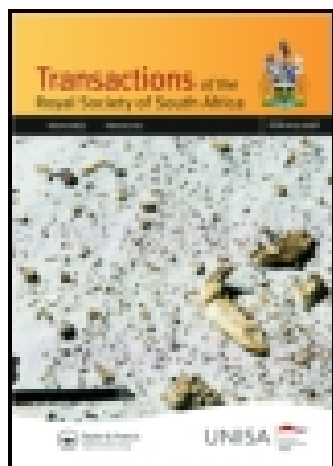


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The light-ratio of one magnitude to the next is taken at 2.5, so that the above difference corresponds to 3.1 of light-ratio. This result is interesting, from a careful discussion of the motions of these two stars it appears certain that their masses are very nearly equal or at least not different by more than one-tenth of their amount. They are therefore undoubtedly of different physical constitution. Another valuable application of this instrument is to photometric measures of the Satellites of Jupiter. The Satellite which is being eclipsed is compared with one of the others at some distance from the planet. The light of this latter may be assumed constant and affords a reference point by which the progress of the eclipse can be measured.

XI. ON SOME SOUTH AFRICAN RIVERS.

—By J. E. BALFOUR, C.E.

[Communicated by the President. Read April 25th, 1883.]

The writer began by giving some statistics of the *Orange River*. He stated that the fall of the river bed between the point where the Telle Spruit joins it, on the South-West border of Basutoland to Prieska averages about three and a half feet per mile. The level of the water is from 30 to 40 feet below the land on each bank. The great flood of 1874 rose at Prieska and in other places between 50 and 60 feet above the bed of the river, flooding the strip of alluvial soil more or less covered with trees which is found along both sides of the river.

With regard to the *Olifant's River*, Clanwilliam, the report of Mr. Philip Fletcher, written in 1862, gives a very complete account, especially from the point of view of navigation. In 1882 Mr. Balfour was instructed by the Hydraulic Engineer for the Colony to visit the river and to take the necessary levels and measurements for the purpose of ascertaining what means could be employed to use the water for irrigation. Mr. Balfour's report on the Olifant's River is printed as an appendix to the Hydraulic Engineer's report for 1882. The total length of the river is a little more than 150 miles from its source to the sea, and it drains an area of 13,000 square miles. Its perennial waters are derived from its tributaries rising in the Cold Bokveldt and the Cedar Bergen ranges. Some of these streams rise high up in the mountains, which are chiefly composed of sandstone, and bring down water comparatively pure and clear of silt; they run constantly, and although the water of some of them is subjected largely to loss from absorption, evaporation, and in some places from irrigation, they nevertheless maintain a strong perennial flow. Comparatively little rain falls in the basin proper of the river itself. The tract of land from the village of Clanwilliam following the river to the sea and westward to the coast being of a very dry character, the rain clouds pass over this track and break upon the Cold Bokveldt and the Cedar Bergen, supplying the streams on the Eastern as well as the Western slopes. The lower tributaries are the Doorn, Troc-Troc and Holle Rivers, which

flow only occasionally after heavy thunderstorms, or occasional falls of rain. Their physical characteristics are dry and torn up channels with abrupt variations in the inclination of their beds, flat when passing through level plateaus, steep when rushing through abrupt and narrow passes, high banks in alluvial or soft soil, and often bounded by perpendicular escarpments in mountainous or hilly tracks. These tributaries drain an enormous extent of country, from the border of Bushmanland in the North to Vogel Vlei and Calvinia on the East, and the Roggeveldt mountains on the South. When in flood they rush on precipitately, widening their channels, undermining their alluvial banks, fretting and foaming to escape through the rugged and narrow poorts, arriving with a mighty rush at their debouchure, where they disgorge their semi-fluid contents into the river, which, if the flood is great enough to overflow its banks, leaves a rich deposit of Karroo silt spread over the land, enabling the cultivator to produce crops which appear almost fabulous.

Ordinary floods of the Olifant's River rise from ten to twelve feet above its bed ; these are the results of the winter rains supplying the upper tributaries. Extraordinary floods are the results of heavy rains within the drainage area of the lower tributaries, and very extraordinary floods are most probably produced by an exceptionally heavy rainfall taking place simultaneously over the whole of the drainage area.

The *Berg River* is the third of our western rivers flowing into the Atlantic ; it is 130 miles in length and has a drainage area of nearly 4,000 square miles ; its tributaries are all supplied by the winter rains falling westward of the Great Winterhoek and Drakenstein mountains. Unfortunately the character of our rivers, and especially the three above mentioned, render them unsuitable for navigation. The Orange, Olifant's and Berg have each a constantly moving sand bar drawn across their mouths upon which the surf breaks dangerously, almost prohibiting entrance. Small vessels drawing eight feet of water have sailed up the Berg with the tide for a distance of thirty miles, but during the greater part of the year the reduced quantity of water flowing towards the sea renders it unsafe for anything but very small craft to ascend.

The Olifant's River has a very safe land-locked harbour if entrance could be obtained to it, but the varying sand banks which stretch across the channel of the river at intervals along its course a short way below the surface of the water are obstacles to the navigation of vessels any larger than boats. The tidal wave ascends the Olifant's River a distance of 25 miles and it ascends the Berg 45 miles.

The supply of water to our rivers is of a fitful kind owing to the nature of the country which they drain and the unstable character of the rainfall. One year may be characterized as particularly wet, and the two or three succeeding years particularly dry, or in the east of the drainage area a drought may prevail and in the west unusual heavy rains may fall simultaneously. It is likewise affected by the permeability or impermeability of the ground.

The normal condition of some rivers and tributaries is perfect dryness,

they only flow after heavy rains. The most characteristic river of this kind in the western district is the Zak, a large tributary of the Orange River flowing through the Nieuwveldt and Achterveldt; its length is a little over 350 miles from the Roggeveldt and Nieuwveldt mountains, where its course begins; its drainage area is approximately 32,100 square miles and is almost devoid of vegetation, except the stunted bushes on which the possessors of farms equal in area to English counties graze a few thousand sheep. When a thunderstorm breaks over this tract or when a general rain prevails, the Zak becomes a river of fluid sand, keeping within its banks generally till somewhat north of Brandvley, where it has not yet formed any definite channel and where it loses much of its water among the long flat stretches of alluvium which are a peculiarity of that region. These floods are very uncertain; the river may come down once, twice or three times in a year, but some years it does not flow at all. Much of the soil of these flats is covered with the well-known white efflorescence denoting "brak" ground, and extensive vloers or salt-pans, which exist there, are natural depressions in the alluvium, which get filled with water during floods; they rarely have outlets but are emptied by evaporation. When a layer of dissolved salts remains spread over the bottom, each following flood adds its quota of salts, consequently these vloers become inland lakes of salt water.

This white saliferous and alkaline deposition is generated in the same manner in many places along the river valley, where it permeates the soil to considerable depths.

To ascertain what proportion of the rainfall is discharged by our rivers a series of close scientific observations should be instituted. The Mississippi is said to discharge one quarter of the rainfall into the sea, the Elbe one quarter of the rainfall, the Seine at Paris carries off one-third of the rainfall. In Great Britain from a fourth to a third part of the rainfall is perhaps carried out to sea. The writer has calculated the probable discharge of the three rivers he has specially mentioned, allowing one-third of the yearly rainfall as the quantity which finds its way into the ocean. From the table attached to Mr. Gamble's paper on the rainfall of South Africa, read in 1878, Aliwal North, Concordia and Keerom, three stations within the drainage area of the Orange River, show 25, 9 and 8 inches respectively, which gives a mean of 14 inches. Clanwilliam show 10 inches and Stellenbosch and Malmesbury 23 and 19 inches, or 21 inches as the average. By this, the only available data, the discharge of the Orange River is equal to 3,220,000,000,000 cubic feet, the Olifant's 100,000,000,000 cubic feet, and the Berg River 65,000,000,000 cubic feet per annum respectively. But in connection with their discharge the geological and fertilizing actions of our rivers are of equal importance, the latter if utilized would become a source of riches. The greater part of the mineral matter held in solution by the Orange and Olifant's Rivers in floods is taken up from the Karroo plains.

It is to be regretted that these vast carriers are allowed to transport their riches to the ocean, instead of distributing it over the dry and parched lands through which they flow.

Many of the tributary rivers when swollen are rolling currents of mud consisting as much of sand as water, and when the flood is great enough to cause an overflow, the reduced velocity of the scattered waters induces a settlement of this rich silt. During the writer's visit to the Clanwilliam district he measured various strata of silt and found them to vary from $\frac{1}{4}$ to 6 inches in thickness.

The Olifant's River has so deepened its bed and eroded its banks that the area of the waterway is now much greater than it formerly was. Fifty years ago overflows were of annual occurrence, now they do not take place at all, hence the poverty of the farmers along its banks.

The Berg River deriving its water principally from springs, not from spasmodic tributaries, changes its features at a considerably slower rate than either the lower Orange or the Olifant's Rivers.

The deepening and widening of river beds by erosion in this colony very often proves disastrous to the dwellers on their banks; first, by placing the water they require for agricultural purposes beyond their reach; secondly, by the destruction of the fringe of forest which usually borders them. The banks get gradually covered with sand brought down by the river, which when it becomes dry is blown into sand dunes, forming a nucleus upon which the wind operates to blow it over the fields in every direction. Now the average specific gravity of the stones in a river ranges between two and three times that of pure fresh water, hence when they are borne along they lose from half to a third of their weight in air, and any observer may see in rivers which have their course through rocky and mountainous tracts huge stones, which could not be moved by the same amount of impetus on dry land, that have been transported far down from the point where they were originally in situ. Heavy falls of rain add enormously to the transporting power of rivers; a constant fall of several inches fills all the hollows and rivulets within the drainage area; each tiny stream washes up and carries with it a certain amount of soil and gravel to the tributaries, which in their turn erode and convey a greater proportion to the river, which soon becomes a turbid flowing mass.

The quantity of mineral matter transported by rivers has been carefully measured in Europe, America and India, but the most explicit and accurate results on this subject yet arrived at have been made in America by Messrs. Humphreys and Abbott, the engineers charged with the investigation of the Hydraulics and Physics of the Mississippi. Clear water erodes but little, hence the wearing away of the banks and deepening of channels in our South African rivers is the work of the detritus carried down in floods. The writer found that the Olifant's River had widened its channel 30 feet in 22 years; this he determined from information obtained from old residents and from measurements taken from the existing banks to old tree trunks, standing well out in the channel, which twenty-two years ago stood upon the bank.

This increased width of channel enlarges the surface area of the floods but lessens their vertical height. The banks being eroded, as a natural consequence, the strips of forest are destroyed which acted as screens to keep the heavier and less fertilizing portions of the silt and detritus in

the river, allowing it to collect on the top of the banks, adding to their height and aridity.

To obviate this deterioration I would suggest that massive dams of loose rubble be thrown across rivers possessing characters of the above description, such as have been built across the Jumna, Ganges and other Indian rivers for irrigation ; this would effectually raise the level of the river beds and moderate the velocity of the flow. The distance from the sill of each dam to the toe of the one above it would in reality become an artificial lake of comparatively still water. One result would be the silting up of the river bed, and the banks no longer being subject to erosion would become eligible sites for tree planting along the entire length within the influence of the dams. This system of moderating the flow of rivers might be advantageously carried out on a smaller scale on the tributaries. Those which are silt bearing would enrich the contiguous farms, and those tributaries whose sources are high up in the mountains, where rock and boulders are plentiful, could be effectually weired up in the narrow parts, their waters being led out to fertilize the sides of the valley below each dam. Moreover the destructive denudation and erosion carried on by these mountain streams and torrents would be reduced to a minimum.

In recommending this system the writer speaks not without precedent, or authority, as to its ultimate economical effect. Provinces in India, the physical features and character of which resemble those of South Africa, have become wealthy and prosperous under British rule through having their rivers and streams dealt with in this manner.

There has as yet been very little done for the meteorology of South Africa, and next to nothing is known of the Hydraulics and Physics of our rivers. The Government has established observing stations in many places throughout the colony, but meteorological and hydraulic observations to be of much use should be prosecuted on an extensive scale. The drainage areas of our principal rivers and tributaries should be closely and thoroughly observed. Rain gauges might be placed within them on the crests of the watersheds, the prominent faces of the slopes, and in the bottom of the kloofs and valleys, and if they are attentively and carefully watched a very close approximation to the amount of rainfall would then be obtained.

Then again the rivers and large tributaries should be gauged in several places and a record kept of their flow ; by these means the proportion of discharge to rainfall might be arrived at. The water passing during floods and flowing perennially should be analyzed to ascertain the nature and quantity of minerals carried in suspension, as well as what is chemically dissolved, and what is driven along the bottom. The slow but progressive changes in the channels and deltas are to be noted. If this work is scientifically performed the transporting capacity of a river can be obtained, and previous to any great work being started for the improvement of our rivers, these operations should be carried out. To examine and report upon a river, and its facilities for irrigation, navigation and general improvement, without being in possession of correct data, is groping in the dark.