resort	
55)	60,0	33,!	stone and gravel with bitumen cover; concrete spillway (S)	town supply ground water reserves	
531)	3,25	10,(	earth dam	hospital supply; irrigation	Fed by a canal from the delta of the Cuvelai-extension under construction

S = Gravity Dam
Bo = Arch Dam

examined. In a few years when the regimens of these rivers have been established, it will be easier to assess their potentialities.
A series of sills could be made, for instance, in the Omaruru River and in the Black and White Nossob, and serve the growing of fodder particularly as good alluvial soil is available along the river banks. The stretch of the Omaruru River between Omburo, 40 kilom. above Omaruru, and Okambahe, 65 kilom. below, was considered for this purpose. Sills of reinforced concrete, or steel sheet piling walls could be constructed here at intervals determined by the gradient and aggradation of the river bed. Above the part to be built up there should be a retaining basin for flood protection for regulating the discharge and for keeping this stretch of the river bed clear of large masses of silt. By regulating the discharge, the dammed water flows slowly through controlled outlets into the sandy river bed and saturates it. In this way losses by evaporation are greatly reduced. These methods are so adaptable that they can be applied to river courses of all sizes.
A dam project for Bethanie on the Konkiep, which was already suggested during the German times in South West, by the well-known geologist Dr.P.Range, will be carefully investigated and replanned.



Ondersoek na die water-voorsieningsskemas in Suidwes-Afrika



DIFFERENCES IN WATER LEVEL AT THE AVIS DAM 1933-1958. Fuss - feet, Aufschlickung-sedimentation. □ - water supplied to Windhoek, o - unused water left in dam or dam dry, ↑ - dam overflow in action. Observation period - 301 months, water used - 110 months (36.5%), water not used - 167 months (56.2%), dam dry - 22 months (7.3%).

Following surveys by the Administration, it is now planned to connect the Neckertal Dam by means of a canal, with the proposed dam on the Löwen River Naute because from the two dams together 8,000 - 10,000 hectares of alluvial land on the banks of the Löwen River can be irrigated, on the Farms Naute and Gawachab. These two farms are therefore still to-day the property of the Administration and are not given out to farmers.
The northern border rivers offer great possibilities for the economic development of South West Africa. On the lower course of the Cunene River where it
A beginning has now been made with the development of the Fish River Basin by the building of the Hardap Dam near Mariental. In the German times, four sites for dams were marked in this river basin and in 1913 the German Reichstag set aside money for a thorough geological, hydrographical and pedological research and survey of the whole of the Fish River Basin.
It is often wrongly said that the first dam, in Komatsas, had already been approved then. What was actually approved was the thorough planning which the authorities realized had to be done first. The four big projects suggested were: Komatsas, Kokerboom-Naute, Homs, and the Naute in the Löwen River, a tributary of the Fish River. Investigations, surveys, and estimates were made for Komatsas but no plans for immediate building. Three dam sites have now been selected in accordance with the better knowledge of geological and hydrographical conditions today: (a) the already completed dam at Hardap, 5 miles below Komatsas; (b) 50 m. high dam in the Berseba Reserve adjoining the Farm Neckartal and known as the Neckartal Dam Project; (c) the long-known dam site in the Naute of the Loewen River, which was visited by Dr. Rehbock in 1896 and by Alexander Kuhn in 1902 and more than once examined during the German times.
forms the border between South West Africa and Angola, hydro-electric plants and pumping stations for the irrigation of several thousands of acres of farmland in Ovamboland could be constructed. The Okavango and the Caprivi Strip Rivers, Kwando and Zambesi, are especially suitable for irrigation purposes. According to preliminary investigations three major dams could be constructed

between the Rua Cana·Falls of the Cunene and the sea for the generating of hydro-electric power, thus leaving the natural beauty of the Rua Cana Falls untouched. The first dam site is 47 km. below at the 6 m. Ondorusu Falls where a wall 50 m. high would form a 2,700 million cubic metres dam extending back to the Rua Cana Falls. The following figures show how this project compares with South Africa's biggest dam, the Vaal Dam, and with the Kariba Dam in Rhodesia, and some of the dams in Germany:

Edertal Dam	202 million cbm	
Bleiloch Dam (Saale)	215 million cbm	
Hardap Dam	250 million cbm	completed
Okavango Dam at Mbambi East	2,100 million cbm	proposed
Vaal-Hartz Dam	2,360 million cbm	completed
Cunene Dam at Ondorusu	2,700 million cbm	proposed
Bodensee (Lake Constance)	50,000 million cbm	
Kariba Dam	156,000 million cbm	completed

The damming of the river at Ondorusu would allow, even in dry seasons, a discharge of roughly 50 cbm/s below the dam, and a constant power of 25,000 HP could be developed here.
The second hydro-electric power station could be built above Epupa Falls which have a total height of 140 m. This plant could possibly develop peak power with the help of pump storage, and its capacity would be twice that of the Ondorusu Dam.
The third proposed site is at the end of the Baynes Mountains, a few miles above the confluence of the dry Marien River. Here the proposed wall would be 200 m. high and the capacity 11,000 million cbm, double that of the Epupa Dam. If these hydro-electric power stations were to convert only 50 cbm/s into power they would produce a total of about 200,000 HP or 150,000 kWh, and as the enormous storage basin of the Marien River Dam will regulate the flow to a greater volume per second, the power production would in all probability be even higher.
There are possibilities for irrigation on the Marien River plains. Water could be led to suitable land by a tunnel through the Baynes Mountains.
The combined Cunene power stations would be able to supply the whole north of the land with electric power up to a line Walvis Bay - Windhoek - Gobabis. Besides the towns, the mines and the fisheries, the whole railway line could be electrified.
The southern part of the country could similarly be supplied with current from the proposed Orange River Dam.
The table below shows a comparison of annual output, between existing and proposed power stations.

Bleiloch Dam (Saale)	40 million kWh	
Tauern Power Stations	830 million kWh	
Cunene Power Stations	1,300 million kWh	proposed
Orange Power Stations	2,350 million kWh	proposed
Kariba Power Station	8,180 million kWh	

On the 400 kilom. stretch where it forms the border, the Okavango offers the possibility of intensively irrigating 50,000 - 60,000 hectares of land. A bigger dam would only be possible in its middle tract, 15 - 20 kilom. below Katuitui, where the border of Ovamboland touches the river. Near Mbambi East, the Okavango winds between hills which consist in part of solid rock like the reefs in the river bed itself. In the lower tract, above Kuringkuru, it meanders in big loops and bends which have caused practically everywhere a broad alluvial terrace on the one or other side. The river narrows again in the Caprivi Strip and more massive rock formations appear in the surrounding country and in the river bed itself.

The Mbambi East Dam, 35 metres high and with a capacity of 2,100 million cbm. should store sufficient water for the irrigation of the above mentioned river terraces. The inhabitants of the river bank are now cultivating some large but limited areas and their agriculture is based on rainfall alone. An experimental irrigation plant is nearing completion, and is intended to serve as a model for more extensive irrigation projects.

In the central regions of South West, mainly around Otjiwarongo, further development is almost impossible because of the shortage of water. An aqueduct from Mbambi East would improve the position, and the increase in population and economic activity warrants such advance planning.

A second Okavango Dam would be possible near Mucusso in the Caprivi Strip in a part where both river banks are in South West and where there are some suitable sites for building.

After the confluence of the Quito, the volume of the river is doubled and the Popa Falls could be developed for the production of hydro-electric power and the electrification of a railway connexion to this agricultural region. The harvest from the upper river basin could be transported in flat-bottomed barges and transferred to the landing place and railhead which could be erected at Andara. The Portuguese use the Okavango for river traffic, but navigation is hampered by the many rapids at low flow. Once the river is dammed it can be used as an inland waterway.

The Okavango Basin, together with the eastern Caprivi Strip could become an enormous granary. This would mean a turning point in the development, not only of South West Africa, but also of Angola and Bechuanaland, provided these territories are prepared to collaborate.

In the eastern Caprivi Strip more than a hundred thousand acres of land could be opened up for irrigation, by building a dam on the Kwando and regulating the discharge, by canalizing the Linyanti and draining the swamps, and further, by building dykes with control inlets for the Zambesi floods, and by a suitable canal system. For these projects, observations over many years are necessary. A start has been made on a small scale but the problem is an urgent one and needs to be tackled immediately.

Although the northern rivers appear to enjoy a surplus of water it must be borne in mind that the area improved by the Okavango, for instance, only extends about a mile on either side of the river after which it gives place to an entirely waterless region with vast dry forests and bush savannah.

South West Africa is a dry land and water as a raw material is more precious than gold or any other ore. It must therefore be carefully conserved and distributed where it is needed now and in the future, only then can it form a sound basis for the future development of the country.

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WASSERWIRTSCHAFT

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Met 'n artikel deur die Direkteur van die Departement Waterwese, S.W.-Afrika

Including a study by the Director of the Water Affairs Department, S.W. Africa

Dr. ing. Otto Wipplinger

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