KENYA.

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Conf.72 14th May 1926.

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IRRIGATION POSSIBILITIES: WATER LAWS.

Trs copy report by Mr A.D.Lewis Director of Irrigation Union of S.Africa and states that it is proposed to defer further observations until the receipt of Mr Sikes' comments.

C.O. 533/317

Previous Paper

36486 25

X 8m 4/6

E.a.O'Keeffe 5/6

W.Bottomley 2/6

nt Paper

992

Mr Robbins

I am sorry I have not had time
to see this before they go to leave.
But no other business calls for at
the moment so pressing, but one
including those of the Silver Co:
when 1697 [97/8] is disposed of this
might be recirculated to be
Thomas Ch. Lawrence

17/6/36

(the Mayor of Rose's letter of 5/8/48/37)

KENYA.

GOVERNMENT HOUSE,
NAIROBI,
KENYA.

No. 72

CONFIDENTIAL.

14 May, 1926.

Sir,

With reference to Mr. Denham's despatch No.784 of June 23rd last and my telegram of August 14th, regarding the visit of Mr. C.D.Lewis, Director of Irrigation to the Government of the Union of South Africa to report on the possibilities of irrigation and on water laws generally in Kenya, I have the honour to transmit for your information 2 copies of Mr. Lewis' report. Arrangements are being made for the printing of this report of which 6 copies only were received and further printed copies will be furnished to you in due course.

2. The Report is of great interest and value. The importance of water-boring operations had already been realized and, as you are aware, the sum of £6,500 has been inserted for such purchase in the Colonial Loan Schedule, vide my despatch No. 54 (Confidential) of the 16th April, 1926.

3. The importance of the enactment of uniform water legislation in the East African Dependencies was urged at the Tukuyu Conference and accepted by the Governors' Conference. It is the case that a draft Bill was prepared in 1921/1922 by Mr. F.L.Sikes, Director of the Public Works Department, when he was Hydraulic Engineer, but it appears that Mr. Lewis had not seen this draft before writing the sections of his Report dealing with water laws. This Bill was not proceeded with owing to the Staff retrenchments in

RIGHT HONOURABLE
LIEUT.COL. L.C.M.S.AMERY, P.C., M.P.
SECRETARY OF STATE FOR THE COLONIES,
DOWNING STREET, LONDON, S.W.

19 2/

1922). But whatever form the final legislation takes there is no doubt that its administration will be very considerably more expensive than the present system and it will be necessary to have Estimates of cost carefully prepared before proceeding to legislative enactment.

4. Owing to the fact that Mr. Lewis' report was only received a short while prior to Mr. Sikes' departure on leave there was no time for the expression of the considered opinion on the various points of the report and more particularly on the question of water laws. Further the post of Hydraulic Engineer provided in the current Estimates has not yet been filled. I anticipate that Mr. Sikes will prepare his comments in the course of his leave and it was proposed to defer further observations until his advice has been received.

I have the honour to be,

Sir,

Your most obedient, humble servant,

GOVERNOR'S DEPUTY.

COLONY AND PROTECTORATE OF

K E N Y A

REPORT

ON

IRRIGATION,
WATER SUPPLIES FOR STOCK,
WATER LAW, ETC.

BY

A. D. LEWIS, M.A., M.INST.C.E.,
(DIRECTOR OF IRRIGATION, UNION OF S. AFRICA).

DECEMBER 1926.

C O N T E N T S.

INTRODUCTION.

1. In a letter dated June 26th 1929, the Acting Governor of Kenya Colony asked the Governor-General of the Union of South Africa whether an expert irrigation engineer could be seconded for a period of 6 months in order "to explore the possibilities of irrigation schemes", "make preliminary investigations into local conditions and advise on the best course of action to be taken and also generally on Water Laws".

In reply, the Governor-General offered the services of the Director of Irrigation for a period of two months only, which offer was accepted by the Acting Governor.

2. I arrived at Mombasa on September 8th, and on that and the following day discussed with the Acting Governor, the Director of Public Works and the Acting Chief Native Commissioner the nature and scope of my enquiry. I then proceeded to Nairobi and from there undertook five "safaris" before finally leaving Mombasa on November 7th.

The safaris were - (1) to the Thika River irrigation scheme and through the Ukamba Reserve to beyond Kitui and Kwithe, and to Machakos and beyond by motor and on foot; (2) across the Rift Valley, and northwards to Rumuruti; then to Nanyuki and south through Nyeri and Fort Hall; (3) along the railway line from Kiu to Tsavo River by trolley, branching off on foot and horseback and by motor to investigate possible water supplies within a few miles on either side of the line; (4) to the Lugal Ngorongo in the Rift Valley and beyond Narok to the Loita Plains, and (5) northwards along the coast to Malindi and about 30 miles up the Sabaki River. Three meetings with district committees or the public were attended at Naivasha, Rumuruti and Thika.

3. As my investigation progressed, I was able to communicate my partially-formed opinions to responsible officers. At an early stage I was impressed with the difficulties in the way of irrigation, not only from the physical point of view, but also from the human or population point of view, and the scope of my enquiry was accordingly extended in one important respect, namely, that the supply of water for stock-raising purposes was to receive more attention than irrigation possibilities. As a consequence, the former subject is dealt with in my report at greater length than the latter.

4. In the course of my investigations, I had to seek information on a number of subjects, such as - rainfall, geology, stream measurements, water law judgments and administration -, information which was essential in order to study the problems referred to me. I have summarised portions of such information in this report, so that the data may be known on which I have worked, and in the hope that, gathered together in a single report, they may be of use to those who have to follow up the subjects in the future. In this connection, while writing my report, a considerable amount of time has been devoted to the making of the rainfall and geological maps and also to the table of discharges, which accompany this report, as I felt that there was an urgent need for these. Even though based on somewhat sketchy data, they should supply something definite to start on for subsequent amendment and additions.

5. In conclusion, I wish to express my thanks to the many officers of the administration and members of the public of Kenya for unfailing assistance in every direction, which enabled me to produce a report, however imperfect, in the very limited time which I was able to spend in the country, and I must also thank many officers of my department and of other departments of the Union of South Africa for kindly assistance in the preparation of this report.

CHAPTER II.

GEOLOGY.

CONFIGURATION, FORMATIONS, UNDERGROUND WATER AND SOILS.

1. CONFIGURATION.

6. If a contour map of Central Eastern Africa is studied, it will be noticed that a huge pointed oval crown of very high country, round about Lake Victoria Nyanza, stands out above the surrounding lower lands. The major axis of the crown runs north and south on longitude 33° and is nearly 1000 miles long, stretching from 4° north opposite Lake Rudolf to the northern end of Lake Nyasa in the south. The minor axis runs along latitude 8° south, from near Kilimanjaro to the northern end of Lake Tanganyika, a distance of about 800 miles.

7. It is with the northern half of this crown and the country to the east of it that we are chiefly concerned. Lake Victoria Nyanza lies in the dished centre of this half, receiving most of its drainage and spilling over into the Nile. The most remarkable feature of the crown is that very high ranges of mountains run round the rim, and most remarkable of all is the fact that both in the east and in the west the rim consists of twin ridges with a very deep narrow depression, like an elevated gutter, between them. These depressions are the two rift valleys, each bounded by twin escarpments. A chain of lakes lies in either valley, those in the western rift being the most famous - Albert, Edward, Kivu and Tanganyika. Lying in the bottom of a raised gutter, they are unlike most other lakes in that they have very narrow drainage areas, and, as a rule, only that water which falls on the area between the escarpments flows into the rift lakes.

8. Kenya Colony embraces a small part of the north-eastern segment of the crown, including a portion of

Lake Victoria Nyanza in the dished centre, and a considerable length of the high eastern rim with its Rift valley. The latter runs in a general direction North and South and is, on the average, about forty miles wide. On either side of it are high escarpments, rising two or three thousand feet above the bed of the valley. From the western escarpment the country falls rapidly to Lake Victoria Nyanza, and from the eastern escarpment the fall is at first steep but gradually diminishes to the Indian Ocean.

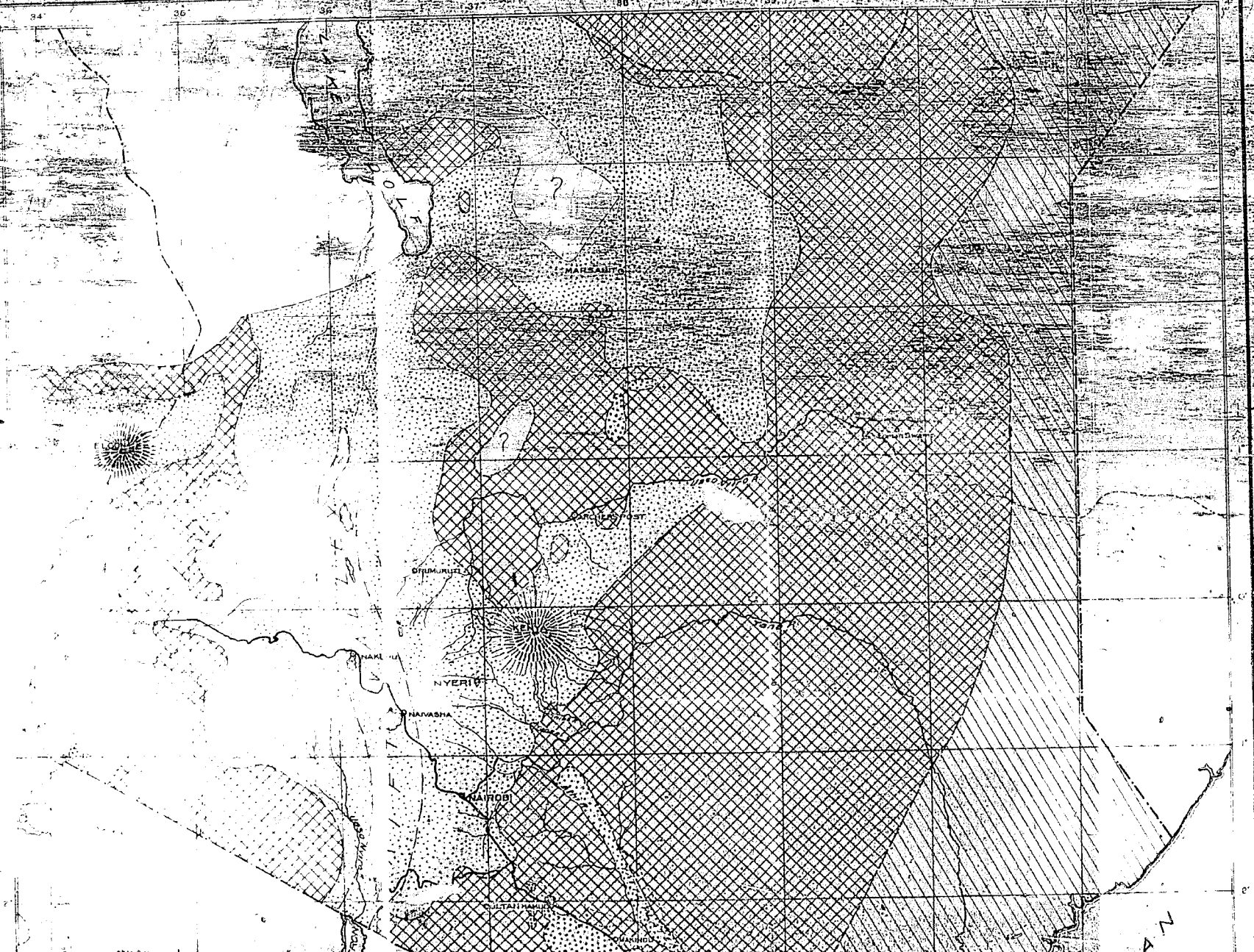
9. The general configuration is well illustrated by a section along the railway line from Lake Victoria Nyanza to the Indian Ocean, a total distance of 607 miles. Starting from Kisumu on Lake Victoria at a level of about 3728, the line rises within 100 miles to a height of over 8000 feet at the flat summit of the eastern escarpment. In the next 40 miles it drops more than 5000 feet down the escarpment to Nairobi. It then runs across the Rift Valley for nearly 60 miles to Limuru, climbs some 1600 feet in less than 20 miles to the top of the eastern escarpment, and from that point, at nearly 8000 feet altitude, it drops in the next 300 miles to the sea, at first steeply and then at easier grade. So great is the slope towards the sea in these 300 miles, that it is possible to coast downhill on a trolley nearly the whole distance with only occasional pushing for short lengths. The section along the Tana River given in Plate 3 illustrates the configuration further north, where the country flattens out more towards the coast.

10. With the exception of the north-eastern desert lowlands, the general nature of the country is, therefore, very steep. A consequence of this is that there are very few possibilities for large water storage works. There are practically no plateaus, and, although there are large areas called plains, it is more on account of their smooth surface and short vegetation than on account of their extension. Actually, they all have a very considerable slope

II. GEOLOGICAL FORMATIONS.

11. It is impossible to describe the geology of the country at great length. For a concise summary, with a bibliography, reference should be made to the excellent article in the East African Red Book, (1925), written, I believe, by H.L. Gilman, Director of Public Works.

12. It is unfortunate that there is no complete geological map of the country. In the absence of such a map, I have compiled the attached rough geological map (Plate 1) from all available sources and from personal observation in the areas which I traversed. It makes no pretence to great accuracy, but it is hoped that it may serve as an initial effort to assist in the study of the many problems in connection with water and as a basis for subsequent correction.


34
35
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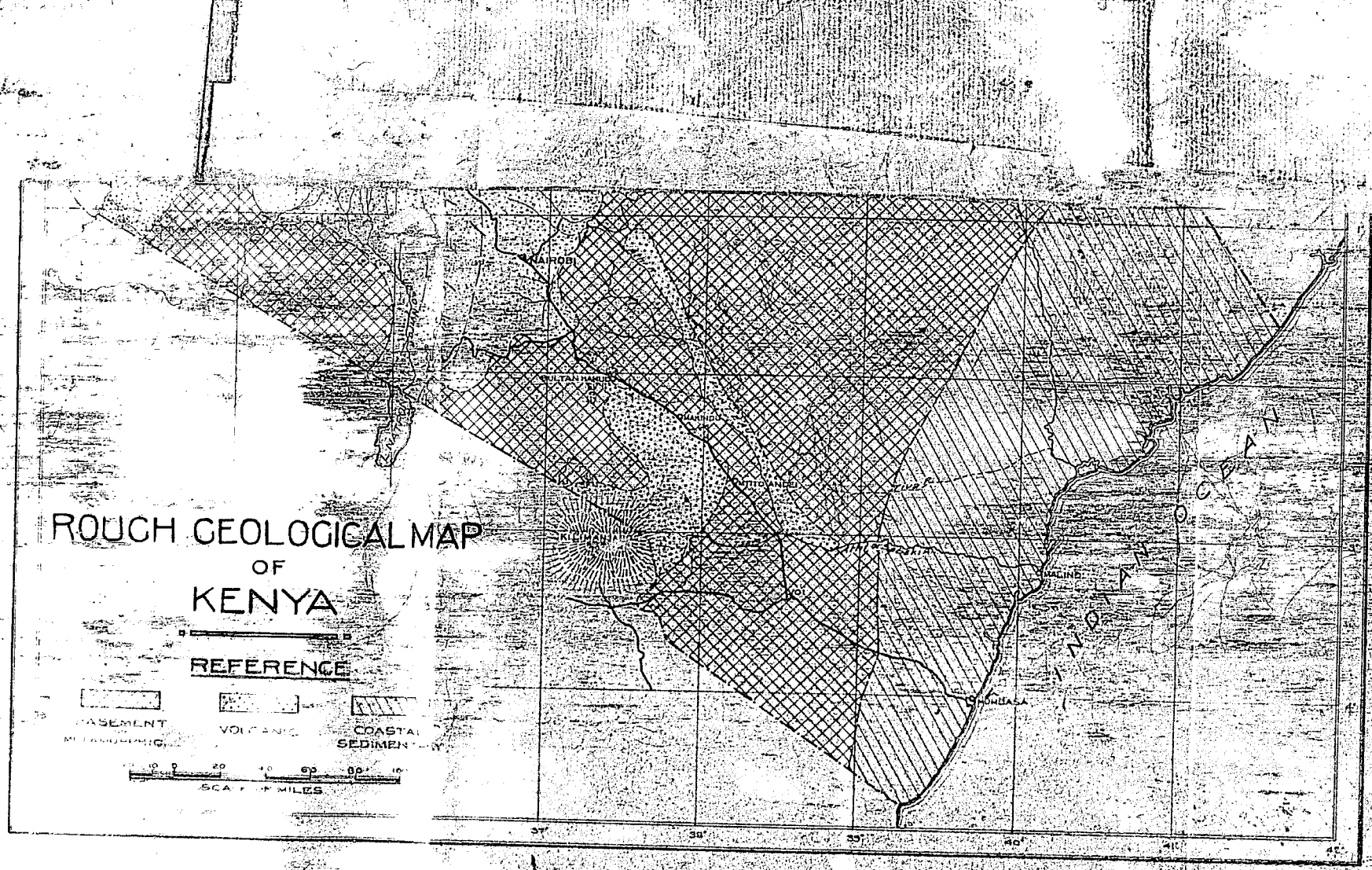
MARSABIT
LAKE TURKANA
MARSABIT
MARSABIT FOREST
ELGON
ELGEYO
MARAKWET
NYERI
NAIVASHA
NAIROBI
KAJIADO
MAKINDU
TANA RIVER



ROUGH GEOLOGICAL MAP OF KENYA

REFERENCE

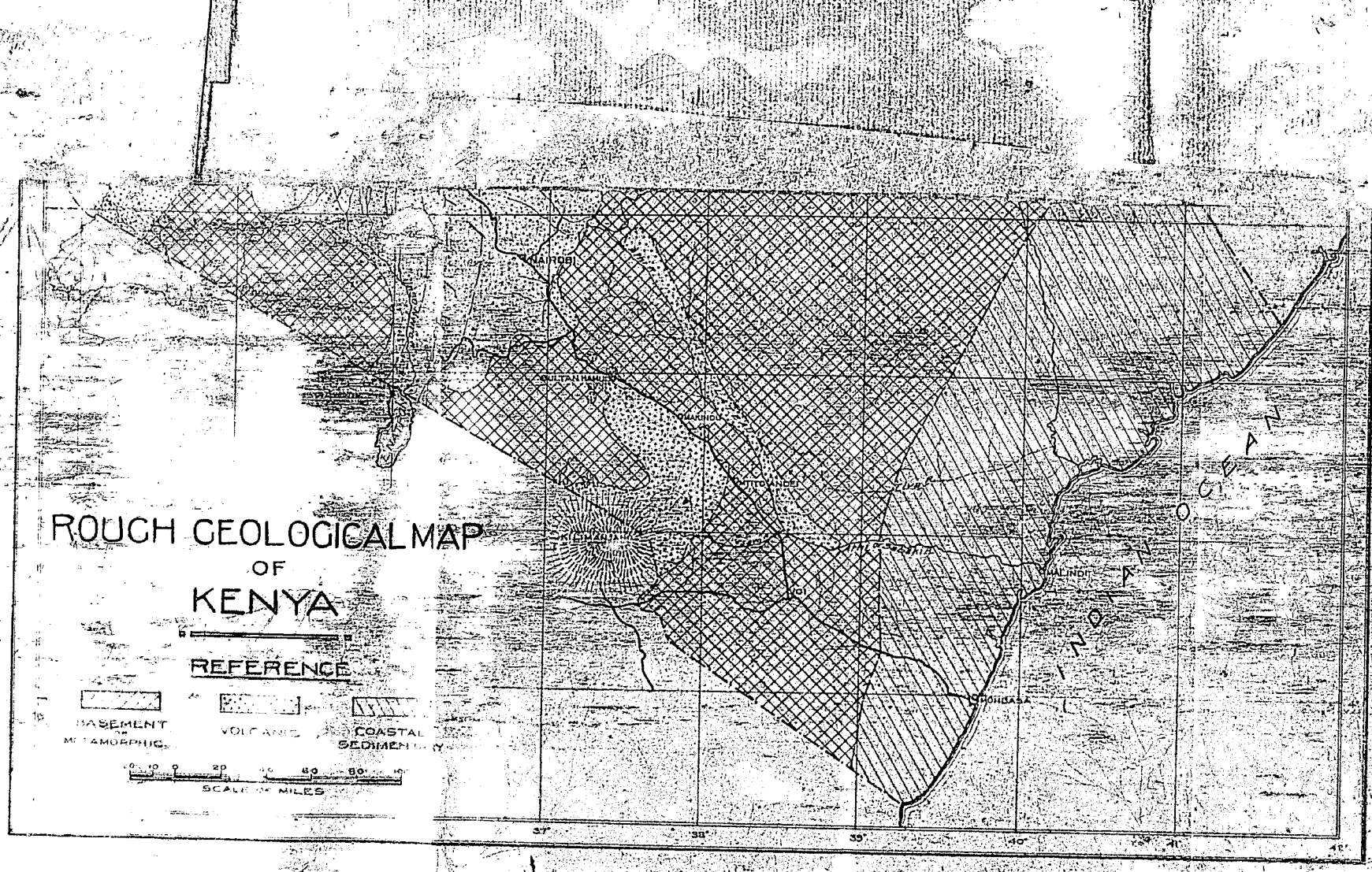
BASEMENT

VOLCANIC

COASTAL SEDIMENTARY

SCALE OF MILES

A. O. Lewis M. INST. C.E.
DECEMBER 1925



ROUGH GEOLOGICAL MAP OF KENYA

REFERENCE

BASEMENT METAMORPHIC

VOLCANIC

COASTAL SEDIMENTARY

0 10 0 20 40 60 80 100

SCALE OF MILES

A O Lewis M. INST. C.E.
DECEMBER 1925

13. Only three types of formation are shown on the map - (1) the Basement or "metamorphic", (2) the Volcanic and (3) the Coastal Sedimentary. No attempt has been made to subdivide these groups, and small areas of such formations as the lake sediments and the coral limestones are not shown.

14. The basement formation is the oldest and forms the foundation rock of the country. The volcanic formations have broken through it and poured or settled over its surface, and the sedimentary formations have also been laid down on it when it was covered with water. In many cases, where the volcanic rocks overlie the metamorphic rocks thinly, it can be seen that the lavas flowed down ancient valleys in the older formation.

The basement formation consists essentially of crystalline granitic and gneissic rocks, in most cases displaying pronounced foliation. Although hard, compact and not very porous, they are generally traversed by numerous planes of jointing and of crushing and by crevices, which permit the ingress of water and help to contribute to the weathering of the rock. The breaking up of the surface rock leads to the release of much quartz sand, which accumulates in the river beds. In fact, a feature of the rivers in this formation is the quantity of sand which fills the channels and travels along their beds. In the sand of the dry rivers water is often found close to the surface, and the native water supplies consist very largely of shallow holes scooped out in the sand. The sand would be a serious problem in projected storage reservoirs, as its accumulation in them would rapidly diminish their storage capacity.

If the geological map be superimposed on the rainfall map, it will be seen what a large area of the metamorphic formation lies in regions of low rainfall, and its importance, therefore, in the problem of water supplies will be realised.

16. The volcanic material originated from isolated volcanoes or from long rifts in the crust of the earth. Of the former type, the most notable are the three high peaks of Kilimanjaro, Kenya and Elgon, situated on the points of an isoceles triangle. Each of the two equal sides, meeting on Kenya in an obtuse angle, is about 200 miles long, one of them running almost due north and south. The heights of the peaks are 19,320, 17,040 and 14,107 feet, the two former being perpetually covered with snow. Besides these peaks, there are numerous other smaller volcanoes, the area south of the railway between Sultan Hamud and Nakuru being remarkable for the number of little dome-shaped volcanic peaks.

Of the formations originating from rifts, by far the most important are those within the Great Rift Valley. Without going into the theories of its origin, it should be stated that the result has been to produce a long deep valley about 40 miles wide between two steep walls or escarpments of volcanic material. From the edge of either escarpment the lava sheets slope down away from the Rift Valley in steep planes, or sedges, with a set like the sloping of a cottage roof. The lava extends as far as 60 miles in places from the edge of the escarpments, and on the west it joins up with the lava descending from Mount Kenya, forming a saddle watershed north of Nyeri. The eastern escarpment rises to heights of over 13,000 feet in the Aberdare range and to over 8000 feet in the Ngong range. The rainfall over all the volcanic highlands is heavy, and, being forest-clad, they form the sources of most of the permanent streams running eastward to form the tributaries of the Tana and of the Athi Rivers.

On account of the uniformity of the lava flows over great lengths and of the material composing the volcanic slopes, the streams run straight down the slopes for considerable distances in parallel lines close together without joining, like the hollows in a corrugated iron roof.

/o the bulk of the volcanic area is at high elevations and enjoys a good rainfall, the problem of water supplies is not an urgent one. The chief exceptions are in the Rift Valley, in the northern frontier province and in the area south of the railway between miles 170 and 240.

The Rift Valley is filled with volcanic material; lavas, tuffs, etc., through which numerous extinct volcanoes protrude. Streams descend into it from the escarpments, but most of them rapidly disappear underground. Others find their way into lakes, most of which are saline. None of the water of the Rift Valley reaches the sea.

The volcanic formation is an exceedingly porous one. The lavas themselves are very much traversed by cracks and joints, into which water enters very readily. The numerous tuffs, often interbedded with the lavas, are also very porous indeed. Projects for storage reservoirs are, therefore, made very difficult on account of the uncertainty as to whether the basins created will retain the water and as to the quantity of water that will reach them after travelling over such very porous ground.

16. The coastal sedimentary formation extends as a long narrow band along the coast throughout the country from Tanganyika to Abyssinia. It overlies the metamorphic formation, but its boundary has not been precisely defined. Along the railway it extends to mile 57 and consists of sandstones, shales, sandstones, grits, etc., mostly dipping at a gentle angle towards the ocean. The rainfall in the south over this coastal belt is higher than over the adjoining metamorphic area and the problem of water supplies is not so urgent, though, on account of a sandy covering over a large area, there is need for the development of further water supplies.

III. UNDERGROUND WATER SUPPLIES:

17. The surface waters are dealt with in the Chapters on irrigation and river flow and we will here deal

only with underground supplies.

18. (a) In the metamorphic areas.

Most geologists would say that in the compact rocks, such as the granite and gneiss, of this formation, the chances of obtaining a good underground water supply are very small. This would be perfectly correct if the supplies were required for extensive irrigation. Irrigation requires large supplies. It is very unlikely that supplies large enough for economic irrigation will be struck by boring in a proportion of holes sufficiently high to make the venture an economic proposition. For stock grazing purposes, however, the supplies required are exceedingly small when compared with those required for irrigation. A supply of water, for example, which would suffice for 600 head of cattle, would barely irrigate an acre of ground. It is important to realise how small a quantity of water we are looking for in each hole in order to satisfy the requirements of stock farming. I shall deal with this matter in the chapter on Water Supply for stock, and only state here that we are not looking for underground rivers, but for small supplies in the neighbourhood of 6000 gallons per day. Experience in South Africa has proved that the chances of finding supplies of this strength in metamorphic areas are sufficiently high to justify extensive boring operations, and I have no reason to believe that the chances are any less favourable over large portions of the metamorphic area in Kenya. Artesian water is exceedingly unlikely in this formation. Very deep boring in it is also likely to be unprofitable, as the deeper the penetration the more likely are we to get into the fresh compact undecomposed bedrock, wherein water cannot enter or accumulate very easily. In the upper portions, however, to a depth of, say, three or four hundred feet, water may penetrate along planes of jointing, crush and fault planes etc., and cause decomposition of the rock, which not only widens the interstices but allows of slow flow and

considerable storage of water. In the wider river valleys, too, there may be a considerable depth of alluvial deposits. In these and in the sands, which usually fill the beds of the rivers, there are likely to be accumulations of water slowly moving downhill and always feeding the crevices in the underlying rock. I would be inclined to recommend that the first efforts should be made in such wide valleys, preferably just below the junction of two drainage areas, each at least a couple of square miles in extent, where it is known that fresh water underlies the sand in the river bed. We have very little experience in Kenya to profit by, but what little there is, is in support of such a choice. There are two boreholes in the valley of the Kiu River on the farms of Messrs. Draper and Finch at miles 353 and 355 along the railway, where good water was found at depths of 126 and 68 feet, after penetrating relatively soft material except for the last few feet.

10. It is always dangerous, however, to give any general recommendations as to the choice of a boring site from broad geological considerations. Each area and each site for a hole has to be carefully selected by a man who has had an opportunity of profiting by local experience. I cannot leave this subject without a brief reference to the art of "dowsing", as in no part of the world have I found such universal faith in the water diviner or dowser as in Kenya. Without entering into a long controversy on this subject, I will content myself with saying baldly that I have no faith whatever in the possibility of locating underground water supplies by means of a divining rod. Provided, however, that the diviner has had some local experience of water boring, I do not think that he will do much harm, because he must have made some sort of a selection for a site before he begins to divine. It will be realised that this must be so, if it is reckoned that to cover a square mile of country (only 640 acres) in strips only 4 yards wide would

necessitate 440 miles of walking. He may even do some good, for the diviner, filled with sincere faith in his powers, often succeeds in encouraging a doubting farmer to embark on the somewhat speculative venture of finding underground waters and in this way he may serve a useful purpose.

20. An important matter, when water is found, is the test of the strength. This is especially important in holes sunk below a very small drainage area of, say, less than one square mile, or in holes where fine sand has been struck. In South Africa the custom is to continue a test for 9 hours, as it has been found that tests for shorter periods are apt to lead to an overestimate of the strength of the supply. Then, having estimated the continuous daily strength, it is important not to instal a pumping plant capable of pumping as much as the tested strength, since the latter may have been struck and measured in a favourable period. Continuous pumping at or above the tested strength is liable to fill the length of borehole below the pump with sand, block the strainers of the pump, reduce the subsequent supply, and also to damage the pump itself.

With windmills, for example, we shall find that on very windy days, it is possible that the pump, unless turned out of the wind, would draw as much in 24 hours as three times the average daily quantity on which we have counted. With windmill plants, therefore, we should design for not much more than half of the tested strength. In the case of steam power plants, the variations in the rate of pumping are not so great and, if they work for only 10 out of the 24 hours, the underground reservoirs have time to recover during the remaining idle 14 hours, but even in this case the design should be for not more than 75% of the tested strength.

21. (b) In the volcanic areas:

In certain cases where the lavas are thin and obviously fill an old valley in the metamorphic formation

it is possible to trace fairly accurately from surface indications between springs the probable line of flow underground. An example of this is the underground river flowing past Kibwezi Station at mile 103. The water appears at the surface at Kibwezi and again about 7 miles further up in a south-westerly direction. Between these two points it is possible to trace the underground channel from the sink-holes and subsidences of the overlying lava. The water is actually flowing as a stream under the lava and between the latter and the surface of the underlying metamorphic rock. In nearly all the springs near the edge of the volcanic area between Simba and Kibwezi Stations I was able to find the metamorphic rock cropping out just below the spring.

22. Such cases as the above are, however, not very numerous, and the general problem in the volcanic area is more difficult. The greatest difficulty is in the Rift Valley, where the need for water is also very great. Owing to the porous nature of the lavas and tuffs, most of the streams coming down from the escarpment disappear within a short distance. Nobody can say, in our present state of knowledge of the geology of the region, at what depth the water is likely to be arrested. Moreover, there is always the danger that water, if found, may prove to be saline. The water of most of the lakes, for example, is undrinkable. Naivasha is, however, an exception, as its waters are fresh. Within 14 miles south of the lake the bed of the Rift Valley is more than 800 feet below the surface of the lake, and yet no springs occur there. That indicates a steep slope in the underground water table; but, in view of the limited quantities of water entering the lake, there cannot be a very rapid exit underground, which might lead one to suppose that the hydraulic grade of the underground water is not so steep as to make it impossible to reach it at a reasonable depth by boring. If a trial borehole is made close up to the lake, say at 16 miles from it, to the south, and also a

close up as possible to a valley coming down from the western escarpment, we would be aiming to reach one or other of the two water tables sloping respectively from the lake and from the escarpment.

While strongly recommending that such a trial be made, I think it should be deferred for a year until the machines have first had a fair chance of establishing confidence in water boring in more favourable areas. If the trial should prove successful, other holes could be put down further away from the lake and along the foot of the escarpment. If not successful, a trial should be made along the foot of the eastern escarpment below the point where the Kedong River disappears. Less than a year's trial with one boring machine to depths of, say, 600 feet would probably result in 3 trial holes at a cost not exceeding £3,000, and the experience gained would be well worth the expenditure. Should all three prove failures, a geologist should be consulted as to the advisability of carrying any one of them to deeper levels. The only experience in the country of boring in the volcanic area is that at Taveta during the East African Campaign. I am informed that three boreholes were sunk and that at depths not exceeding 200 feet very strong supplies were struck in each of them, but it is not certain whether the boring was not through a thin volcanic sheet into the underlying metamorphic rock. The boring in the volcanic formation was easier than in the metamorphic areas.

Turning to other countries with somewhat similar formations, we have the record of successful borings in the great Columbia River volcanic basin in the American states of Washington, Idaho and Oregon. There, numbers of boreholes have yielded strong supplies in basalt and other volcanic formations, generally at depths considerably less than 700 feet. From experience in that country it may be that in Kenya, compared with boring in the metamorphic area, (1) we would have to look for supplies in the Rift Valley at greater depths, (2) the supplies will be stronger, (3) the boring will

be cheaper, and (4) that the water is under pressure, which may be utilised to raise the water some distance in the hole by carefully placed lining.

23. (c) In the Central Sedimentary Areas:

I was not able to inspect this area in detail. We have the record of the borehole put down at Bamburu Station (mile 42) to a depth of 837 feet, without striking water. While the boring at Bamburu was not successful, it cannot be accorded as decisive against boring in this formation. Although the Taru grits are hard and although the overlying shale group is referred to by Haufe (Huff) as "water-tight", the success attending the drilling of holes in the Transvaal, in an area of not greater rainfall and in rather similar strata suggests that water may be struck at other points in the formation, even in relatively shallow borings.

Haufe's report is adverse to trial near the base of the Taru grits, but in the Union advantage would undoubtedly be taken of the junction of the sediments with the metamorphics, as such a contact is generally a water-plane. The site selected should be such that the granite basement would be struck at about 800'. Again the description of the Maji-ya-Chumvi shales by no means suggests that they should be waterless; in the Union hard slaty rocks and even quartzites are constantly being drilled with success, though naturally large yields are not anticipated.

IV. SOILS:

24. I could not get any comprehensive description of the soils of Kenya. I believe there is a pamphlet, published some years ago, with chemical and physical analyses of typical soils, but it was not possible to procure a copy. In order to get some information on the subject, I collected a number of samples of soil, 13 of which Mr. A. Stead, Officer in Charge of the Soil Survey of the Union of South Africa, has kindly analysed for me.

86. The following are lists of the soil samples, the mechanical analysis and the chemical analysis -

PROPOSED THIKA SCHEME.

Number.	Approx. Lat.			Long.		Altitude.	Rainfall.	Place	Depth inches.	Notes.
I.	1°	15'	S	36°	43'	6000'	41	Near Kabete Station	6"	From coffee plantation, typical red coffee soil from volcanic highlands.
II.	0°	0'	S	36°	59'	6100'	30	Mr.Murray's farm on North bank Naromoru River.	4"	Cotton and coffee growing on this soil under irrigation.
III.		-do-			-do-	"		On top of ridge between Naromoru river and Buguret River.	4"	Lucerne is growing on this soil under irrigation.
IV.		-do-			-do-	"	30	Mr.Anstey's farm North Bank of Buguret River.	12"	Crops growing on this soil give poor return and lucerne difficult to establish.
V.	0°	6'	S	36°	40'	6400	30	From swamp in Sutari River on Mr. Curroy's farm.	6"	Vegetables growing on this soil in midst of papyrus swamp.
VI.	0°	48'	S	36°	26'	6300	26	Near Naivasha Town and Lake in Rift Valley.	12"	Deep sandy soil under proposed irrigation scheme from Molack [illegible]
VII.	3°	12'	S	40°	0'	100	32	South of Sabaki River near Gonhi about 10 miles from Malindi(Coast)	12"	Alluvial soil where rice and maize are grown.
VIII.	1°	12'	S	37°	30'	4300	35	On Yatta Plateau	3"	Shallow soil overlying Phonolytic lava.
IX.	1°	6'	S	37°	32'	4000	35	Six miles south of Mr.Jordan's house near Road.	12"	Soil on top of ridge between dongas overlying Metamorphic rock.
X.	1°	0'		37°	29'	3950	35	Mr.Jordan's lands near house.	12"	Mr.Jordan attempting to grow coffee. Red sandy soil on steep slope.
XI.	1°	1'		37°	32'	3900	35	About 3 miles east of Mr.Jordan's house.	12"	On gentler slope than 10 and at lower level, transition between 10 & 12.
XII.	0°	57'		37°	31'	3600	35	4 miles north of Mr. Jordan'shouse.	36"	Black cotton or turf soil widely cracked at higher levels.
XIII.	0°	30'		37°	31'	3500	35	One mile fromSouth Bank of Tana River.	12"	Red soil possibly derived by alluvial deposit carried from volcanic regions by Tana River.

Sample No.														
Colour when dry			Greenish yellow	Brownish yellow		Dark grey	Yellow.	Yellow.	Yellowish red.	Yellowish red	Red	Brownish grey.	Dark grey	Red
	Diam. mm.	%	%	%	%	%	%	%	%	%	%	%	%	%
Fine Gravel	1 to 3	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
Coarse sand	.2 to 1	3.7	8.1	8.9	0.8	0.1	8.3	0.9	33.9	30.1	53.1	39.8	0.1	20.4
Fine sand	.04 to.2	6.4	15.8	16.7	2.0	1.1	27.6	3.7	31.8	24.0	27.8	22.5	15.1	19.8
Silt	.01 to.04	6.1	16.1	12.8	23.8	5.4	24.1	5.9	6.8	2.4	3.4	3.3	5.6	3.8
Fine silt	.002 to .01	14.3	31.8	33.1	33.1	17.0	27.4	36.6	10.0	5.7	4.4	4.7	9.9	10.5
Clay	Less than .002	62.4	24.1	24.9	24.9	65.4	6.8	44.9	16.2	27.3	11.6	26.6	48.8	39.2
Moisture		6.2	5.0	3.4	8.0	10.2	8.4	7.2	0.9	2.2	0.4	1.3	3.9	3.0
Soluble in $\frac{n}{10}$ acid		Lost	1.4	1.1	6.9	2.2	2.4	2.8	1.2	0.4	0.4	0.2	4.9	2.6
Total		-	102.0	100.6	99.2	101.9	101.5	99.9	100.8	100.0	101.1	98.1	100.8	99.9
Loss on Ignition of Silt, Fine Silt and Clay		6.8	10.1	2.4	6.2	10.0	3.7	9.2	4.7	4.1	1.3	5.4	7.0	7.2
Total Loss on Ignition		7.8	12.0	3.5	6.6	10.3	5.6	10.0	6.4	5.4	1.5	5.9	7.1	7.8

Sample No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
	%	%	%	%	%	%	%	%	%	%	%	%	%
x Iron (Fe_2O_3)	12.10	5.50	5.98	7.04	7.65	5.09	8.83	6.98	3.71	1.51	3.04	6.91	8.61
x Alumina (Al_2O_3)	15.25	7.95	6.29	11.46	11.75	7.69	14.13	7.09	5.00	1.55	0.17	11.60	6.68
x Magnesia (MgO)	0.13	0.68	0.47	0.55	1.02	0.55	1.23	0.53	0.30	0.03	0.23	1.57	0.18
x Lime (CaO)	0.16	1.03	0.23	0.36	1.72	1.50	0.78	0.05	0.18	0.04	0.16	0.16	0.22
x Potash (K_2O)	0.16	0.59	0.45	0.34	0.70	0.54	0.79	0.16	0.24	0.05	0.20	0.08	0.07
x Phosphoric Oxide (P_2O_5)	0.04	0.20	0.05	0.04	0.00	0.02	0.24	0.08	0.03	0.02	0.03	0.02	0.03
Nitrogen	0.25	0.47	0.23	0.27	0.53	0.10	0.24	0.11	0.10	0.04	0.10	0.112	0.11
Reaction to Litmus	acid	neutral	slightly acid	acid	acid	alkaline	acid	acid	acid	acid		alkaline	acid

x These constituents were extracted by strong hydrochloric acid at the temperature of a boiling waterbath, the period of digestion being 24 hours.

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26. The following is Mr. Steadle's report on these soils:-

"The samples were too small to permit of the determination of "available" plant food substances and brak. In reporting on these samples I am at a disadvantage: the country and the climatic conditions are quite unknown to me, as also the special needs of some of the crops that are grown there.

Sample No. I:

Taken near Kubate Station from a coffee plantation. The soil is very clayey, no less than 68 percent of it being constituted of particles of diameter less than .002 m.m. It would undoubtedly be very difficult to work were it not for the high percentage of iron it contains, for ferric hydrate is even more potent than calcium carbonate in ameliorating the undesirable properties of clay. The soil is fairly well supplied with organic matter, and of this 0.28% is nitrogen, which is quite good. The percentage of potash is rather low and that of phosphoric oxide very low. One would expect basic superphosphate to give good results on this soil.

Sample No. II:

From Mr. Murray's farm on north bank of the Naromoru River. Coffee and cotton are growing under irrigation. This is also a very fine-grained type of soil, but the proportion of clay is less than half that in No. I. The soil has a neutral reaction and is very well supplied with all plant food substances. It may be more difficult to till than No. I, due to the very high proportion of fine silt, but one would expect this type to yield well if properly handled.

Sample No. III:

From the same place as No. II but on top of ridge between Naromoru and Bugurot rivers. Lucerne was growing on it under irrigation. Physically it bears a close resemblance to No. II, but differs considerably from it, chemically. It is slightly acid, whereas No. II is neutral, the phosphoric oxide is low, potash good, lime fair, nitrogen good. Liming and phosphatic manuring would probably benefit lucerne on this soil, but No. II would probably give better results with lucerne.

Sample No. IV:

Mr. Anstey's farm, North bank of Bugurot River. Crops growing on this soil give poor return and lucerne is difficult to establish. The large amount of soluble matter leads one to suppose that this soil may be brak, but there was not enough of it to permit of a determination of brak being made. If it is brak this may be the explanation of the poor crops and the difficulty experienced in establishing lucerne, which crop, though a grand brak resister when old, is extremely sensitive when young. Other features that would not be favourable, especially to lucerne, are the acidity of the soil and its deficiency in phosphate. Physically the soil is somewhat similar to Nos. II and III but shows differences in the coarser fractions.

Sample No. V:

From swamp in Mutari River on Mr. Curroy's farm. Vegetables are growing on this soil. This is a very fine-grained soil indeed; the sand fractions are all but absent and the clay no less than 66%. Against this may be set the content of ferric oxide which is good as also is that of organic matter. The soil is rich in nitrogen, fairly well supplied with phosphoric oxide but well supplied with lime and potash. If a good physical condition can be

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maintained, as is probable, the soil should give good returns. Phosphatic manuring might prove beneficial, however.

No. VI:

Near Nalvucha Town and Lake in Rift Valley. Deep sandy soil under proposed irrigation scheme from Nolava. Judged physically this soil would be suitable for irrigation provided there is a sufficient depth of it and its underdrainage is satisfactory. Chemically the soil is particularly deficient in phosphoric oxide, but is otherwise well constituted. Given a suitable system of cropping and manuring, this soil would seem to have much to recommend it.

No. VII:

South of Shbaki River near Gochi and about 10 miles from Nolindi. Alluvial soil on which rice and maize are grown. Except that the soil is acid and of very fine grain (over 80% of clay and fine silt) it gives figures that would seem to place it among good soils. No doubt the good percentage of ferric oxide has a beneficial influence on the tilth of the soil.

No. VIII:

On Yatta Plateau. Shallow soil overlying phonolytic lava. This sample contains over thirty percent of coarse sand. It is deficient in phosphate and lime and contains only fair amounts of potash and nitrogen. It is acid.

No. IX:

Six miles south of Mr. Jordan's house near road. It represents soil on top of ridge between dongas overlying metamorphic rocks. Physically it differs from No. VIII in respect of the finer fractions only. It is more clayey but less silty. It is rather better supplied with lime and potash than is No. VIII, but it is much worse off for regards phosphate.

No. X:

Mr. Jordan's kandy near house. Red sandy soil on top slope. Over 80% of this soil is sand. It is probably very lacking in retentiveness. Chemically there is no department in which it is not poor. This would be described in Europe as a "hungry" soil.

No. XI:

About three miles east of Mr. Jordan's house: on gentler slope and lower. Although it contains forty percent of coarse sand, it is decidedly clayey and is probably a much more retentive soil than No. X, than which it is also much better, chemically considered. It stands in particular need of phosphates however.

No. XII:

Four miles from Mr. Jordan's house: Black cotton or turf soil. This sample was taken to a depth of thirty-six inches. This makes a comparison between it and the others difficult. The finer particles of a soil tend to accumulate in the lower depths and it is quite possible that the surface twelve inch layer is not so clayey as the 3 foot layer. The soil is alkaline and shows indications of brak. It is extremely poor in phosphoric oxide, low in potash, very high in lime and fair in nitrogen. It would probably prove a difficult soil to handle under irrigation. It is all to the good, however, that it cracks open as this would facilitate aeration and the penetration of water.

No. XIII:

One mile from south bank of Tana River; possibly derived from volcanic regions and deposited by Tana River. The soil is not so clayey as No. XII; but

is much poorer in lime and magnesia. It is acid and decidedly poor in potash and phosphoric oxide. It has little to recommend it chemically. The large amount of sand (40%) would do much to counteract the bad qualities of the clay. In this connection the 6.6% of ferric oxide should also prove beneficial.

The favourable action of ferric hydrate on the tilth of heavy clay soils has been mentioned and while the analyses do not show that the iron (which is present in considerable amount in many cases) occurs in the soil as ferric hydrate, the presumption is that this is so to a considerable extent at least in the case of the red soils. Alumina also figures largely in the chemical results, and, if it is present in the soil as hydrate, will no doubt exert an ameliorative effect on the clay content. The chemical examination was not such as would show to what extent alumina is present as hydrate, however.

From the physical side the presence of ferric and aluminium hydrates in the soil is then, all to the good, but chemically they have the undoubted drawback of diminishing the availability of the soil phosphate and of rendering soluble phosphates applied to the soil, unavailable to a considerable extent, especially when the soil contains little or no carbonates of lime and magnesia. For this reason one would expect basic superphosphates to give better results than superphosphates when applied to many of the Kenya soils.

Regarding the amounts of magnesia found, it is to be noted that magnesia exceeds lime in several instances. It has frequently been claimed that when magnesia exceeds lime in amount the soil is rendered less productive than it would be if lime exceeded magnesia. While this may hold in cases where magnesia existing as carbonate exceeds lime existing as carbonate, it is highly improbable that any importance should be attached to the ratio of lime to magnesia when these substances occur as silicates, as appears to be the case in these Kenya soils."

27. The first five samples are of general interest and may be useful to the farmers from whose lands they were taken. They are all from the volcanic areas and in all of them the fine ingredients predominate.

28. Sample VI is from the area proposed to be irrigated from the Molendat River (see Chapter V). A small area of similar soil near Gilgil has been under irrigation for several years and is reported to have given diminishing returns of lucerne. Manuring is apparently essential.

29. Sample VII was taken from the edge of a lake bordering the alluvial deposit in the lower reaches of the Subukia River proposed to be irrigated (see Chapter V).

The soil nearer the channel of the river is more sandy.

30. The remaining samples are from the area proposed to be irrigated from the Yuba River (see Chapter V). They are of peculiar interest as illustrating the development of soils in the humid metamorphic belt of moderate rainfall. As will be seen from the table of elevations the samples were chosen in order descending from the top of the Yuba Plateau down to near the edge of the Yuba River. It will be noticed that on the tops of the ridges between the ravines (sample IX) there is still a fair amount of clay in the top 12 inches. As we descend the steep slopes (sample X) the clay diminishes and the sand increases. As the slope decreases, the clay increases again until finally the black clay soil of the lower levels is reached (samples XII and XIII). It falls again in the steeper red soil near the river. The high percentage of sand in all except the black clay soil is noticeable and we need not be surprised at the large amount of sand in the beds of the rivers of the metamorphic area. The iron, alumina, magnesia, lime and nitrogen show decrease and increase with the slope somewhat similar to the clay.

CHAPTER III.

RAINFALL.

31. On account of its situation about the equator, we might expect the rainfall of the whole of Kenya to be very high. Actually, the country displays considerable extremes of rainfall within its relatively small area.

To understand the general nature of the variations, we should glance at a rainfall map of the whole of Africa. (see inset map on Plate 5). Studying the map between latitudes 30 degrees north and south, and following the 30-inch line of rainfall, we see that all across Africa, north of latitude 14° in the west and north of latitude 8° near the Nile, stretches an enormous desert area, including the Sahara. (The word "desert" is herein not used in its literal sense). After skirting round north of the Abyssinian highlands, this desert continues into the Somaliland Horn of Africa; from there it bends sharply down along the East Coast to a couple of degrees below the equator, then turns inland slightly away from the coast and terminates near the lower end of Lake Tanganyika. Along the south-west coast of Africa stretches the other big desert area, which merges inland across the Kalahari desert in a north-easterly direction, also towards the southern end of Lake Tanganyika, as if to meet the band of desert coming down from the Somaliland horn.

The rest of Africa enjoys a considerable rainfall. We can get a general idea of the distribution of this rainfall if we picture Africa cut out of a piece of blotting paper. Put a heavy drop of inky water in the Cameroons at the corner of the Gulf of Guinea on the West Coast and run a wet finger along the East Coast from Mombasa in the north to Durban in the south. Let the moisture spread over the blotting paper. From the blob round about the Cameroons, where the rainfall is over 400

blobs, roughly concentric rings of heavy, though diminishing, rainfall spread more than half way across Africa towards Lake Victoria Nyanza. From the long narrow strip of longer moisture on the East Coast the rainfall diminishes more rapidly inland and the two moist areas, one from the west and the other from the east, meet in a narrow band south of Lake Tanganyika, separating the two desert bulges, one coming up from the south-east of Africa and the other down from the Somaliland horn in the north-east. The two inky blobs, having joined, form a sort of ill-balanced dumb-bell pattern across Africa, the western blob being the bigger and blacker. From this western blob two mushroom-like excrescences protrude, the larger one embracing the Abyssinian highlands and the other poking into Kenya and enclosing the high escarpments about the Rift Valley and Mount Kenya, and from the eastern strip there is a protrusion towards Kilimanjaro.

Kenya, therefore, although a comparatively small part of Africa, does not lie wholly in either rain blob nor wholly in a desert arch, but embraces a bit of each wet blob and of the Somaliland desert. Its north-eastern area lies wholly in the Somaliland desert, but in the south it has on the east the thin extremity of the East Coast blob and on the west it has the edge of the mushroom-like protrusion from the big Western blob, the two blobs being separated by the continuation of the Somaliland desert on its way to the southern extremity of Lake Tanganyika. It will be seen, therefore, that Kenya is the meeting ground of two rainy areas and of a desert, and considerable variations of rainfall may be expected.

32. Before passing to the detailed consideration of the rainfall of Kenya, we should note a general law in regard to the distribution of rainfall throughout the year in the equatorial regions of Africa. The law is that rain follows the sun in its passage north and south of the

equator, but lags a month or two behind the sun. Thus the sun passes southwards across the equator in September and a rainy period follows there in November. The sun passes the equator again on its northward course in March and a rainy period follows in April or May. At 23½ degrees from the equator, the sun reaches the extremities of its wanderings, in June in the north, and in December in the south. At every point between these extremities (or tropics), it is overhead twice during the year, but as we get away from the equator, the times of passage get nearer together about June in the north and about December in the south. In the same way the two rainy seasons, lagging behind the sun, draw closer together till they merge into one long season with a maximum rainfall in July-August in the North and in January-February in the South. The merging of the rainy seasons into one begins at about 0^0 north and at about 0^0 south, and between these limits of latitude there are two wet seasons, separated by two dry seasons, in the course of a year.

Kenya Colony lies wholly within these limits, and the law applies to it with a notable exception in the eastern corner, to which we shall refer later.

33. In order to study the rainfall of Kenya in greater detail, I have prepared a rainfall map, which is given on Plate 8. It is compiled from the excellent published annual records of the Colony and from all other sources, which I was able to find in a limited time, for the areas surrounding Kenya. It shows the rainfall lines in greater detail than in any previous publication and it is hoped that it will be of some use to those who have to study the water problems of the country in future. On the same plan I have given a rainfall map of Africa and a chart to illustrate the monthly distribution of rainfall.

RAINFALL MAP OF KENYA

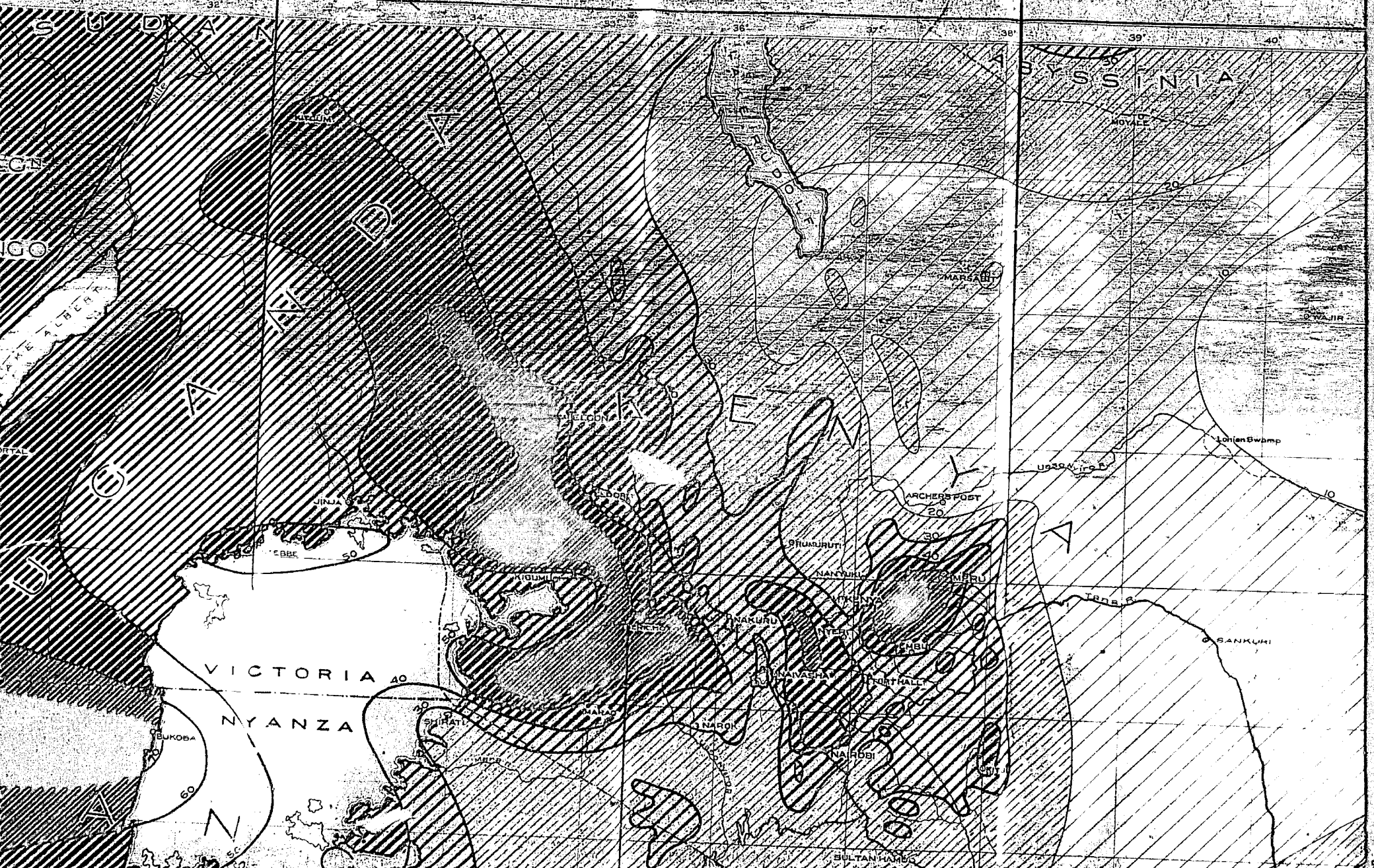
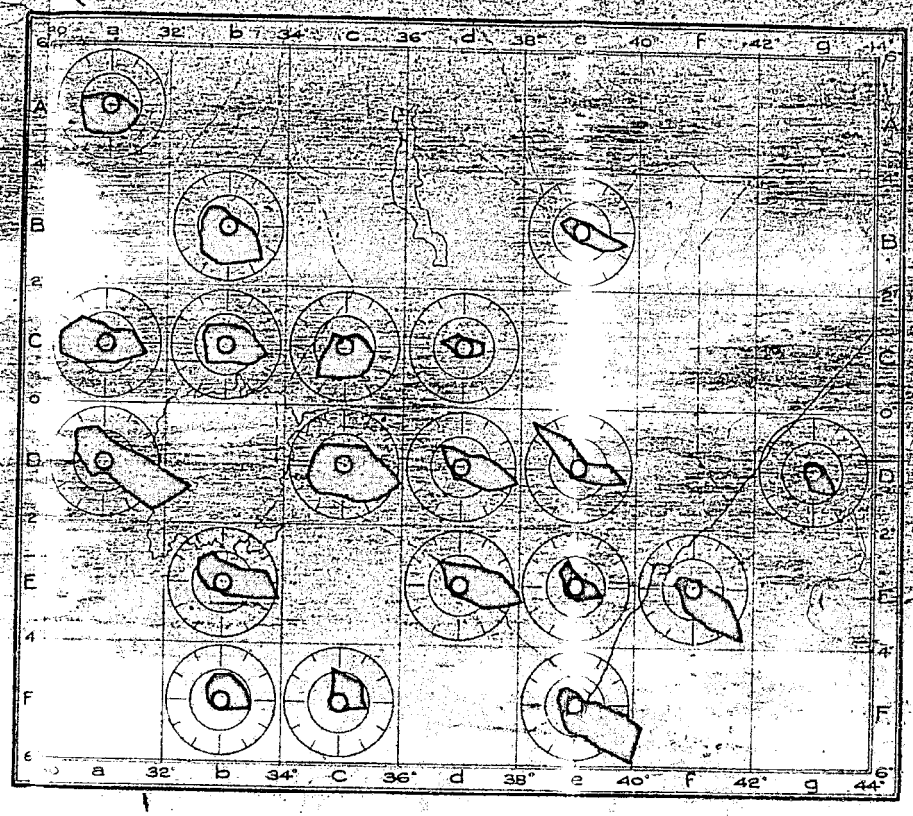
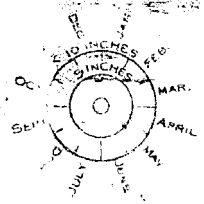


DIAGRAM SHOWING DISTRIBUTION OF RAINFALL

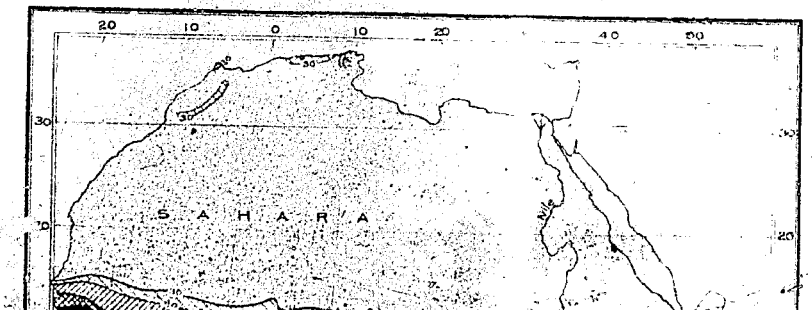


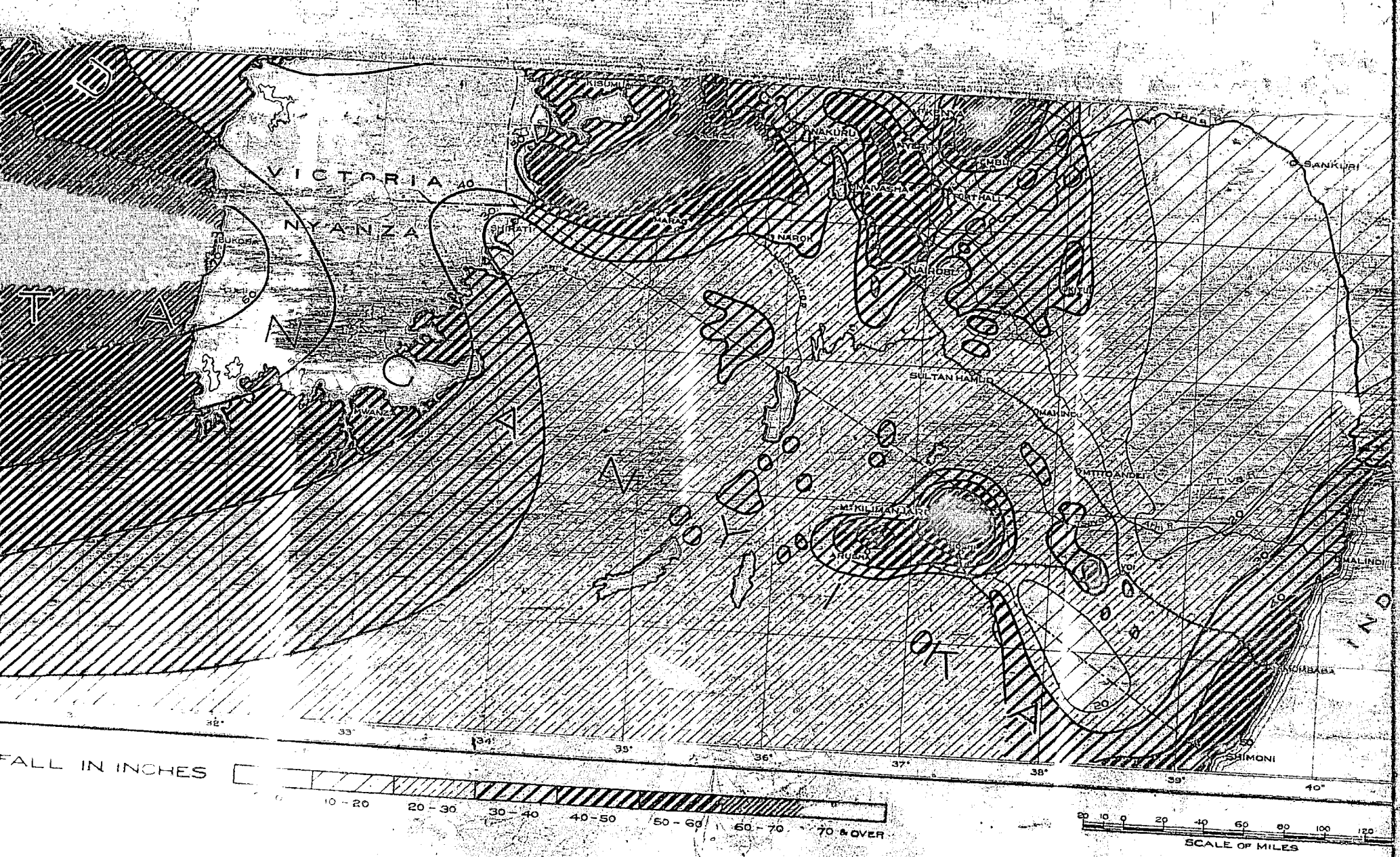
INDEX	
SQUARE	BASED ON
A a	MONGALLA
B b	KITGUM
B e	MOYALE
C a	FORT PORTAL
C b	JINJA
C c	KERICHO
C d	ARCHERSPOST
D a	BUKOBA
D c	KERICHO
D d	NAIROBI
D e	KITUI
D g	KISMAYU
E b	MWANZA
E d	ARUSHA
E e	VOI
E f	MALINDI
F b	TABORA
F c	KONDOA IRINGA
F e	SHIMONI

KEY TO DIAGRAM

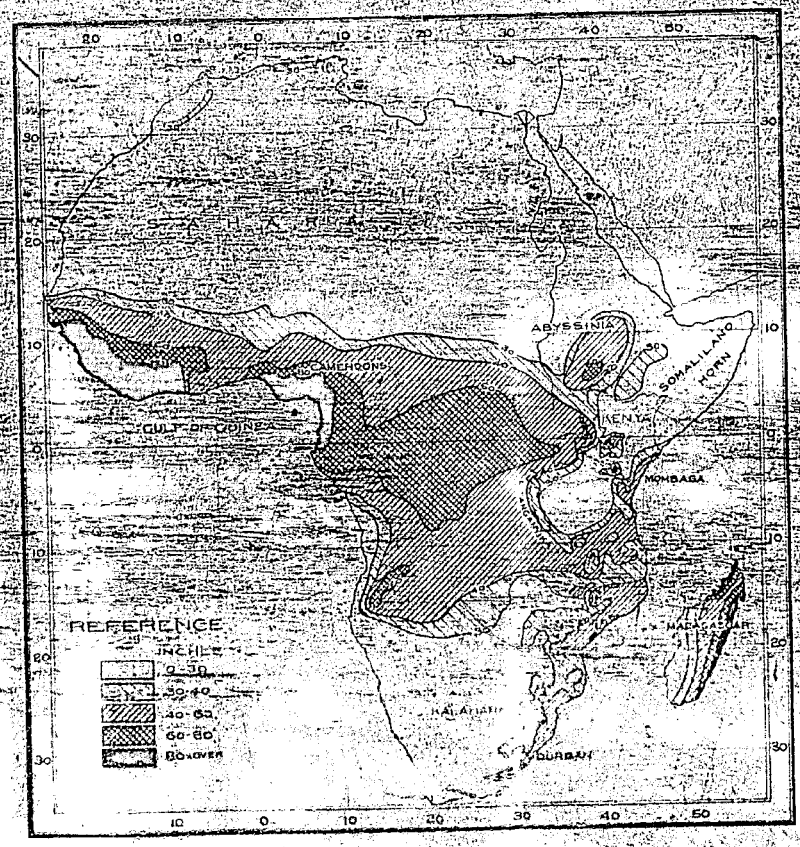


RAINFALL MAP OF AFRICA




VICTORIA
NYANZA
KISUMU
NAKURU
NAIROBI
NARAOK
KERICHO
KITALE
ELDORET
THIKA
NYERI
EMBU
MERU
FORT HALL
GARISSA
GARISSA
SANKURI
SULTAN HAMUD
MAKINDU
KITUI
TIVA R.
Mt. KILIMANJARO
ARUSHA
VOI
MALINDI
MOMBASA
SHIMONI
32°
33°
34°
35°
36°
37°
38°
39°
40°
FALL IN INCHES
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 & OVER
SCALE OF MILES

RAINFALL MAP OF AFRICA



34. We should first notice that everywhere west of a line joining the north-western edge of Lake Rudolf to the south-eastern shore of Lake Victoria Nyanza the rainfall exceeds 30 inches. The only areas east of that line which show a rainfall greater than 30 inches are those at high elevations and the long narrow wedge of country along the coast. The map shows clearly how the great Chalbiland desert pushes into the country, only the high areas and the coastal strip standing out in darker shading. In the Rift Valley there is a length of only 70 miles separating the two bays of the 30-inch line. Along the railway line from the coast to Nairobi there is a length of about 270 miles, out of a total of 330, in which the rainfall is less than 30 inches.

35. The following table gives the areas of Kenya Colony and Protectorate enjoying rainfall between certain limits. The areas are in square miles -

RAINFALL IN INCHES.	AREA BETWEEN LIMITS TOTAL	PERCENTAGE OF WHOLE.	AREA IN WHICH RAINFALL IS BELOW UPPER LIMIT TOTAL	PERCENTAGE
0 - 10	14,000	6	14,000	6
10 - 20	70,000	36	93,000	42
20 - 30	65,000	29	158,000	71
30 - 40	39,000	18	197,000	89
40 - 50	13,000	6	210,000	95
50 - 60	5,000	2	215,000	97
60 - 70	6,000	3	221,000	100
Over 70	1,000		222,000	100
TOTALS	222,000	100	222,000	100

From this table it will be seen that about 42 per cent of the country, almost in a single block, has a rainfall of less than 20 inches. With the exception of a few tribes along the Tana, Sabaki and Uaso Nyiro Rivers and at a few water holes, this huge stretch of country is almost uninhabited.

Nearly thirty per cent of the country lies in areas of rainfall between 20 and 30 inches. This embraces parts of the Ukamba Reserve, the bulk of the Kisumi Reserve and small areas occupied by Europeans. This is the area where the problem of water supplies for stock is most urgent.

Only 11 per cent of the country enjoys a rainfall exceeding 40 inches. The bulk of this lies west of the Rift Valley, and, of the portions lying east of the Rift Valley, excepting the coastal strip, the larger part is occupied by forest reserves and native reserves, particularly of the Kikuyu tribe. With the exception of an area near Lake Victoria Nyanza and the coastal area, all of it is at a greater elevation than 4000 feet and most of it is above 6000 feet.

36. It is clear that elevation has a considerable influence in increasing rainfall, but that it is not the only determining influence is clearly seen from the fact that the low coast lands on the east and the relatively low Congo basin on the west enjoy very high rainfalls. Beyond saying that the prevalent easterly trade winds from the Indian Ocean have much to do with the quantity and seasonal variations of rainfall at and near the East Coast, it is dangerous to advance any theories as to the climatic causes of the variations of rainfall until more meteorological data are available from Central Africa. After all, even the direction of the winds is determined by temperature and pressure conditions over large and almost unknown areas.

37. The seasonal variations of the rainfall are shown in a somewhat novel way in the diagram on Plate 2. The area between latitudes 6° north and south of the equator and longitudes 30 and 42 is divided up into two-degree squares and a typical rainfall station has been chosen for most of these squares. The monthly distribution of rainfall for each station is shown on a clock-like diagram, the twelve months being spread round the face of the clock like the 12

hours of a day. Twelve o'clock represents the division between December and January and the space between 11 and 1 o'clock represents the month of January, and so on round the clock, 6 o'clock, for example, representing the division between June and July. The amount of rainfall in each month is represented by measurement from the edge of the inner small white circle along a radius in the middle of each monthly sector. Two outer circles represent monthly rainfalls of 5 and 10 inches and give the scale of the diagram. The ends of the lengths of rays representing the monthly rainfall are joined up and the enclosed figure is blacked in. We can now use the language of the shooting range in describing the distribution of rainfall. If the black area bulges out towards four o'clock, for example, we know that there is a heavy rainy period in April-May.

38. We should first draw attention to the wonderful contrast between the northern and southern inland conditions by comparing the diagram for Mongalla (Ad) in the north with those for Tabora (Yb) and Kondoa Irangi (Ba) in the south. In all of these three diagrams the whole bulge is between 4½ and 8½ o'clock. In the north it is downwards towards 6½ o'clock, but in the south it is upwards towards 2½ o'clock, i.e. exactly opposite. In other words, in the north the rainy season is from April to October with a dry season for the remaining half of the year, and in the south the seasons are exactly reversed, the dry season being from May to October.

The typical equatorial double seasonal distribution east of the Rift Valley, is seen in the diagrams for Nairobi (Dd) and Kitui (Do). There are two short rainy seasons with maxima in April and November and with comparatively long dry seasons between. The length of either dry season is not so great as in the previous cases and vegetation benefits and adapts itself accordingly. In most of the equatorial areas, the April rainfall is greater and longer than that of November and consequently the water needs of vegetation are greatest in

February-March. Along the coast the April-May rains are by far the heavier, the maximum having shifted from April to May south of the Equator. There is a narrow strip of country, however, through Makindu and Kitui (Dc) on longitude 38°, where the November rains are the heavier, and in this area the most critical months for vegetation are September and October.

As we proceed north from the equator, the horns of the maxima, particularly that of November, tend to swing downwards. Thus, at Archers Post (dd) and Moyale (Bc) a maximum is in October instead of November and at Voi (Ec) it is in December.

West of the Rift Valley and north of 1° south, the diagrams all have this in common, that in the place of the dry-weather period experienced by Ceylon we find a pronounced wet period with a maximum about August considerably greater than the November maximum. It is as if the northern conditions of a single merged rainy season have stretched down through Uganda into this corner of Kenya. In addition, there is a tendency for the early rains to come in March instead of in April and the only dry part of the year is from December to March - (see diagrams for Kericho (Dc) and Jinja (Cb)).

In these conditions of even distribution of rainfall and of high rainfall which help to make this corner of Kenya and most of Uganda such fertile parts of the world.

80. In the previous paragraphs and in the plans we have dealt only with average figures for annual and monthly rainfall. As happens in all tropical and sub-tropical countries, the fluctuations from year to year are considerable. Thus, at Mombasa there was a rainfall as low as 22.1 inches in 1898 and as high as 74.3 in 1932. At Nairobi we have variations from 22.7 to 61.3 and at Machakos from 21.4 to 68.3.

Similarly, in the monthly rainfall, we find, for example, a variation at Mombasa for the month of November from 0.6 in 1917 to 8.6 in 1923.

It is these great fluctuations which make it necessary to consider the possibilities of irrigation even in areas of high average rainfall, especially where valuable crops, such as coffee, involving heavy capital outlay, are grown.

40. While congratulating the administration on its excellent annual publications of rainfall (South Africa, unfortunately, has not got so far), I would like to suggest that the approximate latitude, longitude and altitude of the stations be published, so that they may be located more easily.

41. Also, during my wanderings, I found that there is a very large number of private raingauges in the country, the records of which are not being sent to headquarters. I might suggest that copies of the rainfall map of this report be sent to all known observers as an inducement to get more records.

42. Another matter worth considering is whether the Public Works Department should not undertake the meteorological work, so admirably initiated by the Agricultural Department. The latter department probably comes into more intimate contact with individual farmers, but the former department appears to be more decentralised and the local executive engineers might be able to assist in the good work.

CHAPTER IV.

RIVERS AND THEIR FLOW.

43. In order to emphasize its importance, I begin this chapter with a recommendation, namely, that far more attention be given to the measurement of the flow of rivers than has been given to the subject in the past. No problem in connection with the use of water can be properly considered, even by the light of reports on the subject, without stream flow measurements carefully collected over a number of years. I found myself considerably handicapped throughout my tour by lack of hydrographic information. In order to get some rough ideas on the subject, I was obliged to spend a lot of my time in measurements of stream flow. These, together with other measurements which I was able to gather from miscellaneous sources, I have arranged in five tables at the end of this chapter, and I trust that, being the first of the kind, they will be of some value in stimulating further efforts and in giving some idea of the nature and magnitude of the important rivers of the country. A chapter of bare tables of measurements gives more information than a volume of description.

44. I propose to deal with the subject under the following three heads -

(1) The Western Drainage.

(2) The Eastern Drainage.

(3) The Rift Valley Drainage.

(1). THE WESTERN DRAINAGE embraces all the rivers running from the western edge of the Rift Valley and from the greater part of Mt. Elgon towards Lakes Victoria Nyanza and Edward and eventually into the Nile. The rainfall over this area is high and well distributed, and the rivers are generally abundant, perennial and strong. Irrigation and water supply problems are not of great importance here.

and the Uaso Nyiro (North). The Uaso Nyiro does not reach the sea, but loses itself in a sandy river bed and in the Lorian and other swamps. The Tana and the Athi derive all their low-season water from the highlands bordering the Rift Valley and from Mounts Kenya and Kilimanjaro. Shortly after leaving the volcanic highlands, the two rivers and their tributaries are within a couple of miles of each other. The Tana then takes a big turn towards the North and finally bends back again to the coast in the South. It thus includes between it and the Athi a huge area of country which is almost entirely outside the volcanic formation. All the sources of permanent flow, the highlands, Mounts Kenya and Kilimanjaro, lie outside this enclosed area, which, consequently, has no perennial rivers within it.

29. THE ATHI OR GABAKI RIVER: This river derives all its low-water flow in its upper reaches from the highlands and in its lower reaches is reinforced almost solely by the Tsavo River coming down from Kilimanjaro.

30. The tributaries in the highlands all flow down in deep valleys close together like the channels in a corrugated iron roof. They all empty into the Embakasi, acting like a gutter to the roof, which runs in a northerly direction and, within a short distance from the Thika tributary of the Tana, turns abruptly and flows in a more or less straight line south-eastwards towards the ocean. Only two of the highland tributaries have a low-water flow exceeding 5 cusecs, where they cross the Nairobi-Thika road, namely, the Ruiru and Mdaruga. These originate at the southern end of the Aberdare Range, from the higher parts of which further north the bigger tributaries of the Tana derive their waters.

It will be noticed that the sum of the low-water flows of the tributaries is considerably less than the flow of the main stream which I measured above Kibwa.

Even making allowance for the probability that the flows of the tributaries were slightly greater during my visit than the low figures given for previous periods, it looks as if some water flowing along beneath the surface of the lava has been brought to the surface where the lavas end on top of the metamorphic formation. It would be interesting to prove by careful gauging whether this is the case or not.

51. After these tributaries have joined, the river flows down at first steeply in a series of falls and rapids in the metamorphic formation. The falls are generally from twenty to thirty feet high over the outcropping edges of strata, which have a general strike of 330 to 340 degrees and a dip of about 45 degrees towards the south-west. From any one of these falls it is a comparatively easy matter to land off a furlong almost immediately out of the reach of high floods.

After leaving the volcanic areas, the river decreases in strength throughout the metamorphic area. This is clearly indicated in my gaugings, which show a discharge of 95 cusecs above Kihuni, 65 cusecs at Kibwezi, about 100 miles lower down, and 40 cusecs 70 miles further down just above the confluence of the Tsavo. The water flows in a shallow meandering stream over a sandy bed more than 100 feet wide. At intervals it is crossed by reefs, which strike persistently between 330 and 340 degrees. Although my measurements show a minimum flow of 40 cusecs above the Tsavo confluence, I was informed that in February-March 1919 it actually ceased to flow opposite Kibwezi.

52. The Tsavo River added 160 cusecs at the time of my visit, shortly after rain had fallen in the neighbourhood of Kilimanjaro. It is probable, therefore, that it falls to a lower flow than I observed, but that it is still the biggest tributary. Although the joint flow of the Tsavo and Athi at the confluence was 200 cusecs, 120 miles

lower down and about 30 miles from the ocean the flow was only 140 cumecs. - In a very low year the flow reaching the sea would probably be well under 100 cumecs.

53. The whole of the drainage area lies in the four-seasoned rain belt and, therefore, the low-water periods are at about March and October. These are also, probably, the periods when the water requirements of crops are greatest. The irrigation possibilities of the water are, therefore, limited by the strength of the low-water flow, especially as storage of flood waters is not likely to be an economic proposition owing to the steep nature of the country and the large quantities of sand in the river bed. We know almost nothing as to the strength of flow in the rainy season and it is very desirable that a few gauges be established. The difficulty is that from Kipini downwards there is not a single white person resident near the river. A few ruins and graves of missionaries indicate the unhealthy and inhospitable nature of the country through which the river flows.

54. THE TANA RIVER: This river, by far the largest in the area, derives its perennial water from the higher parts of the Aberdare highlands and from Mount Kenya. The tributaries from the Aberdares, like those of the Athi, come down in parallel deep valleys close together. In fact the Athi and its most northerly big tributary, the Ndarugu, and the most southerly tributary of the Tana, the Chania and Thika, are for a length of about 40 miles hardly ever more than 5 miles apart. It is convenient to divide the river into two sections, the first down to the junction of the Thika, wherein the main stream lies chiefly in the volcanic formation and in which the last of the permanently flowing tributaries enters from the south, and the second in which the channel of the stream lies wholly in the metamorphic and coastal formations and the tributaries all come in on the left bank. - In the first section the bulk of the water comes in on the right bank.

the biggest tributaries being the Chania, Gura, Mathioya, Maragua and the Thika, all from the Aberdare Range. On the left bank the larger streams are the Amboni, Nairobi and Ragati, all coming down from the slopes of Mt. Kenya, with the exception of the Amboni which derives most of its water from the Aberdares. In the second section all the permanent water comes from Mt. Kenya and possibly from the spur jutting out in a north-easterly direction from Maru. The four big tributaries are the Thiba, Ena, Mutonga and the Nzaita. There are no permanent tributaries on the right bank.

56. As to the strength of the flow in the main stream and its tributaries, a number of measurements are given in the table of gaugings in low-water periods. It will be noticed that most of the gaugings are in the upper section and that there are only a few gaugings in the lower section. I have prepared a rough chart (following the table) to illustrate a forecast of low-water discharges throughout the whole river and its principal tributaries. This may be wide of the mark, especially in the four big tributaries from Mount Kenia - the Thiba, Ena, Mutonga and Nzaita, but some assumptions must be made if we are to get any idea of the possibilities of the river. It may serve to emphasise the lack of data and encourage efforts to obtain a reasonably accurate chart of this sort at an early date. According to the chart, the maximum flow is in the neighbourhood of 2000 cusecs below the junction of the Nzaita, the last of the big tributaries and about 220 miles from the sea. Between that point and the sea it is assumed that the flow diminishes to 1800 cusecs.

58. The temperature of the water was taken at various points in May and June 1929. Above the confluence of the Mathioya it was 68 degrees, and it gradually increased to nearly 80 degrees at Sankuri.

57. To illustrate the fall in the main stream, the rough section on Plate 3 has been prepared.

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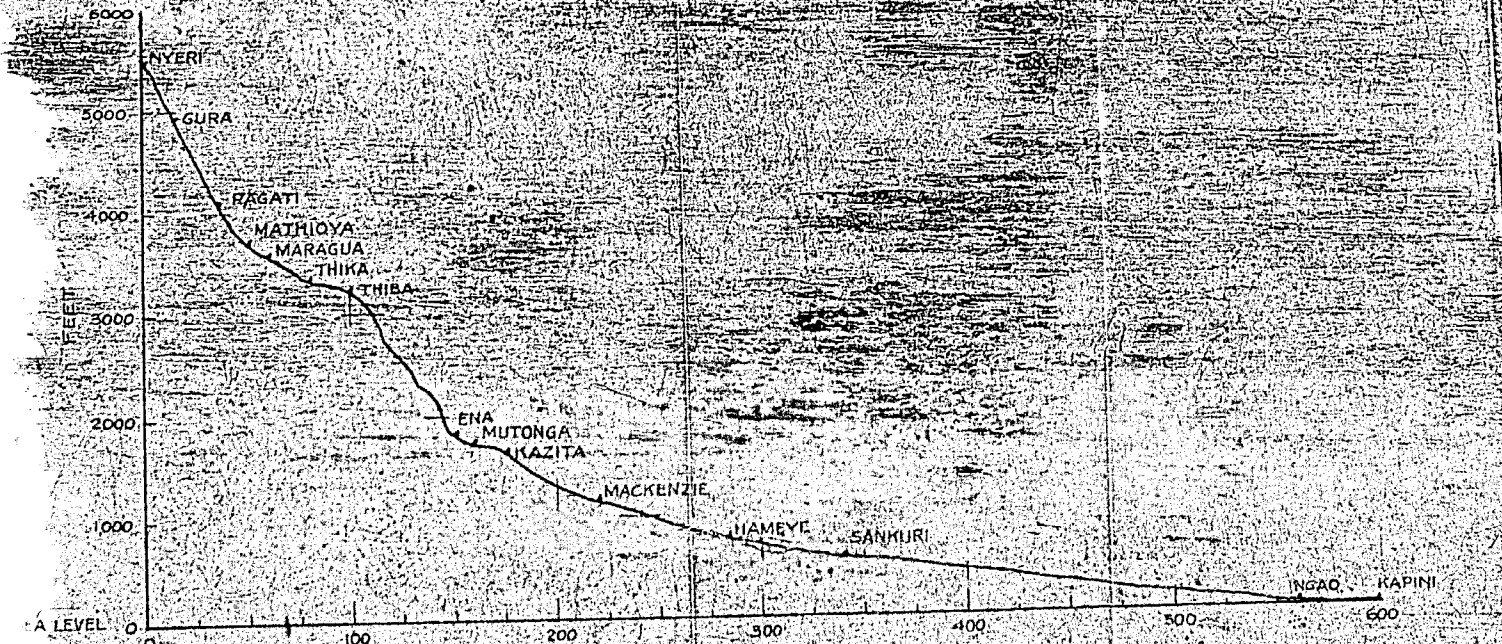
PLATE 3

APPROX SECTION OF TANA RIVER FROM NYERI TO THE SEA.



A.D. Lewis M.INST.C.E.
DECEMBER 1925

This section when studied in conjunction with the discharge chart, indicates the large amount of power available. The most remarkable fall is in the length between the Thiba and the Km, where the Tana breaks through a long chain of metamorphic mountains, tending slightly west of north through Kitui. In this short 80-mile length of the main stream nearly 100,000 horse-power daily run to waste, and in the bigger tributaries very large power resources lie and can easily be utilised at the numerous deep waterfalls in the volcanic areas.

While the power resources lie above the confluence of the Kmaita, the irrigation possibilities on a large scale appear to lie below this point. This is an ideal arrangement, as large irrigation schemes may be possible in the lower reaches without diminishing the power possibilities of the upper reaches.

88. THE UASO NYIRO (north) is the smallest of the streams of the eastern drainage. Its small size is clearly indicated in the discharge chart. The biggest tributaries are the Narok and the Nanyuki. The former derives most of its water from the eastern face of the Aberdare range, Lake Dolopsat emptying into this stream over Thompson's falls. Its discharge at Rumuruti falls below 16 cusecs, and shortly beyond that station it is almost lost in an extensive marsh. The Nanyuki drains the north-western slopes of Mt. Kenya. At Archer's Post the main stream is reported to be nearly dry in low-water periods, and no permanent water ever gets beyond the Lorian swamps. Considering the large quantities of water discharged on the south and eastern faces of Mount Kenia, it is remarkable that such small streams result on the north and western faces.

Enormous quantities of water are lost on all the tributaries in large marshes of papyrus grass. These marshes are a feature of this river. The papyrus grows densely over wide areas and the water builds itself elevated and leaky channels throughout the marsh. The marshes are not in the

nature of lakes, as there is constantly a very considerable fall through their length. The measurements above and below the Reed swamp indicate the magnitude of the losses of water in the marshes. Of 8 cusecs entering the marsh on 11.5.21, more than 7 were lost.

59. (5) THE RIFT VALLEY TRIBUTARIES. None of the water falling or draining into the Rift Valley ever reaches the sea. The comparatively small rivers are lost in the sands, turfs and lavas of the Rift Valley or drain into one or other of the numerous lakes. Almost all of the large lakes are salt, with the notable exception of Lake Naivasha. Into it drains the biggest of the Rift Valley rivers - the Malewa or Morendat. Even that is not a large river and its discharge is said to fall as low as 10 cusecs. None of the other rivers are big enough to allow of serious consideration of irrigation on a big scale, the limited flows being required almost entirely for domestic and ordinary farm purposes and for small farm power units.

60. I conclude, as I began, this chapter with a recommendation for further work in measuring the streams, not only in low water periods, but throughout the year. A few automatic recorders should be erected at an early date, and in connection with irrigation four places seem to require early attention - the Tsavo near the railway station, the Athi at Kibwa, a missionary station, the Tana at Sankuri, an administrative post, and the Morendat on one of the farms near Lake Naivasha.

61. In the tables of gaugings, under the heading of "Method", the following symbols are used -

(1) Weir
(2) Water and floats.
(3) Floats.
(4) Rough floats.
(5) Eye observation.
(6) Rumour or guess.

456A

ATHI or SABAKI RIVER

GAUGINGS IN LOW WATER PERIODS, PROCEEDING DOWNSTREAM.

TRIBUTARY OR MAIN STREAM.	STREAM	PLACE OF GAUGING Lat. South.	Long. East.	DATE	METHOD	CUSECS.
CONTRIBUTING highlands of 37.A3						
MY ATHI		1.27	37.00	22.9.25	5	0.0
KASI	Mbagathi	1.20	36.41	1925	1	2.6
	Tributary	1.27	36.50	22.9.25	4	1.0
OBI	Naivoki	1.15	36.45	3.8.22	1	2.4
	Naivuri	1.16	36.50	Feb.1923	5	0.0
	Gatathuru	1.15	36.50	1924	5	0.0
	Karura	1.14	36.50	4.1.23	1	0.4
	Tigoni	1.07	36.42	10.1.23	1	2.2
	Rui Runka	1.19	36.45	Same as Con.day	4.1.23	1	3.4
	or Ruaraka	1.14	36.50	"	17.1.23	1	4.9
	Kogun	1.29	36.56	1923 & 24	5	0.0
	Gatharaini	1.11	36.50	4.1.23	1	0.5
	Riara	1.03	36.45	5.1.23	1	1.3
	"	1.11	36.50	4.1.23	1	1.6
	Kamiti	1.09	36.55	5.1.23	1	3.6
	Nakuyu	1.06	36.57	24.9.24	1	1.8
	Ruiru	1.09	36.57	1.10.25	5	15.7
ATHI		1.00	37.09	1.10.25	5	10.7
SMALL STREAM Tributaries of 37.A3						
STREAM		1.10	37.24	Above Kibua	15.9.25	5	65.0
		0.10	36.04	Near Kiboroni	8.10.25	2&5	65.0
		"	"	"	11.2.19	5	2.0
		"	"	"	Mar.1919	5	0
ATHI		1.05	36.40	Above pumps	8.10.25	4	0.18
SPRING		1.07	36.21		6.10.25	5	0.005
		0.09	37.06	At Rail bridge	7.10.25	4	1.00
		0.13	37.15	"	7.10.25	4	3.00
		0.16	37.19	Above pumps	7.10.25	4	0.34
		0.20	37.22	Hamani spring	11.10.25	5	5.1
		0.24	37.27	Below railway	8.10.25	2&5	0.0
		0.22	36.03	At joint dam	9.10.25	5	18.5
		0.21	36.06	Below last furrow	9.10.25	4	4.0
RAM		0.58	36.29	Near Tumu	10.10.25	2&5	40.0
		0.00	36.27	Above railway	10.10.25	5	160.0
STREAM		0.10	36.50	Near Nairobi	22.10.25	4	140.0

T A N A R I V E R

GAUGINGS IN LOW WATER PERIODS. PROCEEDING DOWNSTREAM.

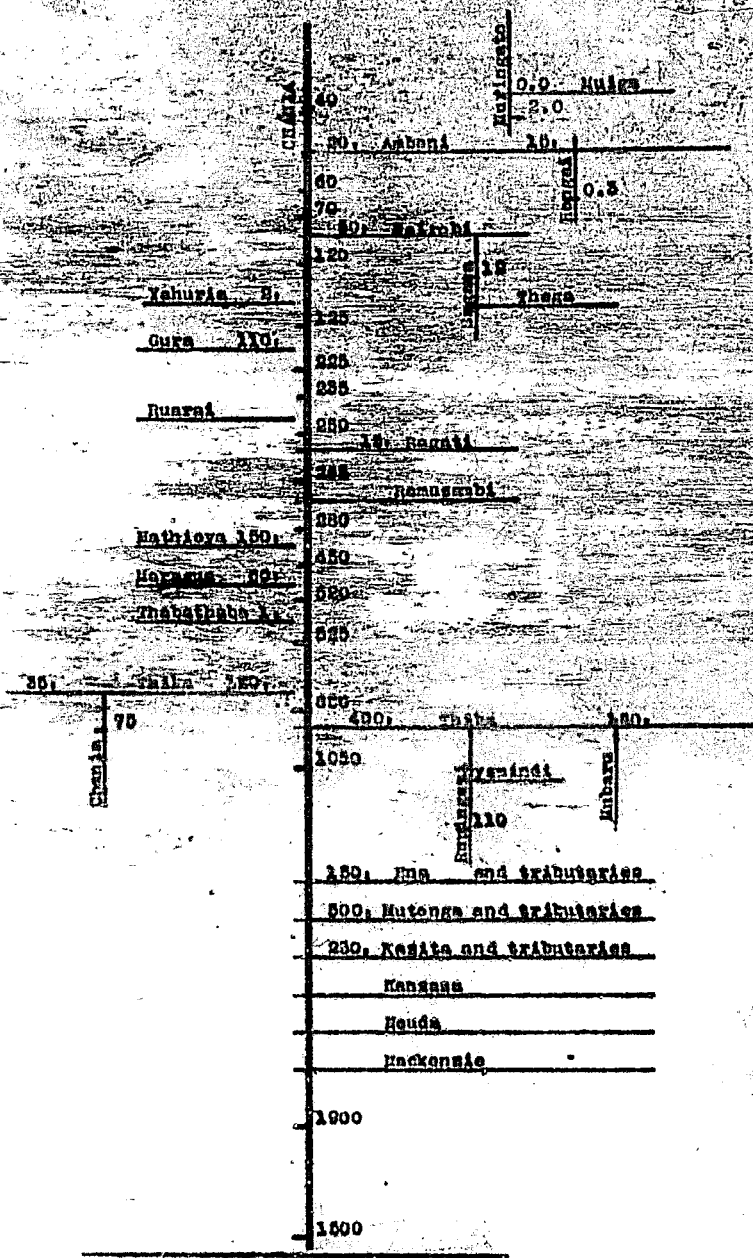
TRIBUTARY OR MAIN RIVER	STREAM	PLACE OF GAUGING Lat.	Long.	Notes.	DATE	DEPTH Ins.	DISCHARGE Cus. Secs.
MAIN STREAM	Chania	0.35	36.57	At Nyeri	7.8.21	3	80
					30.9.25	3	60
					Feb.1924	3	28
ARIGENI	Rongai	0.15	36.59		6.3.24	1	0.5
	Amboni	0.20	36.58		7.8.21	7	34.4
	"				30.9.25	8	15.07
	Muringato	0.24	36.56		14.3.14		
					30.9.25	8	8.0
	Uyira	0.22	36.57		29.9.25	8	0.0
NAIROBI	Thega	0.23	37.02	"above Nairobi confluence".	10.8.21	7	15.0
	Nairobi	0.26	37.02	"above Chania confluence".	13.8.21	3	60.0
YANGIA		0.28	37.03		30.9.25	6	8.0
MAIN STREAM		0.30	37.04	At Tumi-Tumu falls above confluence of Gura	Mar.1919		105
				-do-	Mar.1919	7	108
					23.8.21		150
GURA		0.31	37.04		Mar.1919		110
					"		121
					24.8.21		125
MAIN STREAM		0.31	37.04	Below confluence of Gura	Mar.1919		289
		0.40	37.11	Above confluence of Ragati	"		304
					"		3807
RAGATI		0.39	37.11		Mar.1919		35
					30.9.25	4	20
MATHIOYA		0.43	37.11		Mar.1919		260
MARAGUA	Kaihuura	0.44	37.09		23.3.19		15
	Maragua	0.45	37.09		18.3.19		73
	"	"	"		28.3.19		55
THARA THARA		0.47	37.10		Mar.1919		0.5
THIKA	Chania	1.03	37.03	Above falls	Mar.1919		79
	Thika	1.02	37.03	"	"		56
	"	1.02	37.05	Above confluence of Tana	14.9.25	8	163
MAIN STREAM		0.54	37.31	Below confluence of Thika	13.9.25	8	1190
THIBA	Thiba	0.48	37.21	10 miles below main road	?		217
	"	?	?	Above confluence of Rupingazi	23.8.21		200
	Rupingazi	"	37.26	Above confluence of Nyamindi	7.3.21	4 or 5	128
KAZITA		0.02	37.40	1 mile from Mouth	17.8.21	4	105
MAIN STREAM		2.50	40.15	At Hemani near ocean	6.10.24	4	2600

Note: Possibly last gauging was influenced by tide.

TANA RIVER & TRIBUTARIES.

CHART ILLUSTRATING PORTION OF LOW-WATER DISCHARGE.

Not to scale. Figures are guesses.



UABO MYERO RIVER (NORTH).

GAUGINGS IN LOW WATER PERIODS
PROCEEDING DOWNSTREAM.

TRIBUTARY OR MAIN RIVER.	STREAM.	PLACE OF GAUGING. Lat.	Long.	Notes.	DATE.	METH-OD.	DISCHARGE.
MOKO		0.07S	36.24	Above confluence of Main stream	15.3.21	S	0.0
MANCHICHU	Naramaru	0.10N	37.02		9.3.21		9
	"	0.06S	36.59		29.9.25	S	6
NGUNIT				On road Nyeri-Embu	16.3.21		6
NGURUBI	Ngurubi	?	?		9.3.21		14
	"	0.05S	37.00		29.9.25	S	6
	Kanyua	0.03S	37.03		29.9.25	S	3.5
MAIN STREAM		?	?	On path Nu-mburuti-Kanyu	15.3.21		16
		0.07N	36.53		29.9.25	S	25
SUGAROI	Sugaroi	0.04N	36.40	Above swamp	29.9.25	S	0.0
	"	?	?	"	11.3.21	?	1.1
	"	?	?	Below swamp	"		0.0
	Sogura	0.03S	36.42		29.9.25	S	0.0
NANYUKI	Nanyuki	0.00	37.04		"	S	6.5
	"	"	"		30.1.24		78.0
	Lilai No.1	0.01N	37.05		29.9.25	S	15.0
	"	"	"		9.3.21	?	10
NARUK	Ewaimaia	0.02N	36.22	Above confluence of Nolosana	27.9.25	S	10
	Nolosana	0.01N	36.22	Above confluence of former	27.9.25	S	20
	Naruk	0.03N	36.20	At Thompson's falls	27.9.25	S	30
	"	"	"	"	16.3.21		18
	"	"	"	"	?	S	10
	"	0.10N	36.33	Below Numuruti & above swamp	10.3.21	?	15
	Pesi	0.07N	36.35	Above swamp	11.3.21	?	0.4
	"	0.11N	36.35	Below "	"	?	1.2
	Hutara	0.04N	36.40	Above "	29.9.25	S	5.0
MAIN STREAM		0.37N	37.39	Archer's Post	15.3.21	S	143
		"	"	"	?		Nearly dry.

R I F T V A L L E Y R I V E R S

GAUGINGS IN LOW WATER PERIODS.

LAKE SYSTEM	STREAM	PLACE OF GAUGING Lat. South.	Long. East.	Notes.	DATE	METH -OD	CUB- ECS.
LAKE NAKURU	Uaso Nyiro	1.07	35.45	Above confluence of Narok	15.10.25	4	3
	Uaso Narok	1.07	35.53	Above confluence of Nyiro	15.10.25	4	4
	Siyabei	1.07	36.00	-do-	14.10.25	4	5
	Maji Moto Spring (hot)			Below source	15.10.25	3	0.5
LAKE MAGADI	Kedong	1.03	36.38		Sept.25 to Oct.14. 1925	4	5 ish
		1.13	36.50		10.10.25	3	0.5
LAKE NAIVASHA	Malewa or Morendat	0.40	36.25		26. 9.25	3	50
	"	"	"		25. 3.21	3	40
	"	"	"		?	4	15
	Gilgil	0.30	36.20		26. 9.25	4	4
	"	"	"		?	4	0.1
LAKE ELMENTEITA	Nderema		?	Upper	?	1	10 ?
	"	0.23	36.13	Lower near lake	?	4	0
LAKE NAKURU	Enderit	0.27	36.06	Near lake			0
	Njoro	0.20	35.58		25.9.25	1	3
	"	"	"		Lowest of past few seasons	1	1.1
LAKE BARINGO	Molo	0.25	35.55		- "	1	0.5
	Rongai	0.26	35.56		"	1	1.2
	Olobomsita	0.23	36.08?		"	1	1.7

CHAPTER V.

IRRIGATION.

62. From what has been written in previous chapters, it will be gathered that the possibilities of irrigation in Kenya are not very extensive. Considering only the low-water flows of the principal rivers and excluding the Tana River, the following are probably the maximum areas that could be irrigated, if no ignored other demands on the water -

	Acres.
From the Athi and Tsavo and tributaries	10,000
From the Uaso Nyiro and tributaries	5,000
In the Rift Valley	2,000
TOTAL	22,000

or, say, 30,000 acres.

From the Tana River we could probably irrigate 150,000 acres. It is, therefore, the one outstanding river from which irrigation on a large scale can be achieved.

Nor can this area be increased very much by means of storage works, for, as we have seen, the bulk of the country is too steep for the construction of economical storage dams; in the volcanic areas the formation is too porous, and in the metamorphic areas there are the enormous quantities of sand in the river channels.

63. Apart from these physical difficulties, there are the difficulties of population, communications and markets. All along the Tana River, for example, the population is exceedingly scanty, and, except in the practice of a messy sort of swamp irrigation near the mouth of the river, is quite inexperienced in the art of irrigation.

I do not intend to suggest any means of overcoming this difficulty. That is a matter with which the Administration, familiar with the conditions of the country, will be able to deal; but I wish to emphasize its importance

here, lest it should be overlooked by enthusiasts, who may urge the country on to the adoption of large and expensive irrigation works, without having first devised most carefully a scheme for settling up the area to be irrigated with a population experienced in irrigation or capable of learning its essentials within a reasonable time and also capable of enduring the severe climatic conditions of the lower Tana regions.

From my necessarily limited observation of the natives of the country, I should hazard the opinion that it will be many years before a large number of them will be fit to settle on an expensive irrigation scheme. Their methods of agriculture are still most primitive, the plough is almost unknown, the men are inclined to leave the tilling of the soil to their womenfolk, and their ambition in extending their agricultural operations does not seem to extend beyond the production of merely enough food for their own families and of sufficient wealth for the acquisition of a limited quantity of wives and, in some cases, a large quantity of goats.

There are enormous areas of country where the rainfall is sufficient for the extensive practice of ordinary agriculture, if reasonable care is taken to conserve the moisture in the soil. Until the possibilities of agriculture without irrigation are further exploited, I would hesitate to recommend the expenditure of large sums of money on irrigation works for the natives, especially in view of the fact that there are considerable and growing demands for the labour of the natives in various other directions in the country.

It is possible that they can be trained to the necessities of agriculture under irrigation, but I am of opinion that the initial experiments in this direction should be on a small scale, so as not to risk too much capital, and that they should be under European direction.

Apart from the possibility of large financial losses, it is possible to ruin the very limited irrigation possibilities of the country by putting untrained natives directly on irrigated areas. In the flat alluvial areas of the Tana, the application of excessive quantities of water to the soil would soon ruin the land, and nothing is more certain than that inexperienced natives will put too much water on the soil. Then, in the non-alluvial areas, the slope of the land is generally so steep that careless irrigation would soon wash away a lot of the soil.

65. We have assumed that the biggest possibilities for irrigation in the country lie in the lower reaches of the Tana, a country quite unsuited for permanent European settlement. Further investigation may show that there are considerable possibilities higher up the river in regions of greater altitude, where Europeans can live without much discomfort. Owing to the fluctuations of rainfall, referred to in Chapter III (Par. 30), we should look for irrigation possibilities even in areas of high average rainfall, say, up to the 40-inch line of rainfall. From the rainfall map it will be seen that the lower reaches of the bigger tributaries of the Tana lie outside the darker areas of rainfall higher than 40-inches. But it should be noted that all of these reaches on the left bank of the Tana lie in native reserves. If it has been definitely decided by the Administration that there is to be no European encroachment into these areas, then we have the same difficulty in the matter of population. Apart from Forest Reserves, the natives occupy all of the high land on the southern and eastern slopes of Mt. Kenya down to the Tana River and also the bulk of the high land on the eastern slopes of the Aberdares. These areas contain some of the most fertile, well-watered and healthy regions in the whole of central Africa. On high moral grounds Europeans are denied entry for ordinary agricultural operations; but, if there are areas along the bigger rivers which cannot be fully used even by

Apart from the possibility of large financial losses, it is possible to ruin the very limited irrigation possibilities of the country by putting untrained natives directly on irrigated areas. In the flat alluvial areas of the Tana, the application of excessive quantities of water to the soil would soon ruin the land, and nothing is more certain than that inexperienced natives will put too much water on the soil. Then, in the non-alluvial areas, the slope of the land is generally so steep that careless irrigation would soon wash away a lot of the soil.

65. We have assumed that the biggest possibilities for irrigation in the country lie in the lower reaches of the Tana, a country quite unsuited for permanent European settlement. Further investigation may show that there are considerable possibilities higher up the river in regions of greater altitude, where Europeans can live without much discomfort. Owing to the fluctuations of rainfall, referred to in Chapter III (Par. 39), we should look for irrigation possibilities even in areas of high average rainfall, say, up to the 40-inch line of rainfall. From the rainfall map it will be seen that the lower reaches of the bigger tributaries of the Tana lie outside the darker areas of rainfall higher than 40-inches. But it should be noted that all of these reaches on the left of the Tana lie in native reserves. If it has been definitely decided by the Administration that there is to be no European encroachment into these areas, then we have the same difficulty in the matter of population. Apart from Forest Reserves, the natives occupy all of the high land on the southern and eastern slopes of Mt. Kenya down to the Tana River and also the bulk of the high land on the eastern slopes of the Aberdares. These areas contain some of the most fertile, well-watered and healthy regions in the whole of central Africa. On high moral grounds Europeans are denied entry for ordinary agricultural operations; but, if there are areas along the bigger rivers which cannot be fully used even by

the natives without the aid of irrigation, and if the natives are quite unsuited for settlement on difficult irrigation schemes in steep country, then I would venture to suggest that no great injustice would be done to the native if irrigation for European settlement were considered for these areas. I saw a little irrigation of coffee in the neighbourhood of Nyeri. The good effect was very noticeable in comparison with the non-irrigated areas. This is essentially a European area and it may be possible to extend the area for coffee or other high-grade crops along the bigger Tana tributaries. Moreover, the enormous water-power potentialities make the area embracing the tributaries east and south-east of Mt. Kenya a very desirable one for future development. I was not able to visit the lower reaches of the Thibo, Ena, Mutongo and Kasita rivers, but if the administration is prepared to consider European settlement there, it may be worth while investigating the possibilities. Otherwise, I should say, investigate the possibilities of the lower Tana first, and, if they are great, do not fritter the water away in upper schemes for natives, especially if, in doing so, considerable possibilities for water power are destroyed.

66. I should state in connection with the lower Tana River that, should a solution of the population difficulty be devised, the investigation as to the best area to be irrigated should start from the confluence of the Kasita, about 130 miles from the sea, rather than at Sankuri, as proposed, and that the marshy lowlands, liable to be submerged by floods, as in the neighbourhood of the coast, be avoided, if possible, on account of the probable expense of protection against floods and of the danger of waterlogging, which might result from the irrigation of a large tract of country with insufficient fall for proper drainage.

67. In regard to the remaining rivers, it will be seen that the possibilities of irrigation are very small

indeed. With the exception of the Merendet and the Tsavo, most of the rivers dwindle down to nothing in their lower reaches. As water is required for human and stock consumption in the lower reaches, we should be nervous about proposing any irrigation schemes in the upper reaches until experience of water boring in the country should prove that we need not rely on supplies which have travelled wastefully for long distances in sandy or porous river beds. Should boring prove successful, we could more profitably utilise the waters of the upper reaches for a number of small irrigation schemes along the Athi and the tributaries of the Uaso Nyiro and on the Rift Valley streams.

68. But there are other possible uses of the water to be considered. In this connection, the requirements of sisal manufacture should not be overlooked. Along the middle reaches of the Athi, for example, it has been proved that sisal grows successfully even where the rainfall is less than 20 inches. Sisal requires water only for the factory. The water requirements for 2000 acres of sisal would barely suffice for the irrigation of 20 acres of ordinary crops, so that with limited water supplies a very much larger area of sisal can be grown than of ordinary crops under irrigation. Moreover, sisal must be grown on a large scale and it can, therefore, carry the expense of mechanical apparatus for tilling and transport. This is of the utmost importance in "fly"-infested areas, where cattle cannot be used. For the smallest possible unit sisal factory we require a larger supply of water than we are likely to derive by boring in the metamorphic areas and, therefore in considering the use of the limited supplies of water from streams, such as the Athi, we should carefully consider the claims of sisal.

69. Summing up the whole position, I regret to have to report that I have come to the conclusion that the immediate possibilities of extensive irrigation schemes in

the country are exceedingly poor.

This conclusion was communicated to the Administration at an early date. As a result of it and in view of my limited time, my trip along the lower Tana River, which had formed part of my originally proposed itinerary, was cancelled.

70. Three investigations were more particularly referred to me - the Athi general problem, a scheme on the Nzeeabi in the Rift Valley and one on the Thika tributary of the Tana.

71. THE ATHI GENERAL PROBLEM:

From the table of gaugings in the previous chapter, it will be seen that the flows in the tributaries west of longitude 37° 10' are too small to allow us to consider any extensive irrigation. On the two bigger tributaries, the Ruiru and the Mbagathi, any possibilities in the upper reaches are, I believe, somewhat compromised by existing power schemes in the lower reaches. We must look, therefore, to the main stream east of 37° 10'. On the left bank we have the high lava-capped Kitita plateau, everywhere close up to the river and with very steep slopes, and, therefore, the possibilities on that bank are exceedingly small. On the right bank the river enters a "fly" area at about latitude 37° 00'. From this point, for about 30 miles upstream along the south bank, is a somewhat densely-populated area of the Ukamba Reserve. The river flows very steeply through this area and there are numerous reefs crossing the stream and forming waterfalls, from which it would be an easy matter to lead off furrows. Bordering the river on the right bank and at the foot of a range of high hills, is a stretch of land about 4 to 5 miles wide on the average, which from a distance appears to be fairly level. Actually, when you come to walk over it, you find that it slopes steeply down to the river and is intersected by numerous deep gullies, running down at close intervals from the

hills to the rivers. Each of these gullies has ramifications and the whole area is, in fact, intensely eroded. On top of the ridges between the gullies there is usually a capping of fairly deep soil and low down the slopes the soil is also deep in places, but in the intermediate steep slopes the rock is generally exposed and the soils are sandy. The soils are similar to those of the Thika area described in Chapter II. On account of the great fall in the river, it may be possible to utilize a canal to command most of the area, but it should be noted that the cost of aqueduct-bridges works along the main canal will be very heavy and the cost of the distribution canals over the steep areas will also be heavy. Moreover, the actual application of the water to the steeply-sloping sandy soil will not only be expensive, but will demand considerable skill on the part of the irrigators to avoid the washing away of the soil. For these reasons alone, it is necessary to be cautious in advocating a big scheme for native settlement, but we should also consider the limitations of the water supply. It is probable that in extreme low-water periods there will not be enough water to irrigate more than, say, 7500 acres, even if it were all allotted to this scheme. That is an area of less than 12 square miles, which is only a fraction of the whole area. But the lower length of the Athi must also be considered. In the next 100 miles down to the confluence of the Tsavo, the river runs close to a length of the main line of railway, which contributes very little to its revenue. It is very important that this area should be developed. It is largely a "fly" area, but, as previously pointed out, the possibilities of signal cultivation should be seriously considered. For all of the above reasons, I recommend that irrigation should only be started on a very modest scale in the Ukamba reserve. One or two small furrows, irrigating up to 500 acres each, might be started as an experiment, if only to see how the native will adapt himself to agriculture under irrigation. The sites for the weirs could be selected at some of the waterfalls. I found by levelling

that from the waterfall at Kitan a short furrow could be very easily taken out, but I did not investigate the area that could be economically irrigated.

78. In the lower reaches below the confluence of the Iwavo there are extensive alluvial flats in the last 40 miles of the course of the river. These alluvial flats, as one might expect and as confirmed by the analysis of a sample (see No. VII Chapter II) and also by the appearance of the rice, maize and other crops growing there, are composed of rich soil. The river appears to have built up its channel in an elevated ridge, and the small side streams consequently discharge into a number of small lakes close up against the steep slope of the country surrounding the flats. It would be desirable to ascertain what the conditions are in the valley during high-flood periods and to select an area not liable to submergence. For two reasons it would be desirable also to select an area of the flats for irrigation as far up the river as possible; firstly, in order to find rock foundation for the diverting weir, and secondly to get away from the coast, where the rainfall approaches 40 inches, to areas where water is a greater necessity for crops. My time and the means of communication at my disposal did not allow of an investigation higher up the river than Kukonani. Two matters require careful consideration in any problem for irrigating this area. Firstly, experience in the past has proved these low-lying flats to be exceedingly unhealthy areas. Secondly, the natives appear to be excessively fond of drink. It is possible that the days I spent in the area, October 27 - 29, were bank holidays; at any rate, large numbers of the male population appeared to be indulging, perhaps too freely, in the fermented juice of the coconut palm, while their womenfolk attended to the fields. Here, again, I was forced to enquire why, in the region of plentiful rainfall near the coast, agriculture without the aid of irrigation had not made further strides. Indeed,

it appeared as if large areas, formerly under cultivation probably before the abolition of slavery, were being neglected and were receiving little assistance from man in the struggle against a smothering growth of jungle.

However, assuming that the difficulties of settlement or of labour can be successfully overcome and assuming that the low-water flow of the Sabaki in its lower reaches does not fall below half of what I measured on 28.10.25, there should be a good economical scheme for about 7500 acres capable of raising valuable tropical products under irrigation.

73. Whether there are any possibilities for irrigation along the Taveo to be considered in competition with this Sabaki area for the limited supply of water, I am unable to say, as I did not proceed to the Taveo.

74. Whatever scheme is adopted in the native areas, I should emphasise the importance of proper supervision by men versed in the art of irrigation. It would be sheer folly to think of constructing a scheme and handing it over to ignorant natives to struggle with the difficulties of irrigation without knowledge of the best crops to grow or of the means for marketing them.

75. THE MOHUMBAT DOWNS.

As we have seen in the previous chapter, the Kerenjat (or Malewa) is the biggest river in the Rift Valley. At the time of my visit (26.9.25), it was discharging about 50 cusecs into Lake Naivasha, but I was informed that it has been known to fall to nearly 15 cusecs. In the last 6 miles of its course it meanders through a large flat area of deep soil, consisting of a mixture of sandy lake deposit and river alluvium. Through the area passes the main line of railway and within it is a newly erected creamery. Round about the area are a number of European farmers engaged in stock and dairy farming. Fodder grown in such an irrigated area would be of great value in periods of drought. Part of the land is

owned by the Crown and with assured fodder it would be an excellent centre for high-class stud animals. Immediately above the flat there is sufficient fall over rock to make it possible to command the flat by means of a short and inexpensive furrow.

All of these features point to the desirability of carrying out an irrigation scheme for about 8000 acres.

The soil appeared to be sandy and possibly poor, but the analysis of a sample (No. VI given in chapter II) seems to indicate that it is not so poor as it looks, although it will require manuring.

A point, however, that requires careful consideration in the effect on Lake Nalvasha of an irrigation scheme of this sort. Naivasha is the chief fresh water lake in the Rift Valley. Farming and stock growers round its shores depend on its water. It is important, therefore, to enquire what effect the scheme is likely to have on the level and freshness of the lake. We have records of the level of the lake since 1913. In that year it rose from 6325 to 6333. In 1914 it fell to 6325 again and in the following year to 6327. In 1916 it fell to 6325 in April and then rose to 6330. In 1917 it fell to 6329 before April and then rose till November, when it reached its maximum recorded height of 6340. Since then it fell with minor rises to 6329 in March 1923, but rose in that year to 6335. At the time of my visit (September 1925), it had fallen to 6325 again, which is the same level as the previously recorded lowest in 1916. These levels are from the P.W.D. records. The levels given on the topographic sheets seem to be too low in comparison.

The present area of the lake is some 70 square miles. As it has more or less preserved its level during these 12 years, the average yearly inflow must have been at least sufficient to balance the difference between rainfall and evaporation, which is probably in the neighbourhood of 250,000 acre-feet. As the lake has maintained its freshness, there must have been a considerable underground leakage which

had to be made good, in addition to the evaporation, by inflowing water. For the irrigation of 2000 acres we would not require to abstract more than 10,000 acre-feet, which would, therefore, be a very small percentage of the inflow and should not seriously affect the level of the lake. Nor should the additional salt in the smaller amount of seepage water resulting from irrigation seriously affect its freshness.

The scheme is certainly one which is worthy of more detailed investigation. An automatic discharge recorder should be erected as soon as possible, further investigation of the soil and a preliminary survey for a furrow line and of the irrigable area should be undertaken.

76. THE THIKA SCHEME:

This scheme is the only one referred to me which has approached anywhere near a definite shape. It is still very vague, but the line of a furrow has been very roughly surveyed and definite proposals have been made as to the land to be irrigated and in regard to other uses of the water.

The area concerned lies between longitudes 37.20 and 37.50, is bounded on three sides by the Athi, Thika and Tana Rivers and includes the upper regions of the dry Kuita Chana tributary of the Tiva River.

In the narrow strip of country between the Thika and the Athi there are two Crown farms, known as Quarantine farms. Immediately downstream of these and stretching round the bend of the Thika River northwards are 10 surveyed farms for European occupation, 8 of which are, I believe, not occupied. These farms extend about 3 to 4 miles away from the Thika River and to within about 8 miles of the confluence of the Thika with the Tana River. Surrounding the farms is a big area of Crown land, abutting on the Thika and Tana Rivers and the Ukamba Native Reserve. This area is at present a sort of commonland. At times it is used by the Ukamba people, whose boundary is not yet fixed very precisely.

The proposal is to take a furrow out of the Thika River from about the top end of the Quarantine farms (approx. longitude 37.02) and run it to the watershed saddle between the Thika and the Muita Chana (approx. lat. 1.10 long. 37.05).

The proposals were, I believe, made in 1924 by certain parties, who desired a concession of a portion of the Crown lands in return for the construction or partial construction of the furrow. The proposals were outlined by one of the parties interested in the concession in a letter dated May 9th 1925. They were reviewed by the Deputy Director of Agriculture in letters dated March 6th 1926 and August 11th 1925, and by the Director of Public Works in a letter dated May 6th 1925, copies of which letters and of a rough locality of the canal and of areas to be irrigated on topographic maps constitute the information supplied to me. No detailed plans of the canals or of the areas to be irrigated have been prepared.

77. From the letter of one of the promoters dated May 9th 1925, I have gathered the following information as to the proposal -

1. The furrow from the intake to the saddle to be 25 miles long. There is a fall of 140 feet available.

2. The canal to be "15 feet wide at water level, 5 feet deep and capable of carrying 100 cusecs on a slope of 1 in 2500".

3. From the main canal near the saddle three minor furrows to be constructed, one 6 miles long parallel to the Thika, another 15 miles long parallel to the Tana and spilling into the Kitambu sluit of the Tana, and a third 12 miles long through the Muita Chana valley, spilling into the Kithioko sluit of the Tana.

4. Of the 100 cusecs, allowing for losses, 17 to go to the area along the Thika, of which 10 to be put into the Mathangroute sluit of the Tana; 29 cusecs to go in the second furrow, of which 10 would be spilled into the Kitambu; 27 cusecs to go in the third furrow, of which 20 to be spilled into the Kithioko; and in addition, 20 cusecs to be spilled into the Muita Chana.

5. 250,000 acres of land in the Muita Chana valley and south of the Tana River to be opened up, half for grazing and half for sisal growing.

6. The areas to be irrigated are rather indefinite.

7. 10,000 acres to be afforested to increase the rainfall.

75. The Deputy Director of Agriculture in his letter of May 6th 1925 makes the following points -

1. The canal to be of 800 cusec capacity to utilise flood water.

2. 95,000 acres commanded and 50,000 acres for sisal. Possibility of spilling flood water into the Muito Chana to encourage a permanent flow.

3. Of the 95,000 acres commanded, estimated that some 80,000 are cultivable and of that area well over half is irrigable.

4. Crops to be grown in the area between the furrow and the Thika River - sugar cane, citrus, wheat, apricots, peaches, figs, lucerne and wheat. Sisal to be grown above the furrow.

5. 15,000 acres to be irrigated and some half-dozen sisal factories and a sugar factory to be supplied with water. A rough estimate of the cost of head-works, intake and furrow would not exceed £35,000.

6. A Concession might be granted over 150,000 acres to persons who would construct and maintain the furrow on condition that 4000 acres be reserved to Government with free water supply for half this area.

76. The Director of Public Works in his letter of May 6th 1925 -

1. Considers scheme worthy of further investigation. Alignment and cross section and trial pits necessary for canal line and soil survey of irrigable areas and for alignment of distributaries.

2. Considers that lining will be required in parts of canals to minimise losses of water, and that final cost for a 800 cusecs scheme will not be less than £70,000 to £80,000.

80. In order to grasp the scale of the proposition, the first point to be considered is the quantity of water available. From the table of gaugings in the previous chapter, it will be seen that the flow of the Thika has been known to fall to about 100 cusecs. At the time of my visit (on 14.9.25) it was 105 cusecs. In view of the fact that economic storage dams of the size which would be required are impossible in the steep upper reaches of the river, I consider that the capacity of the furrow at the intake should not be 800 cusecs, but should be limited to 100 cusecs. If

expensive undertakings, such as sugar and sisal factories, are to depend on the water supply, we should not speculate on the possibilities of flood water. Allowing 30% losses in the furrows, 100 ousecs at the intake would give 70 ousecs at the fields.

81. Sugar has been suggested as the principal crop. Sugar is already produced in Kenya and Uganda and the local needs are likely to be met by small factories in suitable localities. The consumption by natives is likely to increase, but it should be noted that in the case of the neighbouring native reserve, the Ukamba, the administration has imposed severe restrictions on the sale of sugar to the natives, on account of their practice of making intoxicating liquor from it. In this scheme, therefore, it appears that we must consider foreign markets and transit for exports. I presume that this matter has received careful consideration and that the view is held that it is possible to compete successfully, notwithstanding the 400 odd miles of transport to the coast, the somewhat unfavourable geographical position of Kenya in regard to the consuming markets of the world, and the 'dumping' features of the sugar trade. A small scheme could not hope to compete in the world's markets. Only in factories of reasonable size can the overhead and management charges be kept within proper limits. I consider the proposition should not be for an area smaller than 4000 acres. Moreover, these 4000 acres must be in a fairly compact block in order to curtail transport costs of cane to a minimum.

82. The rainfall over the area is between 30 and 40 inches and it lies in the four-seasonal rainfall belt with two short rainfall periods about April and November. Sugar cane would have to be irrigated in the two long dry periods when hardly any rain falls. At the time when the crop requires most water, I consider that two 4-inch waterings

should be reckoned as necessary in a month. If we assume that watering will be carried on during the whole 24 hours, night and day, that would mean that 1 cusec at the field would irrigate 90 acres. For the 4000 acres we would, therefore, require 45 cusecs at the fields. This leaves us 25 cusecs for the other crops and for the proposed sisal factories. If we allow 10 cusecs for sisal, there could be 15 available for other crops over an area of say, 2000 acres.

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63. The first conclusion, therefore, in regard to irrigation, is that we must look to smaller areas than originally proposed. A total of only 6000 acres is required for irrigation, and of this, 4000 acres must lie in a compact block and be suitable for sugar cane cultivation. The soils of this area have been dealt with in Chapter II. Accepting the statement of the Deputy-Director of Agriculture, that the heavy black clay soil is eminently suitable for sugar cane, on examination of the ground proved that the most suitable compact block of black soil in the Tana River drainage, not so broken up nor so steep as the rest of the country, is in the low-lying corner between the Thika and the Tana and bounded by longitude 1° 0' and by latitude 37° 40'. Inside this area we can find more than 4000 acres of black soil, and within it or closely surrounding it, we can find the remaining 2000 acres of other soil suitable for irrigation. As will be seen from the analyses in Chapter II the higher and steeper land is sandy and poor. Judging by the levels on the topographic maps, it is probable that none of the soil in the lower area lies at a greater elevation than 3880 and, therefore, considering the scheme only from the irrigation point of view, we could probably command the land from a point on the Thika River even lower down than that proposed which was at a level of over 4000.

64. It is only when we consider the other aspects of the scheme, namely, the provision of water for stock and for sisal factories, that it becomes necessary to adopt the

alignment to the saddle. In regard to stock, we shall see in Chapter VI that supply by small furrow is difficult in this stony and broken country and a system of pipes is desirable. I believe that the same will apply to supplies for sisal factories. As far as I was able to gather, the following are features of a sisal proposition. A unit scheme comprises about 2000 acres of arable land and additional land for grazing etc. Very big units are not possible on account of the heavy transport costs of the bulky leaves to the factory, the raw material weighing 30 to 50 times as much as the finished article. For the same reason it is desirable that the factory, and therefore the water supply, be situated at a lower level than most of the cultivated area. The disposal of the wet vegetable waste and phormium juice without pollution of a stream is also a difficulty to be seriously considered. For the running of a unit factory a supply of water amounting to about 100,000 gallons per day is advisable, though plants can be worked with smaller quantities.

I do not consider that the proposal to run such small supplies of water down the sandy beds of dry sluits for many miles will prove to be satisfactory. In the first place, the losses of water will be exceedingly [illegible] and in the second place, the factories would probably be located near the stream and pollution is likely.

I would suggest that, if the furrow be carried to the saddle, only five sisal units be laid out in the first place. Three units might be on the west of the saddle above the area proposed to be irrigated and two on the east in the Kuita Chana valley. Two of these on the west might be grouped round factory sites along the Mathangwota sluit, selected at points where power can be generated by the 70 odd cusecs running down to the low irrigable lands. The other three might get their water by means of pipes from the main furrow, and possibly a drop in the main furrow might supply power for these. Should these five prove to be

success, the system could be extended without seriously curtailing the water required for irrigation. I do not favour the pouring of water down the Muita Dhanu valley with the idea of creating a permanent flow in it for stock grazing purposes, as it would require very large supplies to reach any distance. As pointed out in Chapter VI, I think water-boring will prove a more satisfactory way of opening up areas in the Dhanu reserve for stock grazing purposes. 477

85. It will be seen from the above that the sugar proposition requires the bulk of the water and is the chief consideration from the point of view of expenditure on the furrow. If any concession should be granted in return for the construction and maintenance of the scheme, it should therefore be mainly in order to encourage the sugar factory. Observations should be made for water for any irrigation purposes, apart from sugar, and for immediate and possible future requirements of stock, but I do not see that it is necessary to grant concessions of enormous areas for the latter purposes.

86. For the irrigation of the sugar area, it may be possible to drop the water from the main canal down the Mathangrouta sluit, generating power for two sisal factories on the way. This would probably serve during the early years of development, though at a later date a graded furrow with drops would be required.

87. As to the cost, assuming the scheme to be an intake weir and headworks, a main furrow and power drop for 100 cusecs along the line proposed as far as the Mathangrouta sluit and a smaller extension to the saddle, two power furrows on the sluit and three pipe lines to selected sisal units, it would perhaps be best to work on an estimated total cost of not less than £100,000 until detailed surveys are carried out. That would not be an excessive expenditure for 6000 acres of high-class tropical cultivation under irrigat-

10,000 acres of sisal. This figure, of course, does not include the cost of small distributing furrows, of preparing and cultivating the land or of power plant, factories, etc. 178

68. My recommendations are :-

(1) Someone who has had experience of the growing, milling and marketing of sugar should report on the possibilities, with special reference to the matters raised in paragraph 61 above.

(2) Should the report be favourable, the area indicated in paragraph 63 above should be carefully surveyed by close contouring and a soil survey should follow.

(3) The weir, intake and main furrow line should be carefully surveyed and sufficient cross sections should be taken and trial pits put down for purposes of estimating.

(4) The Mathangwota sisal should be examined in detail (see paragraphs 64 and 65).

(5) The agricultural officers should lay out five sisal units, with necessary grazing ground attached (see para. 64 above).

(6) A self-recording gauge should be erected on the river as soon as possible.

(7) The possibility of water power for operating the five sisal factories (and also as an aid in the sugar factory, if the bagasse is not likely to provide sufficient fuel) should be investigated in the river, the canal and the Mathangwota sisal.

CHAPTER VI.

WATER FOR STOCK IN GRAZING AREAS.

PARTICULARLY FOR CATTLE IN THE NATIVE RESERVES.

89. Before proceeding to the engineering aspects of the problem, it is necessary to consider a few matters in connection with the grazing and water requirements of cattle, and, in the case of the Native Reserves, to understand what the aims of the Administration are in providing additional water supplies. Unless we get some clear fundamental ideas on these matters at the outset, we may proceed on wrong lines, resulting in unnecessary capital expenditure and, possibly, failing to achieve the objects aimed at.

90. From the Administrative point of view, I am given to understand that the main object is to curtail the nomadic habits of some of the native tribes by anchoring them around permanent water centres, so that administrative control and supervision may be easier, and in order to exercise civilising influences over them morally and economically, as, for example, in the establishment of schools and in encouraging dairy industries. It is considered that the pastoral tribes are socially and economically inferior to those whose main occupation is the tilling of the soil, and that of the pastoral tribes the most backward are those of nomadic habits, tribes who wander about in the dry areas wherever rain has made water and grazing available to their stocks.

91. In the opinion of the Administration, therefore, the main consideration is the permanence of the water supply at any centre. A population cannot be anchored round a water supply unless that supply is able to support the human and animal life depending on it throughout long periods of drought; but an equally essential factor, and one

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91. In the opinion of the Administration, therefore, the main consideration is the permanence of the water supply at any centre. A population cannot be anchored round a water supply unless that supply is able to support the human and animal life depending on it throughout long periods of drought; but an equally essential factor, and one

that appears to have been somewhat overlooked in the past, is the permanence of the grazing round about the water centre. 480
It would be of little use, for example, to provide permanent water centres under such conditions as would allow the stock depending on them, by perpetual over-concentration, to ruin the grazing within reasonable distance of the water. Such centres would, doubtless, be of great value in keeping large numbers of cattle alive during periods of drought, when the water holes and grazing of other areas had given out. The stock could be kept alive for a limited period, but during this period the grazing round about the permanent centre would be destroyed by excessive concentration of stock over it, and, whenever rains should fall over the distant areas, the owners would hurry with their stock away from the over-grazed area. Without the large permanent water centres numbers of stock would probably perish in periods of drought, and in preventing that they would serve a very useful purpose, but they are not fulfilling the main object of the Administration. The population would be round the permanent water centres only during periods of general drought, and then in excessive numbers; the bulk of this population would run away from such over-crowded centres when rains fall elsewhere, leave the schools empty and the dairies unused, and remain almost as elusive as formerly in matters of control and supervision.

The point which I wish to emphasize is that, if there is to be permanence of residence round about a water centre, due consideration must be given to the probability of permanence of grazing. To aim at absolute permanence of grazing would be an impossible ideal, unless the natives advance to such a stage that they will store up the fodder of plenteous times, in the form of hay, for example, for use in the drier periods; but at any rate, much can be done to preserve the grazing round a water centre by limiting the number of stock depending on it. I doubt whether the necessity for such limitation has been properly realised in previous water schemes to assist the Masai tribe. In some of the schemes carried out and in one of t

schemes submitted to me for advice the aim seems to have been to provide for as many as 10,000 head of stock at a single water centre. Now, just think what it means to water 10,000 head of cattle at a single watering place. Allowing only 10 acres of grazing per head, we would require 100,000 acres of grazing available round the centre. Assuming that there are no barren or inaccessible patches in the area, we would require a circle of over 14 miles diameter. If the cattle are to be spread evenly over this area, wander about in the course of feeding and at the same time reach the drinking place once a day, a large number will have to walk over 15 miles a day! Actually, it would be impossible, even with the best of herding, to spread them evenly over the area; the concentration would be much greater nearer the water centre, with the result that it would not be long before the pastures near the centre would become useless from over-grazing and consequent deterioration and erosion of soil, and the cattle would have to go further afield in search of food and cover over even greater distances than 15 miles in the course of a day. I was reliably informed that the hardy native cattle are frequently called upon to cover such big distances in search of food and water - indeed, that they can exist for long periods, even though they obtain a drink only once every alternate day!

I ask, are we aiming at mere existence of cattle and the breeding of a tough athletic type, or are we aiming at beef and milk? The latter is surely the proper and ultimate aim, and, if it is, then I think that most farmers of experience will agree that it is unreasonable to expect an animal to put on marketable weight or give a useful supply of milk if it has to tramp over enormous distances every day, more especially in the intense heat of tropical regions.

92. The first consideration should, therefore, be to restrict the number of stock depending on a single water centre, so that none will have to travel long distances daily for food and water and so that the permanence of the

grazing may not be destroyed by excessive eating or trampling, which would gradually cause deterioration directly and also indirectly, as, for example, by accelerating erosion of the soil. Restriction by administrative regulations and policing would never be satisfactory. So long as large supplies of water are provided at long intervals, the natives will continue to abuse the grazing and the stock; the only automatic way of effecting the desired restriction is to limit the amount of water available at each centre, and if centralisation is desired, to multiply the number of centres and keep them within reasonable distance of each other.

In addition to the advantages that such a method has in the directions indicated above, there is the further advantage of a saving of useless expenditure of capital on unnecessarily big water supplies. Round a single water centre there is only a limited area of grazing practically available, and this can permanently support only a limited number of cattle. Any expenditure on a water supply in excess of the requirements of such a limited number of stock would be a waste of money. Similarly, an expenditure on schools and dairies, based on the impossible assumption that 10,000 head of stock can remain permanently round a single water centre, would be an unjustifiable extravagance.

The practical problems before us then come down to settling what would be a reasonable spacing of water centres over such an area as the Masai Reserve and what is a reasonable strength of water to supply at each centre.

93. I have no hesitation in saying that a former idea of endeavouring to base as many as 10,000 head of cattle on a single centre is quite unsuitable. I am informed that it is a common custom for the Masai to live in "bomas", where about 2,000 head of stock are centred. It would appear, therefore, not to be out of keeping with the custom of such a tribe to reduce the number of cattle depending on a water centre, as a first measure, from 10,000 to 2,000; but even

this great reduction is, in my opinion, not nearly enough. I would like to see the initial efforts based on a herd not exceeding 500 head, and to be followed by further reduction at a later period. A know native customs are firmly established and changes are resented, but I am also informed that a single boma centre for 2000 head of cattle often contains about four family groups, each possessing a herd of about 500 head of stock, and that these herds usually graze out in different directions each day. There may not, therefore, be great opposition to the splitting up of the larger bomas into smaller bomas, each maintaining only about 500 head of stock. Whether that be possible or not can best be decided by the local authorities. At any rate, I propose basing my subsequent remarks on a herd of this size (500 over 2 months old), as I consider this the largest size that should reasonably be expected to depend on a single water centre. Should larger herds be considered essential, then the conclusions hereunder can be modified accordingly. For the smaller water supplies derived by windmills from the deeper boreholes a herd one half and even a quarter of the above size may conveniently be considered.

94. Let us see, then, what area of grazing ould be provided for 500 head of cattle, for on this will depend the spacing of the water centres. It is naturally difficult to give an area per head of cattle that will apply throughout the country. In South Africa, for example, the figure would vary from 4 to 30 acres according to the nature of the vegetation, the rainfall, the distance between permanent water centres, etc. In Kenya the variations are probably not so great. On the hills near Machakos, where the grass grazing is good, the rainfall high, where water holes are close together and a certain amount of silage is prepared, I was informed by a farmer of long experience that he considered 7 acres a fair allowance for large cattle and that the small native stock could exist on half that area.

These might be regarded almost as minimum figures and, in view of the facts that I propose considering as large a herd as 500 head of cattle depending on a single waterhole, generally in areas of lower rainfall and that permanence of grazing is essentially desirable, I propose adopting a figure of not less than 15 acres per head of stock as a working basis. Naturally, a different figure should be adopted for different local conditions and in each case the advice of the Agricultural Department should be sought.

With a figure of 15 acres per head, our herd of 500 head of cattle would require 7500 acres of grazing. That is equivalent to a circle of nearly 4 miles diameter. If we space our water centres at intervals of about 4 miles, we would have a series of squares of 10,240 acres for 500 head or 20 acres per head. The worst grazing would probably not require a greater spacing than 5 miles, which I regard as a maximum reasonable spacing, merely from the point of view of distance to be covered by an animal per day.

05. We have next to consider what would be a reasonable quantity of water to supply per head of cattle. In determining a working figure we have as many variable factors as in the case of determining the grazing area, but it is equally essential that some figure be adopted for purposes of calculation to be made in connection with the engineering side of the problem.

On this subject we have very little experimental work to aid us. We know that about half of the total live weight of an ox consists of water and that it is essential for healthy living that an adequate quantity of water should be taken regularly by cattle not only to aid the processes of mastication, digestion absorption and assimilation of the food eaten, but also to flush out the intestines and cool down the system by evaporation from the lungs and the pores of the skin. An experiment by Kellner on a stabled ox showed that of 10 gallons of water

drunk, 40% passed in solid excrement, 20 in urine and 2h in breath and perspiration. In a hot climate such as Kenya and under conditions requiring travelling over long distances in search of food and water, the quantity passed under the last head will be much greater. Now a considerable amount of moisture is derived from the food, especially if it is succulent. Indeed, in some experiments in South Africa a number of sheep have been kept alive for several months without supplying them with any other water than was contained in fodder which included succulent growths, such as prickly pears; but we should base our estimates on the grazing available at a time when the grass is dry, which is often the time when the heat is greatest. Even from dry fodder, however, a quantity of water may be formed in the chemical processes of digestion and assimilation of the food. As a chemical problem it is estimated that 10 lbs. of starch or cellulose, when entirely oxidised in the body, will yield 6½ lbs. of water. Whether such chemical water is produced or not in actual feeding, it is common knowledge that cattle must have additional water in order to live. The amount will depend on several factors. For example, the drier the feed the more water they require. Experiments on stall-fed cows showed that, when fed on fresh green grass, they drank less than 10 gallons per day, but when dry grass was given, they drank over 16 gallons per day. Then cows in milk require very much more water than the average, and, according to certain experiments, as much as 4 times the amount that they require when dry, and according to other experiments, about 4½ times as much water in food and drink as the milk they produce. A heavy milking Holstein cow, stable-fed, was given a total of over 33 gallons of water per day in several drinks. Then the size of the animal must be taken into account. A steer will not require so much water as a full grown bull, nor will the small-sized native cattle require as much as an imported beast of a big type.

Taking into account in Kenya the dryness of the grazing in periods of scarcity, the great heat and the distances to be travelled for grazing and water, and, on the other hand, the small size of the average stock of the country and low milking capacity, I have decided to use 18 gallons per day as a basis for an average supply per head of a herd of 500 head (over 6 months old) depending on a single water-hole in periods of drought. This figure will require alteration to suit local conditions. Figures as low as 8 gallons per day for high-grade stock and 4 gallons per day for native stock were obtained on enquiry in various directions in Kenya, but these low figures were for the cooler areas with good succulent grazing, as a rule, and an abundant and close supply of water, and bearing in mind the drier areas and the desirability of increasing the milk supply, I have preferred to adopt a higher figure as a basis.

Applying this figure of 18 gallons to our herd of 500 head, we see that a supply of 6000 gallons per day is required at each water centre, and, as we have previously seen, the holes should be 4 miles apart.

68. It is obvious, however, that such small centres will not justify the erection of schools and dairies at each of them. The Masai, for example, own over 20 head of cattle per unit of population, including women and children, so that the population at a single centre will not exceed 88. It is a difficulty with all pastoral people to concentrate them round schools and dairies. The fundamental fact is that stock cannot be concentrated beyond a certain point and, therefore, the owners cannot be easily concentrated. As previously explained, efforts to concentrate 10,000 head of stock at a single water centre are in my opinion on wrong lines and the best that I can recommend is close grouping of small water centres round about a village with school and dairy, rather than large isolated centres without any method. I propose to consider a grouping of a total of

4500 head of stock in 9 water centres round a village as a sufficient and suitable number to justify a school and dairy. With water centres at four mile intervals, that would mean that no centre need be more than 8 miles from a village situated in the centre of a group. It may be desirable to reserve the central square for special milk cows, grade bulls, dry-land cultivation etc., and even to reduce it in size, but such modifications of the main idea can be worked out later if the general scheme is approved and in any case water will be required for the central village.

For windmills over boreholes, yielding only 3000 - 4000 gallons per day, we would require about 16 water centres, each spaced about 3 miles apart and supporting rather less than 300 head, to settle 4800 head of cattle on the same area of 92,160 acres at the rate of 20 acres per head.

97. I have dealt with the above matters at some length because I do not think that it is possible to consider the engineering problem without some clear ideas as to what is required, and because my own ideas on the matter appear to be somewhat different from those previously followed. Briefly, the conclusions are that instead of aiming at large supplies of water at wide intervals on which large herds depend, we should aim at restricting the herds to 300 - 500 head, the distance apart of the holes to 3 - 4 miles and the quantity of water to 3000 - 6000 gallons per day and at grouping 9 larger or 16 smaller water centres round a village. These figures will be used in considering the engineering problem.

98. Before proceeding to that, one other matter requires consideration and that is the quality of the water supply. I was amazed to see the filthy ways in which almost all watering centres were treated in Kenya. In some of the holes which I inspected the droppings of cattle

and accumulated for sheep so as to make them more like cesspits than drinking places for cattle. I need not enumerate the evils that result from contaminated waters nor enlarge on the necessity for remedying this state of affairs, but I merely mention the matter here, because it is necessary to deal with it in considering the engineering side. I think that if Government is going to increase water supplies, it should set a good example in not neglecting this important phase.

99. With these introductory remarks I proceed to deal with the details of water supplies under the following headings -

(1) Troughs and storage tanks.

(2) Furrows.

(3) Dams.

(4) Pipes.

(5) Wells and Pumps.

(6) Boring and Pumps.

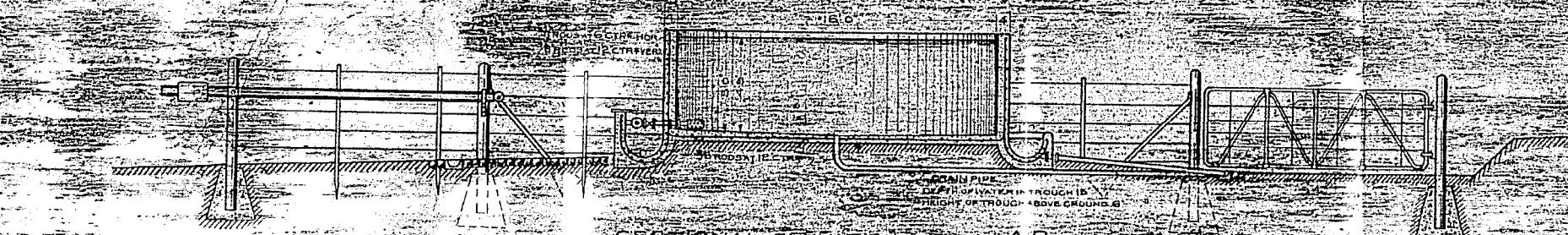
1. TROUGHS AND STORAGE TANKS.

100. We have seen that troughing should form an essential part of every scheme for watering cattle. Our larger unit was 500 head of cattle consuming 6000 gallons of water per 24 hours. Naturally the stock are not drinking throughout the 24 hours. We must make some assumption as to the period which should be allowed per day for watering the stock. We will assume that the whole 500 are to be watered once in the morning within a period of 3 hours. This means that the 6000 gallons must be made available within 3 hours, or at a uniform rate of 33 gallons per minute. We can supply water at this rate directly from a dam fairly easily, because the length of pipe is short, and abundant storage is close at hand. But in the case of long pipes, it would be less economical to install pipes large enough to supply water at this rapid rate than to install pipes to supply water at one-eighth of the rate and to provide storage in the neighbourhood of the troughs. Storage will also be necessary where the water is pumped from boreholes or wells and in the case of pumping by windmills a reserve of storage will have to be provided to carry supplies over periods of feeble winds. In the case of piped or pumped supplies, therefore, storage will become an essential feature connected with the trough.

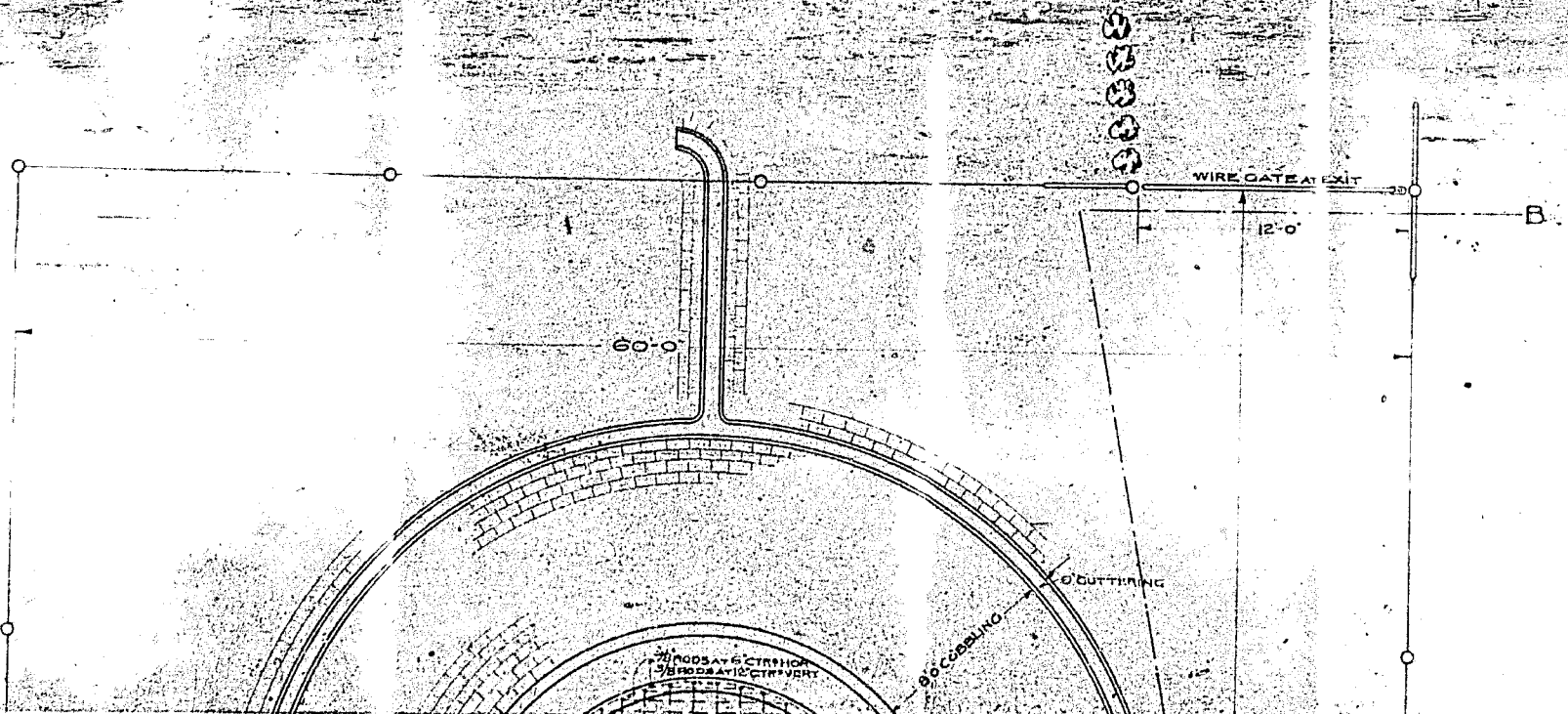
101. Experience in South Africa has shown that the most satisfactory and economic method of providing both storage and troughing is by means of a circular reinforced concrete tank with troughing running round the outside of it and connected to the tank. Apart from economy in construction, this arrangement has the advantage, as the tank stands considerably higher than the trough, that animals are compelled to drink from one side only of the trough. They cannot jump over it and this avoids fouling the water and destruction of the trough. Moreover, it minimises the danger of horning one another while drinking.

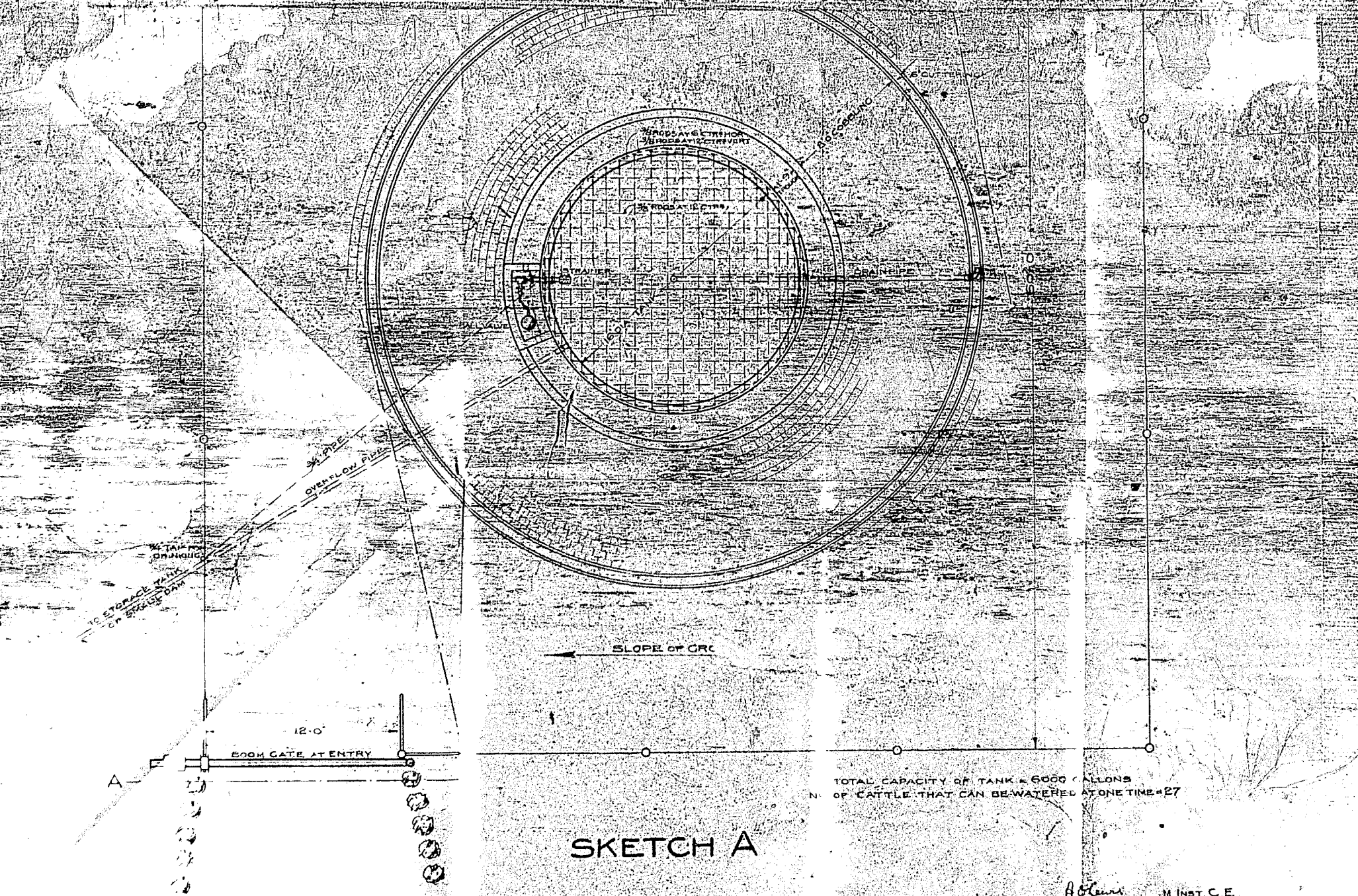
C.O. 5

PLATE 4



SECTIONAL ELEVATION ON LINE A-B





SKETCH A

A O Lewis M INST C E
DECEMBER 1925

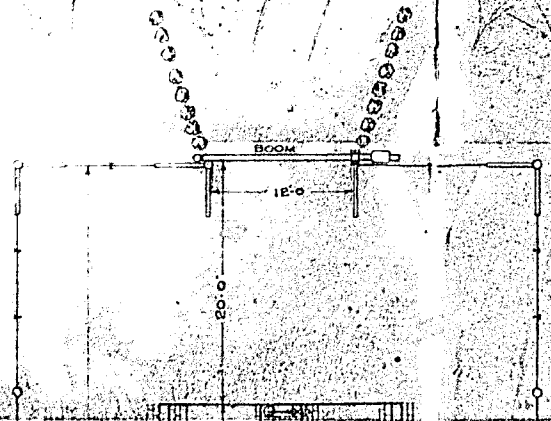
CO.

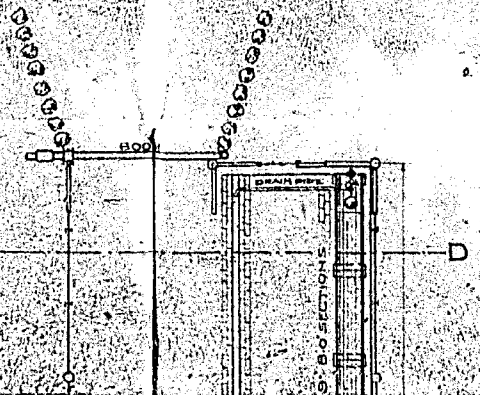
C.O.

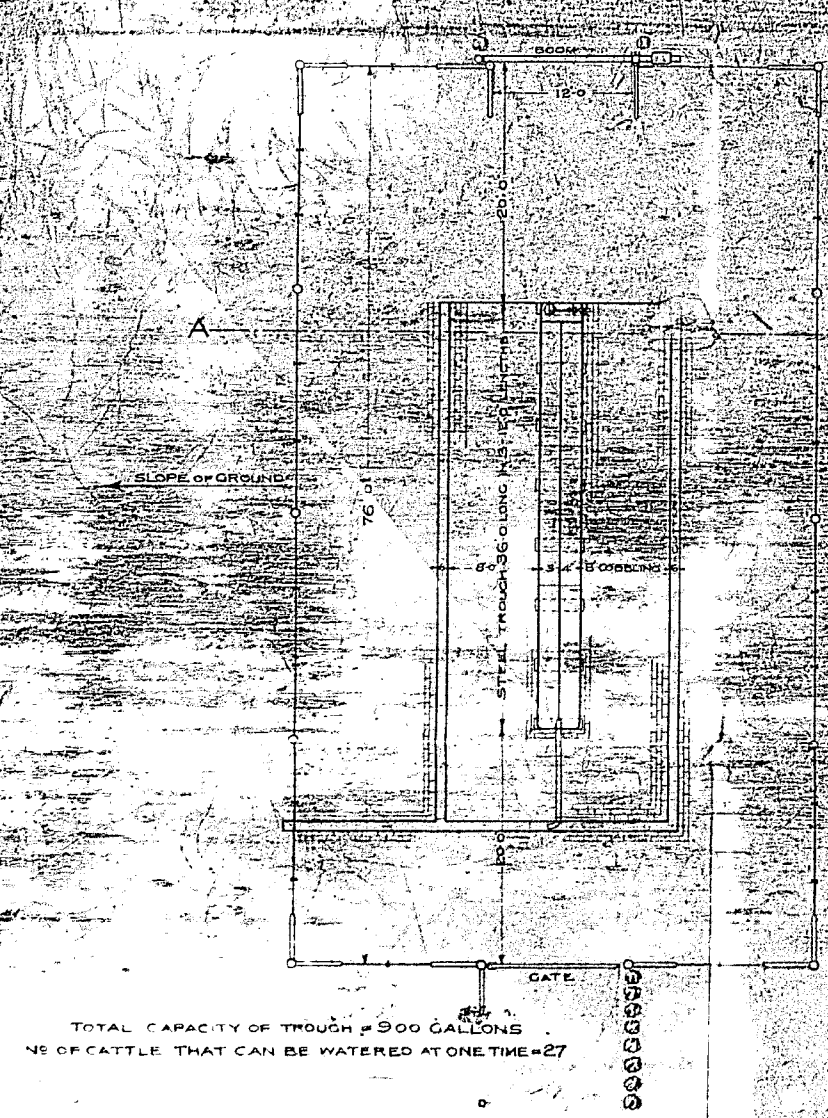
PLATE 5

SECTIONAL ELEVATION ON LINE A-B

SECTIONAL ELEVATION ON LINE C-D

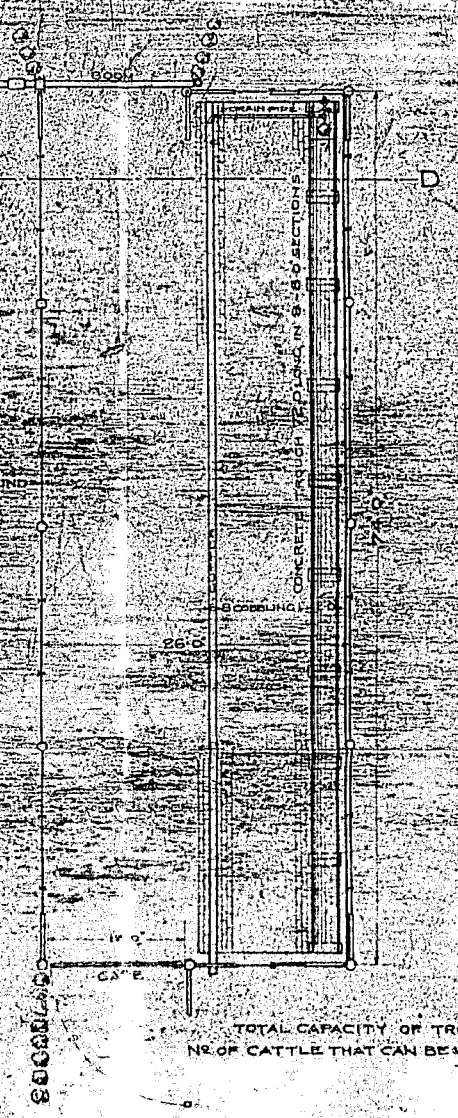






TOTAL CAPACITY OF TROUGH = 900 GALLONS
Nº OF CATTLE THAT CAN BE WATERED AT ONE TIME = 27

SKETCH B



TOTAL CAPACITY OF TROUGH = 600 GALLONS
Nº OF CATTLE THAT CAN BE WATERED AT ONE TIME = 27

SKETCH C

A. O'Leary M. INST. C.E.
DECEMBER 1925

C.D.

Sketch "A" (Plate 4) shows an arrangement of this sort with a tank of internal diameter of 16 feet; this has been found to be a convenient size in South Africa, and, as we shall see, is a suitable unit for the herd we are considering; but the dimensions can be modified to suit circumstances. The trough has been kept low, as it is considered that cattle drink more conveniently when the trough is in this position. It has also been given a dished section in order to facilitate cleaning. An internal width of 1' 9" is sufficient for large horns and a depth of 1' 3" has been found to be satisfactory. The trough is supplied with water from the tank through a pipe controlled by a ball cock valve so that the trough may be kept full automatically. The floor of the tank is dished and is above the water level of the trough for the purpose of preventing the accumulation of dirt in it. An over-flow pipe is also provided for the tank in case the supply exceeds the capacity. This clean water might be run into an overflow dam.

A space round the trough, where the cattle will stand, is cobbled and a drain runs round the outside. This is to prevent the accumulation near the trough of water from the cattle or from the over-flow of the trough and to facilitate cleaning. Round the whole a fence with gates is provided so as to regulate the number of cattle drinking at the trough at any one time. A pipe conveys water outside the fence for human consumption.

Allowing a spacing of 1' 6" per animal, 27 animals can drink simultaneously from this trough, and, allowing 10 minutes for each animal to drink and for its place to be taken by another, we could water 162 per hour and get the whole 500 of the larger herd through in about 3 hours and the smaller herd of under 300 in less than 2 hours.

In cases where we have a constant dependable supply, as with pipes, we need no reserve storage and a depth of about 5 feet in a single tank will be sufficient

for the larger herd. For windmill supplies it would be necessary to provide a storage of at least four times the daily requirements (see paragraph 134). In order to maintain standard features in the matter of steel reinforcement and forms for concrete, it is probably better in the latter case to provide 3 or 5 tanks seven feet high, putting out the trough from one instead of one larger tank. Alternatively, of course, the diameter of the tank could be increased, but above a certain size the circular type of tank loses its advantage in economy and a square type should be adopted.

A rough estimate of the cost of type A tank and trough of the dimensions shown in the sketch, complete with pipes, valve, fencing, cobbling, drains, etc., would be about £170 for 15' diameter 5' high, £188 if 7' high and £140 if the diameter is 12'.

103. In the case of pumped supplies (apart from windmills), should circumstances make it difficult to construct reinforced concrete, it may be preferable, though more expensive, to adopt some type of steel troughing which will provide a limited amount of storage, but in this case the su[illegible] and the pump must be capable of delivering at least 20 gallons per minute in order to water 500 head in 4 hours on account of the limited storage. A length of 35 feet would allow the same number to drink simultaneously as in the case of a circular tank, because they can drink from both sides. A length of 26 feet would suffice if 4 hours are allowed for watering 500 cattle and the water supplies are strong enough. A type of such troughing is shown in Sketch "B" (Plate 5).

103. In the case of dams, no tank storage at all is required and some simpler standard type of troughing without tank could be adopted. To correspond with the circular type, a length of about 70 feet should be provided

and the surrounding fence could be brought up to one side of the trough in order that cattle may drink from one side only. A type is shown in Sketch "G" (Plate 5).

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8. SUPPLIES BY FURROWS.

104. Not much need be said about supplies conveyed in furrows. In most parts of the country the nature of the surface is so porous that the small supplies required for stock purposes would disappear into the ground within a very short distance. The country is also so cut up with valleys and channels that it would be difficult to carry a small furrow at a continuous grade for great distances without long detours and expensive cross-drainage works.

In the artesian basin of Queensland and New South Wales in Australia, the supplies from boreholes are conveyed as far as forty miles from the hole in open furrows. There, however, the supplies generally exceed one cusec, the surface soil is a compact dark clay and the slope of the country, being only a few feet per mile, is too flat to permit of economical piping. Even under these favourable conditions, the losses of water in the long furrows are enormous. In some parts of Kenya it would be possible to lay out small furrows and line them with concrete, but it should be remembered that fences are almost unknown in the country and wild game abound in most regions. Until the number of big game is reduced, when fencing will become the rule, piping will in most cases have to take the place of furrows.

5. SUPPLIES BY DAMS.

105. We have dealt with storage dams for irrigation purposes in the previous chapter. Wherever there is an irrigation dam, a watercentre for stock can be established.

Agriculture, however, is a better means of civilising and controlling natives than stock farming, and, therefore, we need not say much about the provision of water for stock from such dams. Where irrigation is practised, the undergrround water table will generally rise to such a level as to make the provision of water for stock by means of wells and pumps an easy matter, and this is dealt with in Part 8 of this Chapter (Paras. 121 - 129).

106. It is the smaller dams for the provision of water, chiefly for stock purposes, with which we are here concerned. We will consider only earthen dams. Concrete and masonry would prove far too expensive for small stock dams in comparison with earth.

107. These small dams can be divided into two classes - (1) those built to store up the 24 hours supply from weak springs or from small permanent flows in the beds of rivers so that a herd of cattle can be watered daily within a few hours, and (2) those built across dry streams, which only flow after rains.

108. By far the larger number of dams which I saw in the country were of the first type. They are generally confined to the upper regions of catchment areas, and only a very small percentage of them had a catchment area exceeding 2 square miles. The reason for this is, of course, that when the catchment area gets as big as this, we are liable to have floods of several hundreds of cusecs, and to pass such floods successfully round a small dam requires a large expenditure on the spillway. This type of dam has, therefore, a limited range and will only deal with the areas at the headwaters of

streams which are generally steep. Not much need be said about them. A farmer can generally by trial and error and at very little cost build such small dams without any expert advice. If they are carried away by floods, they can easily be replaced.

A useful hint is to puddle the bottom of the dam by driving stock to and fro so as to make it more watertight. In most cases, however, this advice is not necessary, as the stock spend far too much time trampling in the dam and fouling the water.

Very few of those that I saw were provided with troughing, and the best advice I can give is that the stock should not be watered directly out of the dam. The dams should be completely fenced in and the cattle should be watered at troughs fed by pipes through or over the dam, the supply to the trough being controlled by ball valves.

109. While these dams serve a very useful purpose, I think that the better way of dealing with these small supplies is not by making dams in the streams but rather by leading off the flow by means of pipes into concrete tanks and troughs. In this way, not only are the losses by percolation through the soil diminished, but the storage tanks can be placed out of the reach of floods and are, therefore, not liable to be swept away or silted up, as are the earthen dams in the beds of rivers.

For supplies exceeding 3,000 gallons per day a tank and trough of type A would be suitable. For smaller supplies, some other type may be preferable.

110. The chief problem in the country is not, however, to make better use of small perennial supplies, but to store up flood waters in the huge areas of grazing where there are hardly any permanent streams.

111. Here, again, there is not much difficulty in building small shallow dams simply by throwing up earth

banks across channels with very small drainage areas, not exceeding half a square mile in extent. Such dams, being liable to be swept away and to be silted up and also liable to give out on account of evaporation and absorption, cannot be regarded as permanent water-centres, although they serve a very useful purpose indeed in allowing stock to reach, and to remain in for a month or two, grazing areas which would be almost useless without them.

113. To create a permanent water centre, we must be reasonably sure that the dam will not wash away and that a supply of 6000 gallons per day will be permanently available throughout the year, even in a series of bad years. We have previously seen that a large expensive dam is out of the question for a single grazing centre, because not more than 500 head of cattle should be permanently based on the centre. Suppose we spent £10,000 on a large dam which would guarantee water for 10,000 head of cattle, we could not say that the cost per head is ten shillings. If we can only water 500 head permanently on account of the limitations of grazing, the cost would be £20 per head. We need not look, therefore, for our dam sites in the big rivers with large drainage areas. To make adequate provision for passing flo.. d against silting in such positions would prove excessively costly. Our smaller stock dams will, as a rule, be confined to positions where the rivers have small drainage areas.

113. To give any general rules in regard to such a dam is exceedingly difficult, as the many essential factors will vary in each case. Engineering advice is always advisable. However, as many officials in the native reserves are struggling along without such advice, the following suggestions are thrown out as a general guide for a dam for 500 head of cattle, but with a warning that they will not fit all cases.

1. Be chary of building a dam with a bigger drainage area than about 6 square miles. The spillway for larger areas will probably be very expensive and will require special design. The bigger the drainage area, the more rapidly will the dam silt up.

2. On the other hand do not build it for 500 head of cattle with a drainage area much smaller than 2 square miles, so as to give a dam of the size indicated in 3 below a reasonable chance to fill in each rainy season.

3. Build it of such size as to provide about 60 acre-feet of storage. Although 500 cattle will consume only about 4 acre-feet in 6 months, the rest will be necessary to provide for loss by evaporation and percolation and silting in the first few years.

4. Make the spillway 30 feet wide and four feet deep below the crest of the dam adjoining it and rather cut it in rock than allow it to protect soil.

I know that the above 4 suggestions may be very wide of the mark in many cases, but they may serve to fix a scale to prevent several prevalent errors. In the case of the spillway, for example, the universal tendency is to make it too small.

5. The wall should be at least 12 feet high for a length of 300 feet. That is, with the spillway 4 feet below the crest of the dam at the sides (see 4 above) and 6 inches allowance for subsidence in the middle (see 7 below), there should be at least 7½ feet of water over this length in the middle. Shallow dams will give out by evaporation and absorption. On the other hand, get engineering advice for dams over 16 feet high. Without it, rather build two lower dams to get the necessary storage.

6. Make the side slopes 2 to 1 on each face and the top width 6 feet.

7. [illegible] the deep part of the dam 6 inches higher than at the sides, to allow for subsidence.

8. Protect the upstream face with hand-packed stone over gravel but not the downstream face. Do not take any earth from the dam within 25 feet of the downstream toe and keep the dam free from growth of bushes and trees. The reason for this is that when the dam silts up, instead of attempting to scrape out the silt, it is preferable to add to the height of the dam from downstream.

9. Fence in the whole area of the dam, and water cattle at troughs fed by pipes through or over the dam.

114. The price of such a dam would vary considerably with different circumstances. The cost per acre-foot of storage is likely to be high, as the dams will be in the steeper parts of rivers near their sources.

Small dams generally cost more per acre-foot than large dams for this reason and also because the cost of the top four feet, which does not provide any storage, is relatively higher in small dams. £10 per acre-foot would probably not be an excessive allowance on the average and agrees roughly with the average costs of small dams already constructed in the Umhali Reserve. On this basis, the dam would cost £1,000, and, adding the cost of fencing and troughing, we might allow a total cost of £1,200, which is a capital charge of £3.4 per head of a herd of 500 cattle.

The dam will fill up gradually with silt and sand, especially in the metamorphic areas. Allowing £400 for raising the dam 3 feet every 10 years, and £10 per annum for other incidental maintenance, we would have an annual maintenance charge of, say, £50. This, together with 6% on the capital charge, would give an annual charge per head of stock amounting to nearly 5/-.

4. SUPPLIES BY PIPES.

116. One of the most certain ways of providing water is to convey it through pipes from permanent sources of supply, such as springs or perennial streams, to grazing areas at a lower level. The limitation to this method is the cost.

116. For purposes of this discussion the following prices are assumed for the cost of piping laid in position after 400 miles of rail transport from the coast and 30 miles of road transport (these distances are assumed for all estimates of cost in this Chapter).

Diameter, inches	1	1¼	1½	2	2½	3	4
Cost per mile, pounds Stg:	160	210	270	380	500	620	810

117. As the source itself will probably be a water centre, we will not require another large centre within 4 miles. We will, therefore, require at least 4 miles of pipe to establish a single large water centre.

As previously pointed out, it is not desirable to convey a big stream to a single water centre. A stream of only 6000 gallons per day is all that is required for a single large water centre. A one inch diameter pipe is probably the smallest practical size for a length of four miles. To establish a single water centre would, therefore, require four miles of at least one inch diameter pipe, costing £640.

That is quite apart from any storage provision. It is not a practical proposition to water cattle gradually in relays throughout the day and night. We have previously allowed two to three hours only per day for watering a herd. That means that, without storage provision at the water centre, we would have to instal larger pipes capable of supplying water at least eight times more

rapidly than if the water consumption were spread out evenly over the 24 hours. In practically all cases it is cheaper to supply storage than to put in the larger pipes. The cost, as we have seen, of a complete 6000 gallon storage and trough unit of type A is £170, so that the cost of a single centre would be at least £800.

A single centre of this sort for 500 head of cattle may be of the utmost value to a farmer; but from the point of view of native administration we should consider the 9-point or 16-point system for 4500 head of cattle. (See paras. 90 and 97).

116. For a 9-point or 16-point system supplying 4500 head of cattle we would require a permanent flow at the source of 54,000 gallons, i.e. about 1/10th cusec only.

117. The first thing to realize about the method of supplying such systems by means of pipes is the enormous length of pipes required. For the 9-point system with water centres 5 miles apart, about 32 miles of piping are required, excluding the main, and for the 16-point system with centres 3 miles apart, about 45 miles of piping are required. For a 9-point system with spacing of 5 miles, 48 miles of [illegible] would be required. In addition, a considerable length of main will be required. In a particular case referred to me in the Kanni Reserve, the water was to be derived from a river running in a deep channel in a southerly direction on the western escarpment of the Rift Valley and to be conveyed down the escarpment to the bed of the Rift Valley, near Sunwa volcano. As the river lies in a deep valley, the pipe would have to run for many miles before it could emerge from the river valley. This part of the pipe line is not required to supply water for cattle, as the river is close at hand. The main pipe line would probably have to be about 20 miles long before an area of 93,180 acres for 4500 head could be reached at a suitable

grade in the Rift Valley. I have, however, assumed that a 16-mile main could be effectively laid from that river and that in other more favourable localities the main could be reduced to 8 miles.

230. For purposes of arriving at the size of the pipes and the cost, I have assumed that for the main a grade of 1½% would be available and for the distribution system over the grazing area an average grade of ½% in one direction would be available. In all cases the main starts off with a 5-inch pipe and the distribution system tapers off to 1¼" pipes. The following table gives the cost of the system per head of cattle for a 9-point system with water centres spaced at 4 miles and for a 16-point system with centres at 3 miles intervals. To arrive at the whole cost the figures must be multiplied by 4500. I have also added the cost of a 9-point system with water centres spaced at 6 miles intervals, though such wide spacing is not advised.

CAPITAL COST PER HEAD OF STOCK IN POUNDS.

	9-point system 6000 gals.at 4 miles for 500 head.		16-point system 3400 gals.at 3 miles for 280 head.		9-point system 6000 gals.at 6 miles for 500 head.	
	8 miles main	16 miles main	8 miles main	16 miles main	8 miles main	16 miles main
Pan	3.88	4.18	3.85	4.6	4.6	5.76
Storage tank and troughing type A (tanks 16' and 12' diameter).	0.34	0.34	0.5	0.5	0.34	0.34
TOTAL	3.6	4.6	4.1	5.1	5.1	6.1

The first thing to notice is that the cost of the 16-point system is not much greater than that of the 9-point system, and, for reasons previously stated, I would prefer to see 280 head depending on a single water centre of a 16-point system rather than 500 as provided in the 9-point system.

Taking the 16-point system with a 16

mile main, the total cost is £9.1 per head. If we allow a life of 25 years and 6% for interest, redemption and maintenance, the cost per head per annum would be 6 shillings. To establish such a system would require a capital outlay of £42,500. It would supply water to 4500 head of cattle at 16 points 3 miles apart over a square area with a 12 mile side embracing 92,160 acres. 15 miles away from a permanent source of water supplying 64,000 gallons of water per day or 1/10th of a cusec down a grade of 3½ for the main and 6% for the distributions. These paper assumptions would probably not fit any particular case on the ground, but they are given to indicate the methods which I think should be followed and also for comparison of costs with other possible methods of supplying water.

The costs are high, but may be considered justifiable up to a distance of 12 miles from a source of water supply. As the distance increases, the costs will increase, and piping methods can only be applied to the limited areas near to the permanent rivers and springs which are high enough above the grazing areas to give sufficient grade for the pipes. As there are vast areas of good grazing far away from permanent sources of water, the method of supplying water by means of pipes has distinct limitations.

B. SUPPLIES FROM WELLS.

111. As compared with boreholes, wells have this advantage that there need be no great capital expenditure on plant. On the other hand, these two difficulties are met with in comparison with boreholes -

1. In soft material and at depths of over 30 feet, it becomes necessary, if only for the safety of the workers sinking the wells, to line the well, and this is a difficult and expensive matter. With boreholes, it is an easy matter to sink a casing.

2. Once water is struck, it is very difficult to sink the well deep enough in the water, whereas water in a borehole given little difficulty.

These difficulties make the possibilities of well supplies rather limited. In the hard formations, where lining would not be required, the probabilities are that water is at a depth which makes well sinking more costly than boring. In the softer areas, where the water may be at a shallower depth, lining will add considerably to the cost of wells. It is on account of the difficulties of lining that one sees so often in Kenya wells sunk unsuccessfully in hard formations high above a river bed, whereas, at a lower level in the alluvium bordering the river, the chances of obtaining a supply appear to be stronger.

The difficulty is that, except for wells under 30 feet deep, a lining must proceed simultaneously with the sinking and must, therefore, be built from the top downwards and not in the easier manner from the bottom upward. This requires, as a rule, some form of timbering and, therefore, skilled labour. If timbering is adopted, the square or rectangular form of well is best. For any other kind of lining, the circular shape is best and a usual diameter is 6 feet. Corrugated iron sections can sometimes be placed one below the other; but for brickwork the lining must be sunk on a cutting edge, while bricks are added on top.

112. The chief uses of shallow wells are, in my

opinion, (1) to deepen and strengthen existing weak springs, and (2) to draw off water running below the surface in the sandy beds of dry rivers.

123. In regard to (1), the usual method in Kenya of endeavouring to strengthen a weak supply is to open up an enormously wide excavation round it. The net result is generally a larger area for the cattle to get into and to foul, without any appreciable increase in the supply. Such supplies are a danger to the health of human beings and animals.

In these cases I think shallow wells should be sunk. They should be lined, and the lining should be carried above the ground level, and they should be covered in. The cattle should be watered some distance away from the well, so that their droppings will not drain into it. If there is sufficient fall in the country and the well is not too deep, the water may be syphoned out. Otherwise, a hand pump, a Noria, or a windmill may be erected. In all cases the water should be delivered into troughs, from which the cattle can drink.

124. As to the supplies in the sandy river beds, these are the chief sources of supply over enormous areas of country, particularly where the metamorphic rocks occur, as in the Ukamba Reserve. The natives scoop out wide holes in the sand and cover them round with thorn fences. The animals pass through a gate, 2 or 3 at a time, and walk down a gentle ramp to a barrier placed across the pool, which allows them to reach the water without going so far in as to tramp down the sides. Every flood obliterates these holes, but they can be reopened again very easily. I saw very few holes deeper than six feet, probably because it is difficult to keep up the sides in sand at greater depths. In such cases I think that a permanent well, sunk on the bank of the river, well out of the reach of

floods, might be a satisfactory arrangement, combined with hand pump, Noria or windmill and also with storage tank and troughing.

125. For all these wells I strongly recommend a good concrete curbing with suitable cover. A round top including a concrete curb 3 feet deep and two 4" x 4" channel to carry the pump and a cover of 2 inch barred timber, can be provided for £10.

126. For hand pumps with 8" stroke, the following sizes are recommended -

Depth of Water.	Diam. of pump cylinder.	Capacity, gallons per hour, at 30 strokes per minute.
feet.	inches.	
10'	6	1,000
20'	4½	550
30'	3½	350

These pumps with an ordinary lever-type of hand standard could be erected complete for £30. The natives in Kenya appeared to me to be as destructive of pump fittings as those in South Africa, and it may, therefore, be advisable to follow our example and have the pump standards made chiefly from wrought-iron pipe fittings. If the well is strong and continuous pumping is justified, i.e., days of days, the rotary type of hand standard (non-geared) is preferable, but would cost about £15 more.

127. For drawing water from shallow wells, Indian experience has shown that there are few appliances that can beat the Noria or "bakhlas" pump and it should be specially suitable in ranching areas where cattle are abundant. A plant capable of raising from 1,000 to 3,000 gallons per hour could be installed complete for from £40 to £80 for lifts of from 10 to 30 feet. I would strongly recommend the use of this appliance, were I not a little afraid that the indolent native might "inspan" his womenfolk instead of his cattle. Try it anyway.

129. Alternatively, provided the supply is strong enough, windmills could be erected. With the water within 30 feet of the surface, a wheel of 8 feet diameter would suffice on a 40 ft. tower with a 4½" diameter pump cylinder to pump 6,000 gallons per day. For the same supplies at greater depths a larger wheel would be required. These outfits should cost from £90 to £120.

130. Storage and troughing will be required in all cases, and the size will depend on the strength of the supplies of water.

6. SUPPLIES BY BORING AND PUMPING, CHIEFLY WITH WINDMILLS.

130. We have dealt with the geological side of the underground water supplies in the chapter on Geology. The important point to realise here is that we are not searching for large underground rivers. All we require from a single borehole is a supply not exceeding 6,000 gallons per day, for that is enough for the biggest herd which I consider desirable to concentrate on one water centre. A herd of about half that size or smaller is considered preferable. Any supply in excess of 6,000 gallons per day is not of great value for stock grazing purposes.

It is important to realise this, not only from the point of view of the probability of finding supplies by boring, but also from the point of view of the mechanical means employed to lift the water to the surface. In the case of supplies, tested to yield as much as 60,000 gallons per day, we sometimes see calculations proving that it is far more economical per head of stock to instal a suction-gas or steam-driven plant to pump and utilise the whole supply rather than to put in a windmill plant, which could probably not pump up more than one-tenth of the supply made available by expensive boring.

The fallacy of such conclusions is that, in working on a supply of 60,000 gallons, we assume that nearly 6,000 head of cattle can be permanently and efficiently watered at one centre, and that the costs, particularly the capital cost of the boring and the annual cost of the attendant on the pump, can be spread over 6,000 head; whereas I consider 600 head is the maximum number that can bear the total costs. However fortunate we may be in striking such strong supplies as 60,000 gallons, for practical purposes of permanent stock grazing, we must leave some 54,000 gallons in the hole.

131. If we limit our daily pumping to 6000 gallons per day, it can easily be proved that for waters within 300 feet of the surface no other motive power can compete with that of wind in countries where winds of over 10 miles per hour can be counted on for 8 hours per day throughout the year.

As the utilisation of boreholes will depend very largely on windmills, it is important at the outset to note a few points in connection with their working and costs.

Experience in South Africa has proved that in ordinary everyday working any windmill of greater diameter than 14 feet is not satisfactory, but that a 14 ft. wheel is in every way the most suitable to get the maximum use out of borehole supplies. I will therefore, consider only this size in what follows.

I was not able to get any records of wind velocities in Kenya, but I think that, as in South Africa, the velocities inland are very much lower than at the coast and than those given in windmill catalogues. For this reason it is of the utmost importance to be careful not to overload a windmill. Unless we make the maximum use of winds of low velocity, we will find that the cost of storage provision to tide over periods of calm will be prohibitive.

132. For purposes of design and in order to achieve the maximum result from the mill in a country of low wind velocities, I recommend that with the ordinary type of 14-ft. wheel, back-geared 3 to 1 and working on a 10 inch stroke, we should provide for a static load of water and rods of about 700 lbs. only and assume that with this load not more than 10,000 strokes of the pump will be made per day, taken as an average over 6 days during the calmest season of the year.

With these assumptions and allowing for tubular steel rods weighing approximately one lb. per foot,

the diameter of pump cylinder required is given in the following table, together with the quantities delivered per day -

TABLE A.

Depth Feet.	Diameter of Cylinder Inches.	Gallons per day, assuming 10,000 strokes.
50	6 1/8	9,000
100	4 1/8	8,000
150	3 1/4	2,100
200	2 7/8	1,700
250	2 5/8	1,300
300	2	1,000

(to be modified if stroke and back-gearing not as indicated. Gallons are English measure, not American, which is 0.8 of the former).

Most catalogues will recommend much larger pumps than those given in the table, but I consider it most important to begin work in Kenya with the figures given above, which are the result of South African experience in the inland areas.

133. The assumption that we will get per day 10,000 strokes of 10 inches against a 700 lb. load requires that we should get an average of a little under 3 effective horse-power-hours out of the wind per day during 6 days of the ~~west~~ period. With a load of 700 pounds the mill should start in a wind of less than 8 miles per hour and work down to a wind of less than 7 miles per hour before stopping. The following table shows how it is estimated that the power required will be made up -

TABLE B.

Wind Velocity.	H.P. generated in a 14' wheel by that wind under load of 700 lbs.	Hours during an average day of the calmest season during which that wind is available.	Resulting H.P. hours.
6 1/2	0.06	1.7	0.10
7 1/2	0.15	3.0	0.30
8 1/2	0.23	1.8	0.41
9 1/2	0.29	1.5	0.44
10 1/2	0.35	1.2	0.40
11 1/2	0.36	1.0	0.36
12 1/2	0.38	0.7	0.27
13 1/2	0.40	0.5	0.20
14 1/2	0.42	0.4	0.17
Over 15	0.43 - 0.47	0.8	0.36
	TOTAL	11.6	3.01

Without any details of wind velocities in the country, it may be wide of the mark, but it is considered to be conservative. If actual observation of wind velocities in any locality shows more favourable wind conditions than those assumed, then the diameters of the pump cylinders given in Table A can be increased in the direction of those given in catalogues.

It will be noticed that 1/3rds of the power is derived from winds of under 10 miles per hour, which is in accordance with the recommendation above of making the best use of low winds.

134. The maximum power derivable in a very windy day depends on the controlling device which turns the wheel out of the wind. At the highest horse-power of the table, 0.47, the wheel would generate at most in 24 hours about 11 horse-power-hours, which is nearly four times that it generates in the average day. In such a day the quantities pumped would be four times those given in Table A, and these would be the maximum possible to pump. Actually there would not be many days in which so much would be pumped, and we could reckon that 3 times the quantities of Table A would represent the maximum result of a very windy day and night, & therefore, the maximum rate at which our storage tanks could be replenished after a period of winds below the average. A day of zero pumping would be one of winds not exceeding 7 miles per hour. These would also, probably, be very rare, and we might regard a bad day as one which would give only 4 hours out of 24 of wind at 8½ miles per hour, i.e. 0.9 horse-power-hours (4 x 0.23), which, being 1/3 of the average, would serve to pump 1/3rd of the quantities of Table A. If we adopt, as I recommend, a storage provision of 4 times the average quantities of Table A, which are reckoned as the steady supplies required at the water centre, then, starting with full tanks, we would exhaust the supply in 6 consecutive bad days and we would require a number of days above the

average to keep going and to fill the tanks again. Provided, therefore, that during the calmest period of the year we are not likely to get two periods of more than 6 bad days without the intervention of at least as many days above the average, the storage provision suggested will suffice. Experience alone will prove whether this is sufficient, and, if it is not, then more storage tanks will have to be built round the windmill.

135. Reference should be made to paragraph 20 in Chapter II in regard to the importance of testing the strength of boreholes and the limitations as to the size of pumps where the tested supplies are weak.

136. Reverting, now, to Table A, it will be seen that at 50 feet depth a 8" pump is given and that it will discharge 8,000 gallons in an average day. A pump of 8" diameter cylinder is the largest size that can be placed in a 6-inch borehole.

At the lower end of the table we find that at 800 feet depth we require a 2-inch pump, which will deliver 1000 gallons per day. I have not given a greater depth than 800 feet, although a pump as small as 1½" can be inst[illegible], because we shall see that at and below that depth it would be cheaper to put in a power plant to draw out 6000 gallons per day.

137. If we assume that we are likely to get tested strengths in the boreholes equal to twice the quantities given in Table A at the respective depths, then the possible number of stock that can be watered by the borehole-windmill plant under the wind conditions assumed in determined by the depth at which the water is found. The number can be determined by dividing the gallons of Table A by 12, and the storage to be provided can be determined by multiplying the gallons by 4. The distance apart of the centres will be determined as in previous pages.

For comparison with the performance of pipe and other methods, the following plants are considered to establish a single water centre, the tanks to be of type A.

A. Water, 80 feet or less in one hole, one borehole and 6000 gallon plant, storage 2 tanks 7 feet deep (one with trough), 500 head of stock, distance apart of holes 4 miles.

B. Water, 80 feet to 140 feet in one hole, one borehole and 3400 gallon plant, storage 2 tanks 5 feet deep (one with trough), 250 head of stock, distance apart of holes 3 miles.

C. Water, 130 feet to 170 feet in two holes, two boreholes with two 3000 gallon plants, storage 2 tanks 7 feet deep (one with trough), 500 head of stock, distance apart of centres 4 miles.

D. Water, 180 feet to 250 feet in 3 holes, three boreholes with three 2000 gallon plants, storage, number of stock and spacing of centres as for A and C.

E. Water, 270 feet to 300 feet in 5 holes, 5 boreholes with five 1200 gallon plants, storage, number of stock and spacing of centres as for A and C.

To arrive at the costs I will assume -

Boreholes will cost 30/- per foot.

A windmill (40 ft. tower) erected complete with pump and piping will cost from £140 to £180.

Storage tanks, troughing and fencing as for type A.-

2 Tanks 5' depth (including troughing, cobbling, fencing, etc.,) will cost £240

" 7' " " " £360

With these assumptions, we arrive at the following table of costs -

CAPITAL COSTS OF WATER CENTRES OF ABOVE TYPE.

	A	B	C	D	E
Boreholes	100	170	440	870	2300
Windmill & Pump	140	150	320	610	900
Storage & troughs	360	240	360	360	360
TOTAL COST	600	560	1120	1840	3460.
COST PER HEAD OF CATTLE	£1.2	2.0	2.3	3.7	6.9

To arrive at annual charges we will allow 7½% on cost of windmill pumping plant and 6% on the other capital costs and also maintenance charges, chiefly for lubricating oil and

renewal of pump leathers, varying from £12 for one plant to £36 for 5 plants at one centre. The result will be -

ANNUAL CHARGES PER HEAD OF CATTLE IN SHILLINGS.

	A	B	C	D	E
On Capital	1.5	2.6	2.9	4.7	6.8
Maintenance	0.5	0.9	0.8	1.0	1.4
	2.0	3.5	3.7	5.7	10.2

158. Reference should be made to the possibility of providing an ox-gear (commonly known as a horse-gear) capable of being connected to a deep well windmill standard, so that in cases of emergency, when the wind should fail, and if the storage tanks should prove inadequate, the requisite quantity of water could be pumped. Two pairs of oxen working in relays for a total of 10 hours per day should easily be able to work the pumps of Table A and so raise the quantities of water given in the table. The total cost of adding the ox-gear to the windmill plant should not exceed £70 erected.

159. We have first to see how we can utilise boreholes yielding over 6000 gallons per day at greater depths than 300 feet by means of power plants.

At these depths we have seen that the windmill can only raise small quantities of water and can, therefore, not make full use of the water made available by boring. We have also seen that, although a power plant will show up very well against a windmill plant when pumping supplies stronger than 6000 gallons per day, we must confine our problem to supplies of 6000 gallons per day.

Probably the only power plant which will prove economical in Kenya is a steam engine fired with wood fuel. We will, therefore, consider such a plant for two depths of 300 feet and 480 feet.

A four horse-power plant is recommended for both cases with the object of keeping to one standard size.

A type of plant which has been found most successful in South Africa is shown in Plate 3.? The cost, including boiler, engine, power-head, pump (2½" diameter), pipes and fittings, and suitable house is estimated at £800 for the 300 feet hole and £900 for the 450 feet hole.

The price of wood fuel is assumed at 5/- per ton and of lubricating oil at 6/- per gallon. An attendant is required at £52 per annum. 10 hours are allowed for working per day and a single storage tank of type A is required.

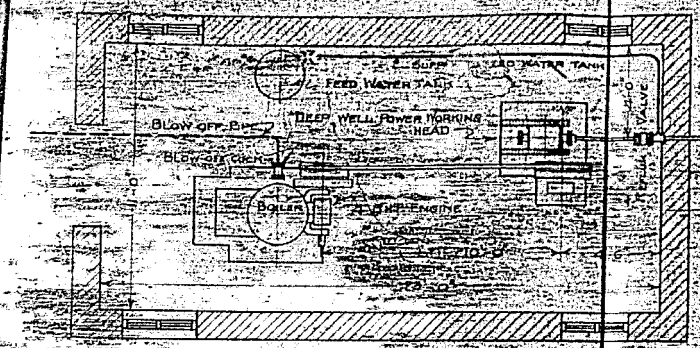
The total capital cost of borehole (at 30/- per foot), power plant, and storage reservoir (£170) will be, for 300 feet £1180, and for 450 feet £1395, i.e. £2.5.0 and £2.15.0 per head of 500 cattle.

Allowing 10% for interest and redemption on pumping plant and house, 5% for maintenance of pumping plant and 2% on other capital charges, the total annual charges will be made up as follows:-

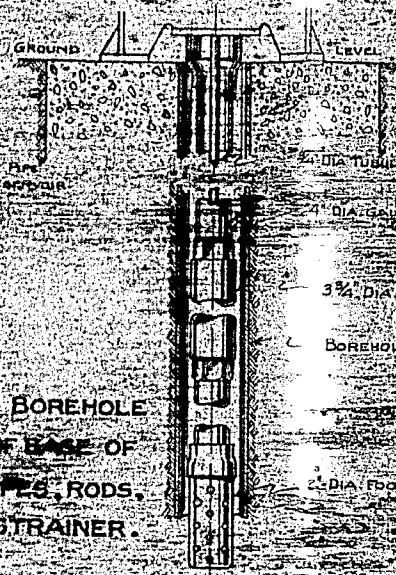
	300 ft. plant.	450 ft. plant.
Interest, Redemption and Maintenance on Capital Costs	£110	£130
Running Costs	120	134
TOTAL PER 500 HEAD	£230	264
Average cost per head	9.2/-	10.5/-

C.O.

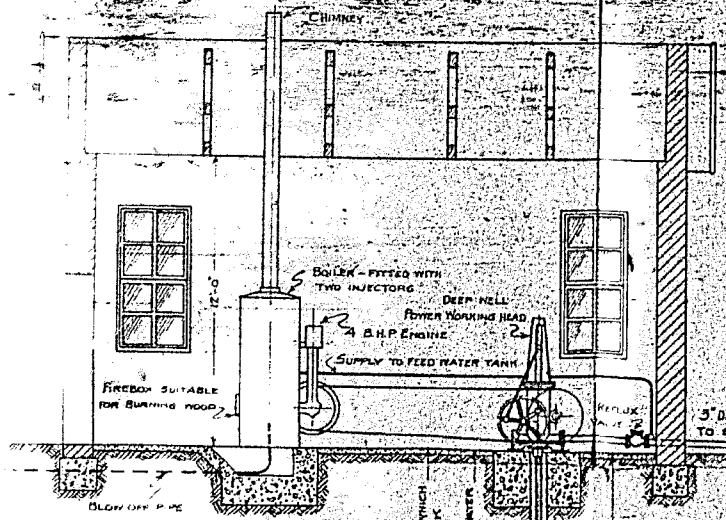
PLATE 6

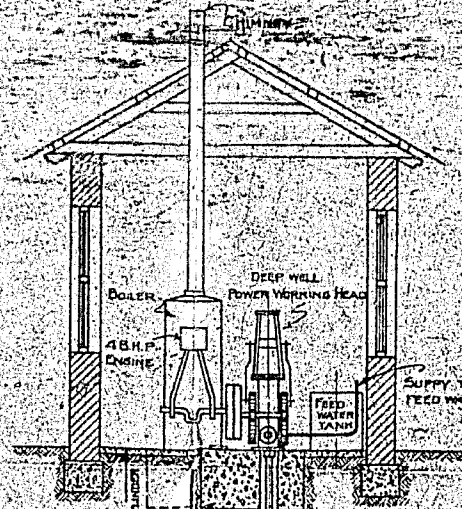


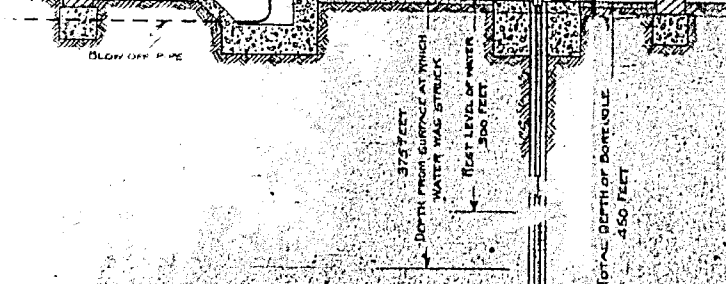
PLAN.

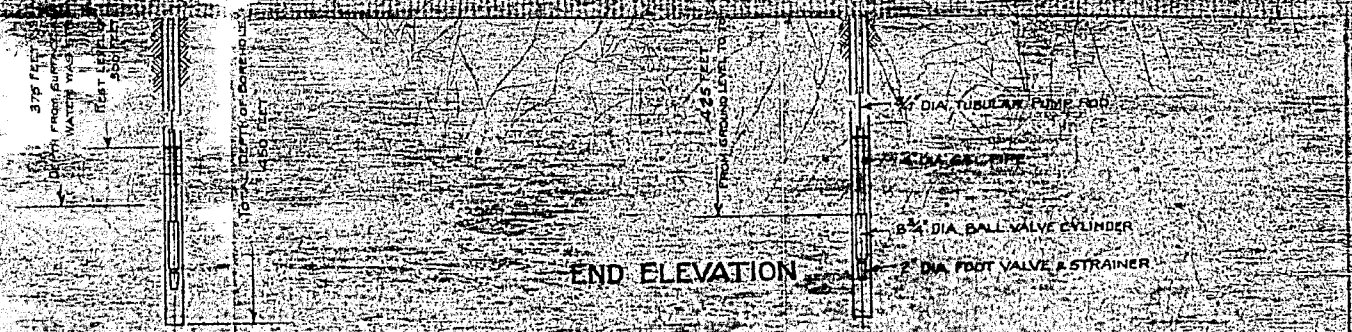


SECTION THRO' BOREHOLE SHOWING DETAILS OF BASE OF POWER HEAD, PIPES, RODS, CYLINDER AND STRAINER.









SIDE ELEVATION

END ELEVATION

TYPICAL LAYOUT OF STEAM ENGINE PUMPING PLANT

FOR BOREHOLE 450 FEET DEEP.

CAPACITY 6,000 GALLONS PER DAY OF 10 HOURS

A Ockers M. INST. C.E.
DECEMBER 1925

C.O.

IN THE MASAI AND UKAMBA RESERVES.

140. There is little that need be said specifically in regard to these areas; most of the questions that arise in them have been dealt with in this and previous chapters.

Small springs should be developed as indicated in paragraphs 108, 109 and 122. Paragraph 124 applies to the supplies in the sandy river beds of the metamorphic formation.

Where the above two sources of supply are not available, we are thrown back on dams, pipes and boring. Comparing the costs of these three methods, it appears that boring is the cheapest, provided that supplies are found within 200 feet of the surface in a large percentage of holes. Dams come next and pipes come to with deeper boreholes; but the localities where dam and pipe methods can be employed are very limited. About 16 dams have been built in the Masai Reserve at a cost of over £10,000. Not half of these can be regarded as successful. There has been no method of grouping supplies and no limitation of stock round about them. In fact, where some of the dams have been built there was already almost enough permanent water for a u[illegible]rd. The difficulties of dam making in the metamorphic and volcanic formations have already been dealt with. The Ukamba Reserve lies almost wholly in the metamorphic area and the Masai Reserve has about half of each. Another difficulty which exists in the Masai Reserve is that the Masai men appear to be too proud to work at dams themselves. Until these grand people learn to do such work, it seems useless to go on building dams for them.

141. I recommend that in a policy of opening up water resources for cattle in the native reserves, the plan of operations should be studied and closely linked up with any proposed road system in the colony, particularly with those

roads which do not pass through "fly" areas. Adequate water supplies along the projected road routes are essential. A "fly" map of the country should be prepared and projected road lines should be laid down on it. Points for 9 or 10-centre community supplies should be laid out along these roads at about 24 mile intervals in the first place and at a later date the intervening 12 miles of country can be filled in along the roads. A number of the roads should be planned from railway stations or feeders to the railway.

CHAPTER VIII.

A WATER BORING POLICY.

143. It is clear from what has been said in previous chapters that there is a reasonable prospect of finding water by boring over large areas of the country in sufficient quantities to establish water centres for stock purposes and at smaller cost than in any other way.

Further, it is very much in the interests of Government that as many permanent water centres as possible should be opened up. Every new centre opened up should mean added prosperity not only financially but also in the advancement of the natives. The Government cannot be inactive in the matter and leave it to private enterprise. In the native reserves, for example, Government alone must be responsible. Then, in opening up new areas for European settlement, experience in South Africa has shown that it is preferable to provide water by boring before demarcating and allotting a farm. If the latter precedes the boring, the settler of limited means may be ruined in a fruitless search for water, and when he finds water, it might lie very inconveniently for his farming operations and might have been of far greater use if the farm had been otherwise demarcated. If it is contemplated to give out further large areas for European settlement, it seems to be a duty of Government to see that proper water supplies are provided before encouraging settlers to take up farms. Even in farms already given out, there are numerous cases where additional supplies of water by boring would increase the value of the farms enormously.

143. Government should, therefore, be vitally concerned in encouraging water boring in the country, and it only remains to see what practical steps are best to take in that direction.

While firmly believing in the general principle that as much as possible of constructive activity

should be left to private contractors, I am convinced that in the case of water boring in Kenya the best results can only be attained if the Government itself undertakes the whole work. The chief reason is the great difficulty in fixing a contract with conditions of payment which will meet the varying conditions over large areas or in particular holes.

144. In different parts of the world the following four methods of payment have been tried:-

1. Cost per foot.
2. Cost per hole delivering a specified quantity of water. No water - no pay.
3. Cost per day of boring.
4. Actual costs plus a percentage.

Combinations of these methods have also been tried, but in most cases with unsatisfactory results.

The difficulty about the first method is that in soft material a contractor may bore more than 50 feet a day, whereas in hard material he may not do one-twentieth of that length. In choosing sites for boring, therefore, the contractor always has his eye to positions which will give easy boring rather than good water. Whenever he strikes difficulty in a hole, he alleges that the chances of finding water by going deeper are very remote, whereas in many cases a little extra depth might yield a satisfactory supply. If an attempt is made to adopt a graduated rate depending on the hardness of the formation, there are no means of classifying or checking the hardness in a deep hole of only 6 inches diameter.

With regard to the second method very few contractors will take it on, except at very high prices and with the right to choose their own site, which is usually the cheapest but often not the most desirable spot for farming operations. Moreover, to check the water strength of a hole would require a careful test and necessitate a trained inspector constantly waiting on a drill to be

present at the test.

The method of payment per day gives the contractor no incentive to press on with the work and cannot be regarded as satisfactory. 520

The last method not only lacks the incentive, as in the former method, but actually encourages extravagance.

For these reasons, I recommend that the Government should inaugurate a water boring sub-department of the Public Works Department. This is the proper department, because it already has a decentralised organisation, and the maintenance of the executive engineers in the various districts would be of value.

145. As to the initial scale of operations I would recommend that, at the outset a large number of machines should not be employed.

A water boring department should never be initiated on a large scale, and at all times a good steady programme of work with gradual expansion is preferable to sudden enlargements. It takes time to build up the necessary staff of boring foremen, and in a new country much of the work must be in the nature of experiments, which will gradually demonstrate the best type of machine and of methods. An initial purchase of a large outfit, based on experience in other countries, may prove to be an injudicious outlay. On the other hand, there should be enough machines to justify certain inevitable overhead expenses, of which the employment of a first class boring supervisor of experience is essential.

I recommend, therefore, that four machines should form the basis of operations at the outset. As to the type of machine, I would like to recommend three percussion drills and one rotary shot drill; but, on the whole, I think it preferable that all four machines should be percussion drills. In the early efforts of training the staff, handling stores and workshop repairs, uniformity will count for a lot. Should the percussion drill not prove successful in any

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particular area, there will always be other areas, to which it could be shifted, and arrangements could be made to acquire rotary shot drills at a later date, should it appear to be necessary. Considering all the circumstances, I recommend a heavy type of percussion drill of 1000 feet catalogue capacity. This does not mean that I anticipate such deep boring, but the engine power available is necessary to operate heavy tools, even at 800 feet, in the formations likely to be encountered in the country. 521

146. The capital cost of these four machines should approximate £4,000. To this should be added an initial capital outlay for tools and spares of £4,000. Stores, including casing and possibly a special 20 ft. lathe for the rescrewing of long drilling tools, will also entail a further outlay of about £1,000, making a total outlay of £9,000. Existing store-sheds of the Public Works Department and workshops of the Railways are assumed to be available at cost price for services.

For the operation of this plant, a head-quarters establishment as follows will be required -

1 Boring Supervisor.
1 Clerk.
1 Storekeeper and six natives (part time) for stores.

To[illegible] cost per annum, say, £1500.

For the field establishment, five drill foremen will be required (one spare) and, in view of the possibility of extension, it is suggested that one assistant learner foreman should always be maintained. Three natives will be required for each drill. Total field salaries per annum, say, £3,300.

The estimated total annual costs for the 4 machines including everything except head office accommodation, would be as follows:-

Head Office establishment	...	£1,800
Field salaries	...	5,500
Transport of personnel	...	700
Rail transport of machines	...	50
Transport of machines in field and supply of fuel and water, assuming these services are rendered free for two machines	...	750
Tools, stores, casing, etc.,		1,200
Machine repairs interest and depreciation		1,000
		£9,800

This works out at £1,125 per machine per annum and if we get 115 drilling days per annum, allowing for days occupied in transport, erecting, testing, weather and breakdown delays, the cost will be £10 per drilling day.

Suppose each drill does 1000 feet in a year (about 7½ feet per drilling day), or 8 holes of an average depth of 200 feet, and that one hole in 8 fails to give water, we would have 7 successful holes and 1400 useful feet per annum per machine at a cost of £1,125, or roughly at the average rate of 30/- per useful foot. These figures are given with reserve. Actual experience over a few years in varying circumstances is the only way in which we can prove whether they are optimistic or otherwise.

RECOVERY OF EXPENDITURE.

147. 1. In Native Reserves the administration, knowing the customs of the natives, will be able to devise the suitable methods of recovering expenditure and, therefore, I will not give any advice, except that the charges for boring should be combined with the other charges in respect of windmills, storage tanks, etc., to complete the water centre or group of centres.

2. Boring on Crown Lands before settlement. As previously recommended, the boring should be undertaken before the boundaries of farms are precisely demarcated. When the farms are surveyed, they should be valued, taking into account the value of the supply of water made available by boring. In most cases, over a group of, say, ten farms, the total of the latter portion of the valuations would more

than cover the cost of the boring, which will, therefore, be easily recoverable by special annual payments, over a period of, say, 10 years. It is recommended that the costs be spread over groups of farms in this way rather than that each farm should bear the actual cost of boring on it. 523

As soon as the settler occupies his farm, the windmill, storage tank, etc., should be erected and arrangements could be made to assist the settler in the cost, which would be added to the boring valuation for purposes of recovery. In passing, it should be noted, that during the period after completion of the boring and before the occupation of the farm by the settler, the borehole is often blocked by hunters, natives and especially children lowering or throwing matter into the hole. To prevent this, and to allow of use of the water for further boring operations, or while the settler waits for the erection of a windmill, it is advisable to instal a hand pump over the borehole immediately after completion.

5. Boring for farmers already in occupation. Experience in South Africa has proved that the only sound way of charging for boring services rendered by Government is by a charge per day of boring. We have seen that the average charge, if spread over all holes, including the unsuccessful, is estimated at about £10 per day and, if the farmer supplies transport, fuel and water, and pays for unsuccessful holes, this charge might be reduced to nearly £9. Whether Government intends to subsidise boring for private farmers or not is a matter for the Government to decide. The overhead charges, for example, may be considered to be a legitimate charge on the community at large, especially in the early experimental stages, and if they are deducted, the rate might be reduced to nearly £7 per day. Any further reduction might be made by keeping to this charge, but granting relief to those applicants on whose farms boring has failed to yield water.

A partial cash deposit should be made by the applicant in advance and, if repayment is spread out over a period, the number of years should not be greater than 10, as the repeated collection of small sums is an expensive matter for the administration.

A copy of the latest government regulations at present in force in South Africa is attached.

140. As to the areas where the four machines should work, I would recommend that for the first year, in order to inspire confidence in boring in the country, all boring should be in the metamorphic areas, as I consider that the chances of finding water therein are less problematical than in the volcanic areas of, say, the Rift Valley. Then, for economy and easy supervision, I think an area close to the existing main line of railway should be chosen. For the same reason, as many machines as possible should be close together, and therefore an area, where private farms, native reserves and crown lands to be opened up all lie close together, should be chosen. We must also be careful to avoid "fly" areas.

For all of these reasons I suggest that 3 of the 4 machines should start in the neighbourhood of [illegible] Hamid at mile 240 on the railway line. One machine could work south-east along the line into the area of crown land, one could work south-west into the Masai Reserve, one could work north-west along the line in a settled European area, or north-east into the Ukamba Reserve, avoiding the "fly" area. The fourth machine might start off in the Kaita plains south-west of Marak in the Masai Reserve or from Archer's Post in a northerly direction into the northern Frontier Province. The boring in the Native Reserves should be in community groups and along projected roads as recommended in the previous chapter.

(16)— 9/11/25—5,000.

UNION OF SOUTH AFRICA

Department of Irrigation,
Pretoria, 6th November, 1925.

REGULATIONS FOR HIRE OF GOVERNMENT WATER DRILLS.

1 Approved applications to bore for water for agricultural purposes shall have precedence over other applications for boring

Payment of Charges.

2 Payment for the hire of a drill shall be made either—

(a) by cash in advance; or in special cases approved by the Director of Irrigation;—

(b) by cash instalments over a period of (3) three years; or

(c) by cash instalments over a period of (5) five years (applicable to lessees of Government farms only).

Payment of Charges by Cash in Advance.

3 If an applicant is required to pay cash in advance for the hire of a drill, he shall deposit with the Director of Irrigation or with any other duly authorized officer of the Government the sum of seventy-five pounds (£75) before the drill may proceed to the site at which boring is to take place, and thereafter such further deposits as may be required by the Director of Irrigation, provided that if, when drilling operations are completed, it is found that an amount in excess of the charges fixed under the regulations has been deposited, such excess shall be refunded

Payment of Charges by Instalments.

4 (a) If an applicant whose application may be approved desires to pay for the hire of a drill by cash instalments, covering a period of (3) three years, he shall provide two approved sureties or other approved security for the due payments of such instalments to the Receiver of Revenue of the district in which the boring is being carried out, or any other duly authorized officer of the Government.

(b) An initial instalment of £25 in respect of each borehole shall be deposited with the Director of Irrigation or with any other duly authorized officer of the Government before the drill proceeds to the site at which boring is to take place

(c) The first instalment of (1) one-sixth of the balance of the boring charges including interest at the rate of 6 per cent. per annum calculated from the date of completion of boring operations in respect of each borehole, shall become due and payable six months from the date of such completion and a further such (1) one-sixth each succeeding six months.

(d) If the lessee of a Government farm desires to pay for the boring of a drill in such instalments covering a period of (5) five years, he shall provide two approved sureties, or other approved security for the due payment of such instalments to the Receiver of Revenue of the district in which the boring is being carried out, or any other duly authorized officer of the Government.

The initial instalment of £25 in respect of each borehole shall be deposited with the Director of Irrigation or with any other duly authorized officer of the Government, before the drill proceeds to the site on which boring is to take place.

(e) The first instalment of (1/6) one-tenth of the balance of the boring charges including interest at the rate of 6 per cent. per annum calculated from the date of completion of boring operations in respect of each borehole, shall become due and payable six months from the date of such completion, and a further such (1/6) one-tenth each succeeding six months.

(f) Attention is directed to certain provisions of the Land Settlement Act (as amended) dealing with boring for lessees of Crown lands and administered by the Department of Lands.

Submission of Applications.

6. (a) Every application for the hire of a drill shall be made on form marked "A" to the Director of Irrigation, Pretoria through the Magistrate of the district in which the property on which boring is desired is situated.

(b) On the receipt of an application on form "A" the Magistrate shall make such enquiries as are necessary to ascertain if the application is in order and, when satisfied, shall forward the application to the Director of Irrigation with his recommendation on form marked "B".

Acceptance of Application.

7. The acceptance or otherwise of an application shall be subject to the discretion of the Director of Irrigation, who may cause such inquiry to be made as he may consider necessary.

Notification of Acceptance of Application and Liability to Cancellation thereof.

8. Where an application has been accepted, notice of the acceptance on the form marked "C" shall be sent to the applicant but no such acceptance or notice shall be understood to render the Government liable to undertake boring for the applicant and the Director of Irrigation may cancel any acceptance and notice thereof, and in case those regulations are altered before boring is commenced on an applicant's property under the acceptance, the applicant will be informed of the revision and he may withdraw his application or renew it under the revised regulations within two months.

Notice of Availability of Drill.

9. (a) Written notice that a drill is available shall be given to the applicant, and in such notice shall be set forth the date and hour from which he shall take over the drill. If on the expiry of such notice the applicant shall not have taken over the drill the acceptance of his application may be cancelled, and the applicant shall, if required, pay the full charges as prescribed by the terms of payment applicable for any delay caused.

(b) The taking over of the drill shall preclude the applicant from any denial of liability for its hire.

(c) The cancellation of his application after notice of the availability of a drill has been received by the applicant shall not relieve him from liability to pay full charges for any delay caused by such cancellation.

Classes of Government Drills.

10. The class of drill provided under these regulations shall be at the discretion of the Director of Irrigation.

The Drill Foreman.

11. (a) The Department shall provide a foreman, who shall have the entire direct charge of the drill and boring operations.

(b) Should the applicant have any complaint to make regarding the foreman or his work, he shall reduce it to writing and shall forward it without delay to the Director of Irrigation, who shall inquire into the matter. No payment for his services shall be made to the foreman by the applicant.

Labour.

12. The Department shall provide, free of charge, the labour required for working the drill, but shall not provide labour for carriage of water and fuel, or additional labour required for unloading, erecting, dismantling, and loading of the plant.

Transport.

13. (a) The Department shall bear the cost of transport of the drill appliances, drill staff, and baggage to the railway station nearest the farm of the applicant who first hires the drill in any district, or in the case of districts remote from the railway to some convenient central place fixed by the Director of Irrigation.

(b) The applicant who hires the drill first in any district shall provide transport for the drill, its appliances, the drill staff, and baggage from the railway station or centre to his farm, and shall use all expedition in this respect.

(c) A succeeding applicant shall similarly provide transport from the previous farm to his own farm, and the last applicant shall, if required, provide transport back to the nearest railway station or centre.

(d) The applicant shall provide transport between his farm and the railway station or such other centre as may be selected for the expeditious conveyance of machinery and stores required to conduct boring operations.

(e) The applicant shall provide the foreman with means of communication to and from the nearest post and telegraph office at least once a week.

Casing.

14. (a) The Department may provide, free of charge, casing required to line a borehole up to a maximum length of 60 lineal feet of casing approximately 6 inches in diameter; any casing required in excess of the maximum length above specified will be supplied at actual cost.

(b) If the nature of the deposits or rock being bored necessitates an increase or reduction of the diameter of the borehole and the employment of casing of a greater or lesser diameter than 6 inches, the length of such casing supplied free of charge will be equivalent in value to the 60 feet of 6 inch casing above specified.

(c) The amount of casing required to line any borehole effectively shall be at the sole discretion of the Director of Irrigation.

Working Hours

13. Working hours shall be calculated on a basis of nine hours per day except on Saturday afternoon which shall be considered a half-holiday. No work shall be done on Sundays.

Supplies by Applicant

14. *(a) Drill staff.*—The applicant shall supply at his own cost such labour, additional to the drill staff, as may be required for the unloading, erecting, dismantling, and loading of the drill, appliances, and equipment.

(b) Water and Fuel.—The applicant shall supply and transport at his own cost sufficient water and fuel of good quality for the efficient working of the drill and for the use of the drill staff.

(c) Provisions for Drill Staff.—The applicant shall either supply food for the drill staff by private arrangement and at reasonable prices or shall transport such provisions at his own cost at least once a month, from the nearest railway station or from a store as may be required.

(d) The applicant shall generally give such other assistance as the foreman may require to perform his work efficiently.

Cessation of Operations

15. Boring operations may be stopped—

when a fair and reasonable supply of water has been obtained in a borehole;

[illegible]

[illegible] of the Director of Irrigation when there [illegible] of the drill or appliances being damaged or [illegible] results from further boring are improbable;

[illegible] Director of Irrigation when a depth [illegible] reached.

Responsibility for Success

16. The Department does not guarantee any successful result from boring operations. The undertaking shall therefore, be entirely at the risk of the applicant, but every reasonable assistance towards a successful issue of the work will be readily given.

Limit of Number of Boreholes

17. The number of boreholes drilled on any one property under one application shall be at the discretion of the Director of Irrigation.

Special Conditions

18. (a) When necessitated by the nature of the ground to be bored in, or by difficulty in getting to the site, or when additional work is required to be done to an existing borehole, or under any other exceptional circumstances, the Director of Irrigation may impose special conditions in addition to the ordinary terms of payment applicable under which boring shall be carried out, but the work shall not be undertaken or continued unless the applicant shall have notified in writing his acceptance of such conditions.

(b) The Director of Irrigation reserves the right to impose special conditions of hire and higher terms of payment in the case of boring operations being undertaken for companies, syndicates, or other bodies, or in prospecting for minerals.

Cores

19. All cores obtained in drilling shall be the property of the Government. The applicant, however, may examine them and may, if he desires, have pieces for analytical purposes.

Charges for the Hire of a Drill.

20. The charges to be paid for the hire of a drill, excepting as provided for in paragraphs 15 and 21 of these regulations, shall be—

(a) for the first day while the drill and appliances are being erected, the sum of £2. 10s.;

(b) for each day when, owing to the nature of the boring site, the time spent in erecting the drill exceeds one day, the sum of £5;

(c) for each day on which operations are conducted after the drill has been erected, the sum of £5;

(d) for each day not exceeding two days of 9 hours each on which the yield of water from a borehole is being tested, including the erection and dismantling of the pump, the sum of £2. 10s.;

(e) for each day in excess of two days of 9 hours each on which pumping tests are conducted, the sum of £5;

(f) for each day on which pumping tests, independent of boring operations, are conducted, the sum of £5;

(g) for each day on which operations are delayed owing to the fault of the applicant or his failure to supply essential services, the sum of £5 or £2. 10s., at the discretion of the Director of Irrigation;

(h) for each day while the drill and appliances are being dismantled, the sum of £2. 10s.;

(i) for each day in excess of one-half day occupied in transporting the drill and appliances from one boring site to another on the same farm or property, the sum of £2. 10s.;

(j) the cost of repairing any breakage or damage for which the applicant or his agent is responsible;

(k) no charge will be made for periods during which a drill may be stopped on account of bad weather, a breakdown not due to the applicant, or of the illness of the drill foreman.

Rebates.

21. (a) When the measured yield of water from a borehole is less than 1,440 gallons per 24 hours (one gallon per minute), the rate of £5 per diem will be charged for the first ten days on which operations were conducted, and for days in excess of this the sum of £2. 10s. will be charged for each day on which operations were continued in such borehole, provided that the amount to be paid at the £5 rate for any borehole shall not be less than £50.

(b) When the measured yield of water from a borehole is 1,440 gallons or a greater quantity per twenty-four hours, the rate of £5 per diem will be charged for the first twenty days on which operations were conducted, and for days in excess of this the sum of £2. 10s. will be charged for each day on which operations were continued in such borehole, provided that the amount to be paid at the £5 rate for any borehole shall not be less than £100.

(c) When the measured yield of water from a borehole is less than 1,440 gallons per twenty-four hours, and no casing has been left in such borehole, a deduction of £10 will be made from the boring charges, provided such deduction does not reduce the charges for the borehole below £50. No rebate shall be allowed under this clause in respect of a borehole in which any casing has been left, irrespective of the length of casing inserted, or of the quantity of water obtained.

CHAPTER VIII.

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WATER LAW IN KENYA.

PART I.

HISTORY AND PRESENT STATE OF THE LAW.

149. If we except certain Indian Acts, which have been applied in the Colony (none of these Indian Acts are of importance in connection with water law), the basic law of the Colony is the English Common Law as modified by Statutes or Ordinances of the Colony. The following extracts from Government Notice No. 337 of 1921 set out the above generalisation in greater detail:-

"4 (2) Subject to the other provisions of this order, such Civil and Criminal jurisdiction shall, so far as circumstances admit, be exercised in conformity with the Civil Procedure and Penal Codes of India and the other Indian Acts which are in force in the Colony at the date of the commencement of this order, and subject thereto and so far as the same shall not extend or apply shall be exercised in conformity with the substance of the Common law, the doctrines of equity and the statutes of general application in force in England on the 12th day of August 1897 . . . save in so far as . . . (the above) may at any time before the commencement of this order have been or hereafter may be modified, amended or replaced by other provisions in lieu thereof by or under the authority of any order of His Majesty in Council or by any Ordinance or Ordinances for the time being in force in the Colony. Provided always that the said Common law doctrines of equity and the statutes of general application shall be in force in the Colony so far only as the circumstances of the Colony and its inhabitants permit and subject to such qualifications as local circumstances render necessary."

"7. In all cases, Civil and Criminal, to which natives are parties, every Court (a) shall be guided by native law so far as it is applicable, and is not repugnant to justice and morality, or inconsistent with any order in Council or Ordinance, or any regulation or rule made under any Order in Council or Ordinance; and (b) shall decide all such cases according to substantial justice without undue regard to technicalities or procedure and without undue delay."

Only two ordinances of the country have dealt with water, namely, the Crown Lands Ordinance of 1902 (which we shall call C.L.O. 1902) and the Crown Lands Ordinance of 1915 (which we shall call C.L.O. 1915). The latter repealed the former.

180. We have, therefore, to look for our Law on the subject in the following order:- 526

(a) To English Common Law, so far only as circumstances permit, and subject to such qualifications as local circumstances render necessary;

(b) To modifications introduced by C.L.O. 1908, which was of force until 1915;

(c) To C.L.O. 1915, which is the ordinance in force to-day.

181. We shall see later that it is a matter of uncertainty as to how far, if at all, C.L.O. 1908 modified the Common Law and, therefore, the latter is of importance in regard to rights acquired prior to 1915.

C.L.O. 1915 certainly did make considerable modifications in the Common Law, especially as to the rights in regard to "extraordinary" use of water (e.g. for irrigation), but again it is a matter of uncertainty as to how far, if at all, the rights of riparian owners in respect of "ordinary" or "primary" use of water (i.e. for the support of human and animal life and domestic purposes) were modified. As it is probable, therefore, that some of the Common Law principles still prevail, it is necessary for a complete understanding of the law of the Colony that we should learn something of the English Common Law in respect to water. We must necessarily be brief and touch only on the general principles, without going into too much detail or too much elaboration of exceptions to general statements. The portion dealing with the "ordinary" or "domestic" use of water is of most importance, but it is convenient to deal with the whole subject of Common Law in one place, so as to note some of its undesirable features and thus guard against any tendency to include these in future legislation. As we shall see, too, it has been held that it remained almost of full force until 1915.

ENGLISH COMMON LAW.

182. The Common Law divides waters into private and public. Private waters are those which belong to an

individual owner and include rain water falling on his own land and such flows of water either dispersed over his land (resulting, for example, almost directly from rain) which do not run in defined channels, or which cease for the greater part of the year. The intermittent rivers did not receive much consideration in Anglo American, but in the South African Courts it has been held that under the Common Law the "dry" rivers are not public rivers and, therefore, the law of "priority of position" holds on such rivers. A proprietor can appropriate them while on his property in the same way as a herd of wild animals.

Another class of private water is the spring water which comes out of the earth on a man's own farm and exhausts itself within his boundaries before reaching a defined channel. Perhaps the most important class of private water, however, is the under-ground percolating water, which can be tapped by means of wells or boreholes. This water belongs to the owner of the land and he can do with it whatever he likes, even though in the course of extracting it he should reduce the strength of water in his neighbour's well or borehole. He might, however, be held liable, if in the course of his pumping operations he c[illegible]ny sort of subsidence in his neighbour's property.

103. Apart from this private water, all other water running in defined channels above or under ground is public water. The State, as such, has no claim to this public water, nor can any individual claim dominium in the water. All that he can claim is a right of user. It is like the air we breathe; no one possesses it, but everyone has a right to use it. Water is, however, different from air in that it runs in channels and in a particular direction, i.e. downhill. The law is that everyone over whose property the public water flows has a right to use it, consistently with the rights of others, and, for human and animal consumption, all who have a right of access to it can use it.

The right of access is important, and no access over private property is difficult to acquire by the Public, except along roads, etc., the necessity for access to the water has led to one of the essential features of Common Law, namely, that the right of user is practically confined to properties whose owners have access to the water, i.e. in general, to riparian properties.

154. If we ignore, for the moment, navigation and fishing rights, the right of user in public waters amongst riparian owners falls into two classes with important distinctions, namely -

(1) ordinary or primary use for domestic purposes, and for the support of human and animal life;

(2) extraordinary or secondary use, which is for all uses other than those which fall under (1), e.g. for irrigation and manufacturing uses.

Use under (1) takes precedence over use under (2), that is to say, there can be no extraordinary use until all the requirements of ordinary use are satisfied.

There is a very big difference in the manner of using or quantity of use in each class. Under class (1) "priority of position" holds, that is to say, an upper proprietor can use as much water as he requires for ord[illegible] purposes without considering a lower proprietor, and in turn he gets no consideration from a proprietor above him on the stream; not even if an upper proprietor exhausts the whole supply and deprives the lower proprietor of any water, provided that the upper proprietor uses the water for ordinary purposes only. On the other hand, if an upper proprietor, by using the water for extraordinary purposes, (e.g. for irrigation) should deprive the lower proprietor in the least of his full requirements for ordinary purposes, the latter would have a claim for injunction and damages. In brief, ordinary use has priority over extraordinary use, and among those using the water for ordinary purposes priority of position holds, whilst among owners using the water for extraordinary purposes, priority of position

has no place whatsoever. This is the important distinction between rights for ordinary and extraordinary uses.

155. For extraordinary use the law is exceedingly vague, and in countries where the quantity of water in the rivers is small in comparison with the demands made upon it, the law inevitably leads to stalemate. In effect, the law is that every owner along the stream can claim to have the water reach his property in such state and quantity that he may make full and proper use of it for all extraordinary purposes, subject to the similar rights of all the riparian proprietors.

As every proprietor is bound by the same conditions, the net result would be that when there is a shortage of water for all requirements, they all would have to abate their requirements; but on what basis any abatement is to be made it is impossible to say, because there are many kinds of extraordinary uses which cannot be compared with each other. For example, how can we abate when one person claims water for irrigating 100 acres and another below him claims water for a 100 horse-power turbine, if there is not sufficient water for both?

156. The matter is further complicated by the fact that there is no principle involving priority of time in the English Common Law; that is to say, those who develop early have no superior right against those who develop later, or even against those who do not develop at all. Whatever rights a riparian owner may have, remain his for all time, even though he may never construct the works necessary to make use of them. The one exception to this is in regard to rights acquired by prescriptive use, which, however, can only be acquired by an upper proprietor against a lower proprietor, and not by a lower proprietor against an upper proprietor, because the lower proprietor cannot as a rule use the water adversely against the upper proprietor, and adverse use is essential to establish a prescriptive right.

167. Moreover, there is no provision or method or machinery for ascertaining or defining the rights of proprietors along a stream. If a lower proprietor considers that his rights have been infringed by an upper proprietor, he may bring a case against him; but that will only settle the matter between these two proprietors, and with regard to all the others along the stream, the same state of uncertainty exists. There is always the danger that the indefinite rights of proprietors, which they may exercise at any future time, will be exercised or may be infringed, and there is no means of ascertaining what these rights are. The consequence is that for every undertaking involving a large demand upon the waters of a river, the only method, apparently, of acquiring a definite right is to proceed to Parliament with a Private Bill, after making elaborate negotiations with all people, who may consider themselves to be affected, for compensation, either by passing down compensation water, or by money payments.

168. The great defect of the Common Law, therefore, in regard to extraordinary use is the uncertainty and indeterminable nature of the right - "Misera est servitus ubi ... est vagum aut incertum". There is no easy method provid... for ascertaining definitely what one's rights are, before embarking on an expensive enterprise for the use of water. Should one chance an enterprise based on a more estimate of water rights, there is a risk of most expensive litigation and a danger of losing a great deal of capital put into the work. Moreover, there is no reward for enterprise, the man who sits still on his rights having as much consideration as the man who makes use of the water for his own good and the good of the State.

169. These are difficulties of the Common Law in any country where the water supplies are limited and where the extraordinary uses of water are a very important considera-

tions. In Kenya there are further difficulties arising out of the nature of the population and, therefore, before passing from Common law to the Ordinances of the country, it would be as well to review a few facts in regard to the local conditions - the nature of the rivers, the population and the system of land tenure, not only because these are very different from the conditions in countries whence the Common Law has sprung, but also because it is necessary to have some of these facts clearly in mind before we can understand the significance of the local ordinances.

160. The nature of the water supplies and rivers will be gathered from previous parts of this report and we need only point out here how very different the rivers are in Kenya from those in Europe. Take, for example, those originating from the Highlands and flowing eastwards towards the Indian Ocean. Most of the permanent water is derived from the high country lying above an altitude of 6000 feet, which is several hundreds of miles from the coast. From there downwards towards the coast the permanent flow rapidly diminishes, so that only two rivers of any size reach the Indian Ocean, namely, the Tana and the Athi. Navigation in the fresh water reaches is confined to canoes and is not a serious consideration.

161. Then, with regard to the population; this is exceedingly mixed and of varying degrees of civilisation, persons of a low scale of civilisation predominating enormously. The population can be divided into three broad groups, namely (1) Europeans (2) Indians and (3) Natives and Arabs. The numbers roughly are -

Europeans	...	12,000
Indians	...	15,000
Natives and Arabs	...	2½ million.

With such a state of population, the Common law idea of equal public rights in water for everyone is naturally out of the question. Indeed, in land matters

and in representation in Government such equal rights are not recognised. Then, whereas in European countries there is very little Crown land and most of the land is in private ownership, a considerable portion of which is freehold, in Kenya, out of a total area of less than 160 million acres, over 100 million acres remain as Crown land, and of the balance, about 50 million acres are reserved for native tribes, amongst whom communal tenure is the rule, individual tenure being hardly recognised, and less than 6 million acres have been surveyed into farms, only a very small proportion of which is freehold. The surveyed farms are occupied almost entirely by Europeans, though a very small area, chiefly in the low lands, is occupied by Indians. These conditions are very different indeed from those in the European countries, and they should be kept in mind in guarding against considering the Water Law only from the point of view of the European population, which, as we have seen, forms a very small proportion of the total population and occupies an exceedingly small portion of the total area of the country. At present, however, we look to this small European section to provide most of the development and enterprise involving the use of water and, therefore, the position of the European in the count requires a little more consideration.

163. The first thing to be pointed out is that the European has become an important factor in the country only within recent years. Less than 60 years ago the interior of the dark continent was an unknown book to white people. Lake Victoria Nyanza was not seen by Europeans before 1858, and Lake Naivasha not before 1883. Great Britain's public interest in the country dates from 1886, when by International Treaty the possessions of the Sultan of Zanzibar were defined to include a ten mile strip along the coast and the rest of the country was divided into spheres of influence between Germany and Great Britain.

Great Britain cannot be said to have

owned any land in the country until 1888, when the Imperial British East African Company was formed to work a concession of the coast possessions of the Sultan of Zanzibar. Operations of the Company were chiefly confined to areas near the coast. Owing to difficulties encountered, they surrendered their claim to the British Government in 1895, when a Protectorate was proclaimed.

Up to that time practically no titles to land were recognised, or grants made, outside the coastal strip; and in inland areas, I believe, there are only two cases of freehold grants prior to that date, which are recognised at the present time. One is an area, at present not defined, in the neighbourhood of Kilimanjaro and the other is an area sold in 1891 by Kilundu, representing the Ukamba people, to the East African Scottish Mission in the neighbourhood of Kibwezi. In 1893 this sale was confirmed by the Company in the following words - "The Imperial British East African Company does hereby grant, transfer and convey to the East African Scottish Mission at Kibwezi and successors, 100 square miles to have and to hold in perpetuity forever, so far as their power enables them to do so". The Company appears to have been in doubt as to whether it had any right to grant or sell land.

163. After the Imperial Government had taken possession, regulations were published in 1897, enabling the grant of leases for 99 years for land not occupied by natives; but Europeans were not attracted to the country until after the completion of the Uganda railway in 1901.

European settlement might be said to have begun in the following year, 1902, when the C.L.O. 1902 was passed. Up to that date, apart from the 100 square miles granted to the Scottish Mission round about Kibwezi, not more than 500 acres had been granted. C.L.O. 1902 provided for grants of land (a) as freehold and (b) as leasehold for 99 years; but the tendency was to restrict all grants of freehold,

and, indeed, no freehold grants were made after 1913. In 1915 the C.L.O. of 1915 was passed, the chief alteration being the increase of the leasehold period to 999 years and the practical elimination of freehold grants. Every encouragement was given to convert old freehold grants into leasehold.

164. It will thus be seen that European settlement is hardly more than 30 years old, that an exceedingly small portion of the country is occupied or can be occupied by Europeans, and that occupation by Europeans is chiefly leasehold. The native reserves even form a small portion of the whole area and in them tenure is tribal or communal and not individual; in fact, the Crown is really the owner of these reserves. The bulk of the country is Crown Land, much of it uninhabited and a very large area uninhabitable.

In the above circumstances, it will be understood, apart from the peculiar physical conditions, that the Common Law principles are totally inapplicable to the conditions of the country, as they assume private ownership of land and a sort of equality or proportionality of right amongst all owners.

165. We can now proceed to consider the first Ordinance which dealt with water, namely, the C.L.O. 1903. The following are extracts from this Ordinance of Sections bearing on the question of Water Law.

EXTRACTS FROM C.L.O. 1903, NO. 21 OF 1903.

WATER:

3. A CONVEYANCE, LEASE, OR LICENCE FOR THE TEMPORARY OCCUPATION OF CROWN LAND UNDER THIS ORDINANCE SHALL NOT CONFER ANY RIGHT TO MINERALS IN OR UNDER THE SAID LAND, OR TO THE WATERS OF ANY RIVER OR LAKE.

14. Except where expressly varied or excepted, there shall, by virtue of this Ordinance, be implied in every lease under this Ordinance covenants by the lessee -

(d) To permit travellers to encamp with their servants, animals, wagons and baggage, for a period not exceeding forty-eight hours, on any part of the land leased which is uncultivated, and which is not within a quarter of a mile of a dwelling-house, and to allow them access, with their servants and animals, to any river, stream or lake upon the land leased.

TRAVELLERS RIGHTS OF ACCESS TO WATER.

29. (1) Travellers shall be allowed to encamp with their servants, animals, wagons, and baggage, for a period not exceeding forty-eight hours, on any land purchased or leased from the Crown under this Ordinance, which is uncultivated, and which is not within a quarter of a mile of a dwelling-house, and shall be allowed access with their servants and animals to any river, stream, or lake upon the land.

(2) Any person refusing to allow travellers to encamp, or to have access to water, under this section, or interfering with travellers who are encamped, or any traveller refusing after request from the owner or lessee of the land to depart after the expiration of the forty-eight hours, or interfering in any way with the comfort or convenience of the owner or lessee of the land, shall be guilty of an offence, and shall be liable to a fine not exceeding 1,000 rupees, or to imprisonment of either kind not exceeding two months, or to both.

EXPLORATION, RESERVATIONS AND COMPENSATION.

23. (1) The Commissioner may at any time enter upon any land sold or leased under this Ordinance, and there set up telegraph lines across such land or may lay sewers, water-pipes, or electric lines therein, without paying compensation, but making good all damage.

(2) The Commissioner shall not be entitled under this Section to interfere with any dwelling-house.

24. Where any sale or lease of land under this Ordinance transfers more than 100 acres, the Commissioner may at any time hereafter enter upon such land and construct railways, canals and roads for the benefit of the public across such land without making compensation for the land, but compensation shall be payable for all buildings destroyed or damaged.

25. Where any sale or lease of land under this Ordinance transfers less than 100 acres, the Commissioner may at any time hereafter enter upon such land and construct railways, canals and roads for the benefit of the public across such land, paying compensation for the land.

26. The Commissioner may at any time hereafter enter upon any land sold or leased under this Ordinance, and there construct railway stations, sidings or any other public works, paying compensation for the land.

27. (1) The Commissioner may at any time hereafter enter upon any land sold or leased under this Ordinance, and take therefrom stone and other materials for the making or repairing of roads, railways, canals or other public works.

(2) If the materials are taken from cultivated land, compensation shall be payable by the Commissioner, but not otherwise.

28. The Commissioner may by writing under his hand authorise contractors, their servants and agents, to exercise the powers conferred upon him by section 23-26 inclusive of this Ordinance.

DEVELOPMENT:

. . . . Implied covenants by the lessee

14. (a) To use and develop the natural resources of the land leased with all reasonable speed having regard to all the circumstances of the case.

15. In all building leases granted under this Ordinance there shall, by virtue of this Ordinance, be implied, unless such covenants are expressly varied or excepted, covenants by the lessee -

(c) To provide reasonable drainage and water supply, having regard to the situation and purpose of the building and the health of the neighbourhood.

16. In all leases under this Ordinance of areas of land for the purposes of agriculture or breeding or raising cattle, or for the growth of india-rubber, cotton, tobacco or other vegetable productions, or as a timber forest, there shall, by virtue of this Ordinance, be implied, unless such covenants are expressly varied or excepted, covenants by the lessee -

(a) To improve and develop the resources of the land in a prudent and businesslike manner, and to abstain from the undue destruction or exhaustion of any timber, trees or shrubs for the sale or cultivation of which the land is leased;

NATIVES:

30. In all dealings with Crown Land regard shall be had to the rights and requirements of the natives, and in particular the Commissioner shall not sell or lease any land in the actual occupation of the natives.

. . . Covenants implied by the lessee -

16. (b) That the lessee, his servants and agents, will not interfere with the settlements or villages of the natives, or with land allotted for native settlements or villages, and, so far as possible, will avoid all quarrels with the natives in or near the land leased.

(c) To refer all disputes between the lessee, his servants or agents, and the natives in villages or settlements in or near the land leased to the Collector of the district.

REGULATIONS:

33. The Commissioner may make rules with regard to the following matters, and generally for carrying into effect the provisions of this Ordinance, and may apply such rules in whole or in part to the whole or to any district or districts of the Protectorate.

(No reference to Clause 3 or to water).

34. The Commissioner may by rules under this Ordinance prescribe the forms of conveyance, etc., (no reference to water).

166. Under Section 38 of C.L.O. 1902, rules were made in the following year, 1903, and again in 1909, but, as both these sets of rules have been held in the Courts to be ultra vires, we should not allow them to influence our interpretation of the Ordinance. As we shall see, when we come to Case Law, there have been two conflicting interpretations of the main principle of the Ordinance.

In the first case - Booker versus Secretary of State (1909) - Judge J.M. Barth held that "all right to the waters of a river is vested in the Crown and would so vest if the whole length of such river were within the Plaintiff's boundaries" and that "it is clear that the legislature intended to prevent riparian owners acquiring rights which otherwise they might have acquired".

At a later date (1918) in the case of Jamal versus Singh, Judge Pickering held that "Section 3 of the C.L.O. 1902 is merely declaratory of the Common Law, except, possibly, with regard to lakes"; that ownership of the water itself and the right of user in the water should be distinguished; that section 3 repeats the Common Law doctrine, namely, that there is no ownership of the water in a public stream; th stream of water running in a defined channel is not capable of being granted"; but that it is clear that the Common Law rights of user remain to riparian owners and should be recognised. This, being the later judgment, even if it does not over-rule the former, conveys the present interpretation of the Ordinance. It is true that all the actions of the Administration, in granting water permits, etc., were based on the former interpretation of the Ordinance; but it is difficult to see how that interpretation can be justified.

English Common Law formed the basis of the Law of the country. This is the first Ordinance dealing with water. Ordinances are "declaratory or remedial according to the different nature of their objects or provisions.

Declaratory Ordinances are where "... Parliament has thought proper, in perpetuum rei testimonium and for avoiding all doubts and difficulties, to declare what the Common Law is and ever hath been. Remedial ordinances are such as supply some defect in the existing law or redress some abuse with which it is attended". If we compare the statement of the law as contained in this Ordinance with the summary of the English Common Law given in previous pages, it is difficult to come to any other conclusion than that this Ordinance is merely declaratory of the English Common Law, the conclusion arrived at by Judge Pickering. At the very least, the owner must retain certain Common Law private rights in water and certain rights for ordinary use. Section 3, for example, only mentions rivers and lakes. Waters of springs, waters falling on land and underground percolating waters are not mentioned in the section and, therefore, according to Common Law, remain the private property of the owner.

Then, Sections 14(d) and 20(1) and (2) give ordinary rights to travellers. Would it be reasonable to deny to an owner of property rights which are given to travellers over his property? Moreover, in Sections 14(e) and [illegible] the owner is expected to use and develop the natural resources of the land with all reasonable speed and in a prudent and businesslike manner, and in 15(c) to provide water supply for buildings. How can he be expected to do these things, if he has no right to the use of the water flowing over his property? And if he has any right at all, it does not seem to be correct to say that all right to the waters of flowing rivers is vested in the Crown, and even to go so far as to say that he has no right when the whole length of the river lies within his ground.

The important Section 3 seems only to declare the Common Law principle that there is no right of dominium in public waters, but not to remove the Common Law

right of user. If there had been any intention to deny this latter right to riparian owners, then it should have been stated in more precise language and some means should have been provided in the Act indicating the manner in which such right can be acquired. It is absurd to think that it is meant that the water should simply flow through riparian properties and that no owner should be allowed to use it even for ordinary purposes. It is clear, however, that the administrative officers considered that the Ordinance did alter the Common Law principle very considerably and that it was necessary for a riparian owner to acquire a permit from the State for use of water for extraordinary purposes, and also in some cases for ordinary purposes.

The rules of 1903, subsequently declared to be ultra vires, were obviously framed on this assumption. It is possible that Judge Barth was influenced by these rules when he stated that "it is clear that the legislature intended to prevent riparian owners acquiring rights which otherwise they might have acquired". If the rules are ultra vires, we can only look to the ordinance and the Common Law together to see what was the intention of the legislature.

In interpreting an ordinance "the general rule is that the language is to be read according to its ordinary grammatical construction, unless no reading it would entail some absurdity, repugnance or injustice. One recognises that rule where the repugnance arises between the words of the section to be construed and those of some other section in the same Act or in some other Act which is in pari materia with it" (Broom p. 5 & 6).

As indicated above, it is considered that the only interpretation which does not lead to repugnance and absurdity is that the 1903 Ordinance was merely declaratory of the Common Law. A point worth considering, however, is that in the countries where the Common Law has originated,

most of the Crown Land has passed into private ownership. In Kenya exactly the reverse is the case, the Crown being still the largest owner and at the date of C.L.O. 1902 almost the sole owner.

167. The following are extracts from the first rules published in the Official Gazette of January 1st, 1903:

EXTRACTS FROM RULES (THE OFFICIAL GAZETTE OF JANUARY 1, 1903).

"Rules made under the Crown Lands Ordinance cannot in any way abrogate that Ordinance but merely supplement its provisions".

"The present rules deal only with Agricultural land".

"Rules for the purchase of land under the Crown Lands Ordinance 1902".

6. "No stream or piece of water which extends beyond the limit of one holding may be dammed up diverted or in any way interfered with either directly or indirectly (for instance by sinking a well so near it as to draw off water). Provided that the leave of the land officer in writing may be obtained to dam up, divert or use water in any other way for temporary purposes for a period of not more than 1 year and provided that for periods exceeding 1 year a Crown lease for water may be granted".

7. "All lands purchased from the Crown shall be subject to any irrigation rules that may be hereafter made".

11. "No sewage filth or refuse shall be allowed to enter into or foul in any way any lake, pond, stream or water course."

These rules seem to recognise an owner's right in [illegible] waters, but in regard to public waters, the principle that no use of the water could be made without a permit from an officer of the Government was introduced. Even ordinary use, i.e. for domestic purposes, without a permit seems to be excluded. These provisions are obviously contrary to the Common Law, but as the rules have been declared ultra vires, we will not consider them in further detail especially as a search in the registers of water permits discloses the fact that not more than 3 permits, at present uncancelled, were issued previous to 1909, when the second set of rules was published.

168. The 1909 rules are as follows -

THE OFFICIAL GAZETTE, JUNE 1st, 1909, PAGE 865.

IRRIGATION RULES.

Irrigation projects will in future be classed as follows:-

CLASS I.A. Public Works Irrigation Projects, Major.
CLASS I.B. Public Works Irrigation Projects, Minor.
CLASS II. Private Irrigation Projects.

The Rules regarding CLASS I.A and I.B will be issued hereafter.

The following Rules have been approved by the Governor for CLASS II.- PRIVATE IRRIGATION PROJECTS.

1. Under the Crown Lands Ordinance 1903, a conveyance, lease, or licence for the temporary occupation of Crown land, does not confer any right to the waters of any river or lake.

Under the Crown Lands Ordinance 1903, such conveyance, lease, or temporary licence shall not, unless otherwise expressly provided, confer any right to the waters of any river, lake or stream, other than to such water as may be required for domestic purposes upon the land held, leased or occupied.

2. No landholder may construct a water furrow on his land without permission. The application must be made to the Land Officer, who will note on it what land the applicant holds, and the length of river or water frontage, and then forward it to the Commissioner of Public Works.

3. The Commissioner of Public Works will thereupon, in consultation with the Land Officer, direct an enquiry to be made by a Committee consisting of an officer of the Land Department, one from the Public Works Department, and two landholders. If it is proposed to take water out of, or through a Native Reserve, the Provincial Commissioner must be informed that he may direct the District Commissioner to attend the Committee.

4. The Committee will submit a report to the Commissioner of Public Works on the proposed project, the Officer of the Public Works Department supplying the necessary professional information. Special regard must be had to the claims of the other landholders on the water.

Each case will be decided on its merits, and the applicant must abide by such conditions as may be imposed on him by the Commissioner of Public Works after considering the Committee's report.

5. The over-flow of water used for private irrigation purposes must be returned to the river, lake or stream by each landholder within the boundaries of his farm, unless otherwise directed in writing by the Commissioner of Public Works.

6. Should the demand for irrigation from a river, lake or stream hereafter increase, owing to an increase in the number of farms, or for other reasons or should the water in the river, lake or stream become unduly diminished from any cause, the Governor reserves the right to make a redistribution of the water on an equitable basis, and all persons shall comply with any orders which may be issued for this purpose.

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7. It will be the duty of the officers of the Public Works Department from time to time to inspect the rivers, lakes and streams, and the irrigation works on them, in order to see that the conditions relating to each such work are properly observed.

8. No charge will be made for water used for irrigation purposes by persons authorised to use the same under these rules until March 31st, 1915.

The Governor reserves to himself the right to charge an irrigation rate at the end of this period, if after full enquiry such rate is justified.

9. Every privilege permitted under or by virtue of these rules shall be subject to any Irrigation Rate which may hereafter be made, and may at any time be disqualified by the Governor for failure to comply with any condition or order or if the Governor shall be satisfied that such cancellation is required in the public interest.

10. The Commissioner of Public Works may permit officers of the Public Works Department to assist Settlers by their advice in the construction of private irrigation works, (when the services of a qualified Civil Engineer in private practice and with experience in Irrigation Schemes are not available).

There shall be paid by the Settlers to the Government for the services so rendered by officers of the Public Works Department such fees as the Governor may from time to time determine.

COMMISSIONER FOR PUBLIC WORKS.
May 17th, 1000.

These rules were also held to be ultra vires; but over 200 permits (at present uncancelled and registered in the office of the Director of Public Works), were issued under them on 1909 and 1910. In the latter year the C.L.O. 1915 was passed; but the rules required by this Ordinance were not published before 1919, and between 1915 and 1919 more than 150 further permits were issued under the 1900 rules.

These rules are only of interest as indicating the development of the administrative views.

Under Clause 1, a right to public waters for ordinary purposes is recognised. Under Clause 2, a water furrow may not be constructed without permission, though nothing is said about power development. Under Clause 3, a Committee was designated, but, so far as I can gather, such Committees were rarely convened. Under Clause

6. "special regard must be had to the claims of other landholders in the water". Each claim is decided on its merits and the final decision is made by the Commissioner of Public Works. He takes the place of the Commissioner of Lands. There is nothing to indicate whether the "claims" to be considered are based on Common Law or on priority of time or priority of position; whether irrigation has any priority over power; or, in fact, what principle will guide the hand of the Public Works in coming to his decision. Clause 6, however, destroys the idea of any sort of guarantee of right resulting from the issue of a permit. If priority of time is in any way a principle followed, the advantage of the principle in encouraging development by a guarantee of rights is very much curtailed by the uncertainty introduced by this clause.

Clause 7 throws the police duty on the officers of the Public Works Department.

Clause 8 implies that the State has the right to sell water. Clause 9 adds to the uncertainty of the right introduced by Clause 6. The cancellation is, however, by the Governor and not by a head of department, and must be in the public interest. Different Governors may have different views of what is in public interest and Parliament has to decide in every case.

The general impression of these regulations is that the tendency was to allow, with more certainty, rights for ordinary use of water, but to regard the water not required for ordinary use as belonging to the State, the State having the right through a single head of Department to grant rights by licence.

As previously stated these rules were ostensibly in force till 1910 and even later, although they were not legally of any force. Actually they were not always implicitly followed, as the Committee required in Clause 3 was not always constituted.

169. We now proceed to C.L.O. 1915, which repealed C.L.O. 1908.

The following are extracts from C.L.O. 1915 -

EXTRACTS FROM
CROWN LANDS ORDINANCE 1915
No. 12 OF 1915.

Repeal:

3. (1) The Crown Lands Ordinance, 1908, is hereby repealed.

Saving Clause:

So far as consistent with this Ordinance such repeal shall not affect -

(i) The past operation of the Ordinance hereby repealed.

(ii) Any agreement, lease or license heretofore granted or agreed to be granted, under the said Ordinance hereby repealed.

(iii) Any estate, right, title, interest, power, duty, obligation, liability or burden of proof created or imposed by or acquired or exercisable under the said Ordinance repealed hereby in respect of or under, or in relation to such agreement, lease or license.

(iv) Anything lawfully done or commenced or agreed or authorised to be done under or in pursuance of the said Ordinance repealed hereby in respect of or under or in relation to any such agreement, lease or license.

(v) Any divisions, exchanges, proclamations, reservations, rules, grants, appointments, payments, surveys, surrenders, disabilities, acts, proceedings, matters and things lawfully made, had, done, created or authorised by under or in pursuance of the said Ordinance repealed hereby.

(2) All such matters and things mentioned in the foregoing subdivisions of sub-section (1) of this section are, so far as consistent with this Ordinance, hereby preserved and continued and declared to be of the same force and effect as if the said Ordinance were still in force or as if they were under this Ordinance as the case may require.

"Crown Land" shall mean all public lands in the Protectorate which are for the time being subject to the control of His Majesty by virtue of any treaty, convention, or agreement, or by virtue of His Majesty's protectorate, and all lands which shall have been acquired by His Majesty for the public service or otherwise howsoever, and shall include all lands occupied by the native tribes of the Protectorate and all lands reserved for the use of the members of any native tribe.

"Live Stock" shall include horses, cattle, sheep, goats, swine, camels, mules, donkeys, ostriches and poultry.

"Prescribed" shall mean prescribed by this Ordinance or by any Rules or Regulations made thereunder.

6. The Governor, in addition to, but without limiting any other right, power or authority vested in him under this Ordinance may -

(1) Subject to the provisions of any Order-in-Council or to any general or special instructions of the Secretary of State, grant lease or otherwise alienate in His Majesty's behalf any Crown Lands for any purpose and on any terms and conditions as he may think fit.

8. The Governor shall appoint a Land Officer who shall have charge of the administration of this Ordinance, and shall further appoint such Assistant Land Officers as the Governor may deem necessary to transact the administration of the Ordinance and of any law regulating the sale, letting, disposal and occupation of Crown Land.

60. The First Schedule to this Ordinance including the rules therein shall have effect as part of this Ordinance.

61. Except where expressly varied or excepted there shall, by virtue of this Ordinance, be implied in every lease under this Part covenants by the lessee -

(1) That he will within the first three years of the lease effect or place on the land leased improvements of the nature and to the value specified in the First Schedule hereto as the improvements to be effected within such time upon a farm of the like area.

64. The Governor-in-Council shall, either by general or particular description and whether the same has been surveyed or not, reserve from sale, lease or other disposal under this Ordinance, any Crown Land which in his opinion is required for the use or support of the members of the native tribes of the Protectorate. Such reservation shall not confer on any tribe or member of any tribe any right to alienate the land so reserved or any part thereof.

67. The Governor-in-Council may at any time by Proclamation in the "Gazette" exclude from lands reserved under section 64 any land which may be required for any of the following purposes:-

1. Public works.
2. For public reservoirs, aqueducts, canals or water-courses.

without paying compensation except for buildings and crops destroyed or damaged.

75. A CONVEYANCE, LEASE OR LICENCE UNDER THIS ORDINANCE, SHALL NOT UNLESS OTHERWISE EXPRESSLY PROVIDED THEREIN CONFER ANY RIGHT TO THE WATER OF ANY SPRING, RIVER, LAKE, OR STREAM, OTHER THAN TO SUCH WATER AS MAY BE REQUIRED FOR DOMESTIC PURPOSES UPON THE LAND SOLD, LEASED OR OCCUPIED UNDER THE LICENCE.

76. A conveyance, lease, or licence under this Ordinance shall not unless otherwise expressly provided therein confer any right to the foreshore.

80. The Governor-in-Council may at any time enter upon any land sold, leased or occupied under this Ordinance and there do any work which he may consider necessary for maintaining or improving the flow of water in any river or stream on such land, and may construct and maintain dams or divert any river or stream without paying compensation except for buildings and crops destroyed or damaged.

89. When any land sold or leased under this Ordinance exceeds 800 acres or when land is occupied under a licence the Governor-in-Council may at any time enter and resume any lands for roads, railways, tramways, canals, water channels, trigonometrical stations and outspans, without making compensation for the land but compensation shall be payable for buildings and crops destroyed or damaged.

Provided always that in the event of a larger proportion than 4 per cent. of the total area of any land sold or leased under this Ordinance being taken for any such purpose or purposes there shall be paid to the purchaser or lessee, as the case may be, compensation for the land taken in excess of such proportion, such compensation shall not exceed the value of land taken in excess of the said proportion.

90. When any land sold or leased under this Ordinance is 800 acres in area or less the Governor-in-Council may at any time hereafter enter upon such land and resume any land for roads, railways, tramways, canals, water-channels and outspans paying compensation for the land taken.

91. The Governor-in-Council may at any time hereafter enter upon any land sold leased or occupied under a license under this Ordinance and resume possession of land for railway stations, sidings or other public works or whatever nature whether similar to those mentioned or not, paying compensation for the land taken.

92. (1) The Governor-in-Council may by writing under his hand authorize officers of the Government and contractors, their servants and agents to exercise the powers conferred upon him by sections 87 to 91 (both inclusive) of this Ordinance.

(2) Whenever under any of the sections in the preceding sub-section mentioned compensation is payable, such compensation shall not, in any case, exceed, in the case of buildings and crops destroyed or damaged, the market value of the buildings or crops, and, in the case of land resumed, the market value of such land.

(3) Resumption of land under this Part may be effected before the compensation (if any) is paid either by actual entry on the lands resumed, or by the service of notice of resumption on the occupier, purchaser, lessee or licensee.

(4) Whenever land which has been leased is resumed under this Part the lessee shall be entitled to a proportionate reduction in his rent.

REGISTRATION OF TRANSACTIONS AFFECTING CROWN LANDS:

100. All transactions entered into after the commencement of this Ordinance, affecting, or conferring or purporting to confer, declare, limit or extinguish any right, title, or interest, whether vested or contingent, to, in or over, land registered under this Part (other than a letting for one year only or for any term not exceeding one year) and all mutations of title by succession or otherwise shall be registered under this Part.

101. In any action, suit or proceeding to which the Crown or the Government is a party no right or title to the possession of land within such parts of the Protectorate as are at the date of the coming into operation of this Ordinance within the dominions of the Sultan of Zanzibar or the Sultan of Vitu, claimed under and in accordance with Mohammedan law, shall be recognised as against the Crown or Government unless the person claiming such right or title shall not only estab-

lish in himself such right or title but prove to the satisfaction of the Court that he or some predecessor in title was in possession or was entitled to possession of the land prior to the fourteenth day of December one thousand eight hundred and ninety-five.

144. No right-of-way shall be presumed or allowed to be asserted or established as against the Crown by reason only of user, whether such user commenced before or after the passing of this Ordinance.

145. SAVE AS IN ANY SALE DEED OR LICENCE OTHERWISE EXPRESSLY PROVIDED NO PERSON SHALL DAM ANY SPRING, RIVER OR STREAM OR DIVERT ANY WATER FROM ANY SPRING, RIVER, STREAM OR LAKE ON ANY LAND SOLD OR LEASED, OR OCCUPIED UNDER A LICENCE, UNDER THIS ORDINANCE OR ANY ORDINANCE REPEALED BY THIS ORDINANCE OR ON ANY VALLEY LAND FROM THE CROWN FOR THE PURPOSE OF THE PRESCRIBED OFFICER AND SURVEYOR TO SUCH CONDITIONS AS MAY BE PRESCRIBED BY RULES UNDER THIS ORDINANCE OR IN ANY LICENCE OR AUTHORITY GRANTED UNDER SUCH RULES.

ANY PERSON WHO SHALL, IN BREACH OF THE PROVISIONS OF THIS SECTION, DAM ANY SPRING RIVER OR STREAM OR DIVERT WATER FROM ANY SPRING RIVER STREAM OR LAKE, SHALL ON CONVICTION, BE LIABLE TO A FINE NOT EXCEEDING ONE THOUSAND FIVE HUNDRED RUPEES IN ADDITION TO THE EXPENSE OF REMOVAL OF THE DAM OR OTHER WORK ERECTED OR DONE IN BREACH OF THE PROVISIONS OF THIS SECTION, AND IT SHALL BE LAWFUL FOR THE PRESCRIBED OFFICER OR ANY PERSON AUTHORISED BY HIM IN WRITING, WITHOUT ANY WARRANT, FORTHWITH SUMMARILY TO REMOVE SUCH DAM OR WORK AND PREVENT SUCH DIVERSION, AT THE COST OF THE PARTY ERECTING THE DAM OR CAUSING THE DIVERSION.

153. Whoever shall, by materials of any kind, except by gates approved by the Governor, wilfully construct or injure any road street highway or waterway vested in the Crown, so as to hinder the free passage of any person carriage or vessel thereon, shall, on conviction, be liable to a fine not exceeding one thousand five hundred rupees, in addition to the expense of removal, and it shall be lawful for any Magistrate, Justice of the Peace, Land Master, Police Officer, or person authorised in writing by any Magistrate, without any warrant forthwith summarily to remove and prevent every such obstruction at the cost of the party causing the same.

155. (1) Travellers shall be allowed to encamp with their servants, animals, waggons and baggage, for a period not exceeding forty-eight hours, on any land purchased or leased from the Crown or occupied under a licence under this Ordinance, which is uncultivated, and which is not within a quarter of a mile of a dwelling house, and shall be allowed access with their servants and animals to any spring, river, stream or lake upon the land.

(2) If any purchaser, lessee or licensee under this Ordinance or under the Crown Lands Ordinance, 1903, shall satisfy the Land Officer that by reason of lands having been reserved or resumed by the Crown for outspans or of there being other suitable places for encamping, on or near the land of such purchaser lessee or licensee, it is not necessary that travellers should be permitted to encamp on his land, the Land Officer may exempt such purchaser lessee or licensee from all or any of the obligations imposed on a purchaser, lessee or licensee by this section or by section 14 (d) of section 20 of the Crown Lands Ordinance, 1903, as the case may be.

160. (1) Whenever in any section of this Ordinance the expression "prescribed" is used in connection with any matter referred to in the context the Governor-in-Council may in

every such case make rules for the purpose of giving effect to the provisions of such section.

The Governor-in-Council shall have power from time to time to make, alter, or revoke rules for the purposes of this Ordinance.

(2) Any rules under this Ordinance may provide for their enforcement by penalties not exceeding in any case seven hundred and fifty rupees.

FIRST SCHEDULE.

Nature and value of improvements to be effected and maintained on land leased for agricultural purposes.

RULES:

1. For the purposes of this Schedule the term "Permanent Improvement" shall mean -

Water Furrows.
Wells.
Draining land or reclamation of swamps.
Water boring.
Water races.
Water tanks.
Irrigation works.
Fixed machinery.
Reservoirs.
Dams of a permanent nature.
(Other improvements).

The above Ordinance C.L.O. 1915 has not been amended in regard to water and is, therefore, the governing Ordinance to-day. It will be noticed that under Section 152 it was contemplated that rules should be prescribed. No such rules were published until 1919. Before proceeding to these rules and before looking more closely into C.L.O. 1915, it would be as well to deal with the Case Law in the country, because all the cases dealing with water were decided before the publication of the 1919 rules.

CASE LAW.

170. It will surprise many people, particularly in countries like South Africa, where the number of cases dealing with Water Law is considerable, to know that there are only three cases dealing with water in the country. These are in order of time -

Bowker versus Secretary of State 1909 - Judge J.N. Barth.

Jamal versus Singh, 1917-18 - Judge C.H. Pickering.

Hutson versus Stocker, 1918-19 - Judge C.H. Pickering.

The first case was after the C.L.O. 1903 but before the C.L.O. 1913. The second case was after the publication of the C.L.O. 1913, but before the publication of the 1919 rules.

These two cases deal with the important principles of the law. The third case deals only with servitudes or easements and is included here so as to have the whole of the Case Law together.

171. Bowker versus Secretary for Native Affairs 1909 - Judge J.N. Barth.

The case concerns the Kedeng River, which crosses the main road across the Rift Valley below its Eastern Escarpment. The river was a small one in the low-water season, and owing partly to swamps disappeared before reaching some of the lower farms. A majority of the parties interested, (including Bowker) requested Government to construct a furrow round the swamps, so as to enable the water to reach all the farms in the low-water season. Under Sections 24 and 26 of C.L.O. 1903 the Government constructed the furrow passing through Bowker's farm, which he held under lease (?) and which was riparian and exceeded 100 acres. Bowker proceeded to destroy the canal and to bring an action for damages against the State, who counterclaimed damages for wrongful destruction of the furrow. The Judge gave judgment against Bowker, and the following are extracts from the judgment -

"By the way in which the proceedings have been conducted on his behalf, he is now confined to the question of trespass and actual damage done by cutting the canal and draining the swamp, if such trespass and action on the part of the Government be wrongful."

"There is evidence to show that the lower Kedeng and the Kedeng both have defined channels."

"The contention of the Secretary of State is that the Lower Kedeng is a river within the meaning of Section 3 of C.L.O. 1903 and that all rights therein are vested in the Crown. Further that under Section 24 C.L.O. the Government may construct canals without paying

compensation on Crown land or leased under the Ordinance. An alternative defence is that under section 88 C.L.O. the Government may enter on land leased or sold under the Ordinance and construct public works paying compensation for the land".

"River and Stream both mean flowing water and both terms are used indiscriminately to describe flowing water".

"I hold that the Lower Kadong is a river within the meaning of Section 8 C.L.O. and that therefore all right to the waters of the Lower Kadong is vested in the Crown and would so vest if the whole length of such river were within the plaintiff's boundaries".

"It is clear the Legislature intended to prevent riparian holders acquiring rights which otherwise they might have acquired. The right to all the water in a river, in the absence of other adverse rights, must include the rights of conservation and distribution of such water, provided such rights are not exercised to the injury of the property of others".

The Judge held that the works were not a canal under section 88, which applies only to canals for the purpose of navigation and not for any other purposes. However,

"The creation of the works executed by the Def.D. does come within the powers conferred by Section 88. The work was of a public nature to benefit the riparian holders along the Kadong and incidentally the public generally".

It will be seen that the learned Judge held that "all rights to the waters of a river are vested in the Crown" even in private rivers. As we shall see in the following case, Judge Pickering held an entirely opposite view.

The other important decision is in regard to the right of Government to build canals, etc., on behalf of others on any land sold or leased, on the ground that a work which benefits riparian holders and incidentally the public generally is of a public nature and comes within the meaning of "public works" in Section 88. This seems a peculiar way of circumventing the necessity of acquiring servitudes over private property. If the law as laid down here is correct, it is probably still of force, as Sections 87 to 93 of C.L.O. 1918 give similar and even more extensive powers. It is worthy of note that the question of the possession of water permits along the river does not seem to have been raised in this case or in any other case, although the rules of 1903 require such permits.

173. The second case is that of Jamal versus Singh heard by Judge Pickering in 1918-19.

Jamal versus Singh: 1919- Judge C.H. Pickering:

Jamal held under lease an area on which a mill was built in 1908 by a previous lessee on the Awach and Kibbe rivers west of the Rift Valley.

In 1917 Singh completed a dam for a mill just below the lower end of Jamal's leasehold. This caused sand to accumulate in the reach above Singh's dam to such an extent that Jamal's mill could not work and the latter sought

remedy in legal action. 551

It should be noted that Jamal's dam was built prior to, and Singh's subsequent to the 1915 Ordinance, and that neither the officer nor the rules required to be prescribed by Section 153 of the Ordinance were published till 1919 - after this case.

The following is an extract from the Judgment of Judge C.H. Pickering (22.6.18):-

"The argument most strenuously urged for the Defendant was that as regards the user of the water in the Awash the Plaintiffs were mere trespassers and that the Plaintiffs had in reality none of the rights enjoyed by riparian owners under the Common Law. Both Plaintiffs and Defendants hold under the Crown and both rent their plots on yearly leases. Both parties would enjoy the ordinary rights of riparian owners except in so far as such rights have been modified by statute. By Common Law the Plaintiff has a right that the Awash stream shall flow from his lands without obstruction. A riparian owner has also a right to use the power derivable from the stream. I am unable to accede to the suggestion that a riparian owner in this country has been deprived of those two rights in respect of which the Plaintiff complains of Defendants' action. Section 3 of the Crown Lands Ordinance 1908 is merely declaratory of the Common Law except possibly [illegible] to waters. The distinction between ownership of the water (qua) and the ownership of the bed of the stream and the riparian owners is clear and should be recognised. A stream of water running in a defined channel is not capable of being granted.

The rules dated the 31st December 1908 are made under Section 83 of Section 84 of the Crown Lands Ordinance 1908 and should deal merely with the subjects set out in those Sections. Section 3 of those rules so far as it purports to be [illegible] is in my opinion ultra vires. I do not propose to examine the irrigation rules 1908 as I am at a loss to perceive on what legislative authority they are based. In the Ordinance No of 1915 Section 75 appears to state the basic principle of the Common Law a little more fully than the revealed Ordinance of 1908. In Section 83 we undoubtedly find a direct statutory limitation of the rights of a riparian owner, and it is possible that Section 153 is also such a limitation; but this latter section is not retrospective. I am of opinion that the Plaintiff is a riparian owner on the Awash River enjoying all the Common Law rights necessarily incidental to such ownership, subject to the power of the Governor-in-Council to act under Section 83 of the Ordinance No 13 of 1915 and possibly bereft of the right to erect a dam subsequent to June 1915 except under penalties. Probably also a riparian owner has no right in this country to extract water from a stream for irrigation purposes. Such rights in England are based for the most part upon custom. I am clearly of opinion that by obstructing the flow of the stream and causing it to silt up and choke Plaintiffs' lands the Defendant has illegally invaded the two Common Law rights of the Plaintiff to which I have specially referred."

173. The third case is that of Hutson versus Stocker.

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Hutson versus Stocker: 1910-10 - Judge C.H. Pickering:

It is a case of servitude for a furrow from the Ngara River in the Limuru district in the highlands west of Nairobi. The two farms concerned are both freehold and were "sold and conveyed to the owners their heirs and assignees respectively subject to the provisions of the C.L.O. 1902".

A furrow passed over Hutson's farm on to Stocker's farm and the latter claimed a servitude over the former's farm and a share of the water in it, both claims based on verbal agreements between the predecessors in title of both farms made in 1905. Hutson refused to recognise the claim of Stocker and used all the water of the furrow without passing any to Stocker. Stocker actively endeavoured to get what he considered his share down through Hutson's land for purposes of irrigation, whereupon the latter brought an action against Stocker for injunction against trespass. Judge Pickering gave judgment for Stocker. He held that no India Act had been applied nor did any Local Ordinance deal with the subject and that, therefore, he must apply English Common Law and Equity. According to English Common Law easements cannot be created except by deed (Wood vs. Ledbitter 14 L.J. Exch 161). But the Courts of Equity have in a series of cases recognised verbal contracts, and the Judge, applying the principles of equity as laid down in such cases as Duke of Devonshire vs. Eliot and Wallace vs. Cooke, recognised the servitude of Stocker and refused to grant the injunction against trespass as sought for by Hutson.

It appears, therefore, from the judgment that in the case of freehold, at any rate, verbal contracts for servitude are not only binding but can be transferred.

Later, in 1921, Stocker brought an action against Hutson for damages on the ground that the latter, by cutting off water from the former, had caused damage by drought to land irrigated by Stocker. The case was settled by arbitration, Hutson having to pay a considerable sum for damages.

It is notable that, although a permit was issued by the D.P.W. in 1913 to Hutson under the 1909 rules, allowing him to take a share of the river for general farm purposes and to pass on a small amount to Stocker for domestic purposes, (he was using it for irrigation), no mention of the permit and no question of the legality of the use by either Hutson or Stocker is made in the Judgment. Judge Pickering had (in Jamal vs. Singh) previously held that the 1903 and 1909 rules, under which the permit was granted, were ultra vires, and the 1919 rules were not yet published.

174. We have previously dealt with the difference of opinion of the two Judges in regard to the meaning of the 1903 Ordinance and have indicated that it is difficult to come to any other conclusion than that the 1903 Ordinance was merely declaratory of the Common Law.

Coming next to the 1918 Ordinance, the two important sections are 75 and 102.

In regard to these it will be noted that Judge Pickering held, in Jumni vs. Singh, that "Section 75 appears to state the basic principle of the Common Law a little more fully than the repealed Ordinance of 1903", but that in Section 102 we find possibly a direct statutory limitation of the rights of a riparian owner and that probably it takes away from a riparian owner the right to erect a dam and to extract water from a stream for irrigation purposes. Section 102, however, is non retrospective.

In regard to Section 75, if the learned Judge is correct in his view, we must hold it that the right referred to is the right of dominium as opposed to the right of user. It will be noticed that the words "spring" and "stream" have been added to the words "river" and "lake" of the 1903 C.L.O. Whatever rights an owner had of possession in springs and streams under Common Law have been curtailed by Section 75 to the extent that they are for domestic purposes only. The right of dominium in underground percolating waters, etc., remains, and his right of user in flowing rivers remains in common with other riparian owners. The latter right is practically reduced by Section 102 to a right of user for ordinary purposes, because all forms of extraordinary use require damming or diverting of public waters, which is forbidden by Section 102. (An exception might be the generation of power by means of a wheel floating in the river). Even for ordinary purposes,

damming and diverting are prohibited. Moreover, if any river includes "dry" rivers, his Common law right of damming these is removed.

Reading Sections 75 and 152 together, the only Common law rights that practically remain to an owner are complete rights to private water or wells and boreholes using underground percolating water, rights to private water only and rights to public water for ordinary purposes of springs for domestic purposes, provided, in the latter two cases that no damming and diverting takes place. Of course, he has his other Common law rights, which give him redress as, for example, if anyone causes damage to his land by flooding, or if anyone prevents the free flow of water from his property or pollutes the water. One often hears it said that the State owns all the waters of the country and can dispose of them as it wills. The above reservations must, however, be kept in mind, particularly the right of an owner to the use of public waters for ordinary purposes. Even though this may be limited to direct drinking from the river, the owner may have a case against anyone who cuts off his required supply for these purposes by diversion for extraordinary purposes, notwithstanding that the latter may be sanctioned by licence from the State.

Although it is strange that in the Ordinance Section 152 is so far separated from Section 75, there is no obvious reason why the two sections should not be read together in order to arrive at the intention of the legislature. If this is done, we can say of this Ordinance what Judge Barth said of the 1902 Ordinance, namely that "it is clear that the legislature intended to prevent riparian owners acquiring rights which otherwise they might have acquired", particularly for extraordinary use.

It should be noted, however, that in Section 41 (1) of the Ordinance the owner is expected to develop his farm and effect the improvements in the schedule, which include furrows, dams, irrigation works, etc.

178. Section 152 entirely destroys the Common law rights for extraordinary use. In order to see what sort of rights are set up to take its place, we must turn to the rules anticipated in this Section. Although the Ordinance was published in 1915, no rules were published until 1919 and, as we have seen, during this period over 150 permits were granted by the head of the Public Works Department. These 1919 rules are as follows:-

WATER PERMIT RULES.

Government Notice No. 587. B. COSTA

THE CROWN LANDS ORDINANCE, 1915.

RULES.

IN EXERCISE of the powers conferred upon the Governor-in-Council by Section 152(1) of the Crown Lands Ordinance, 1915, His Excellency the Governor-in-Council has been pleased to make the following Rules:-

1. These Rules may be cited as the Crown Lands (Water Permits) Rules 1919.

2. The person for the time being holding the office of the Director of Public Works Department shall be the "prescribed officer" for the purposes of Section 152 of the aforesaid Ordinance.

3. All licenses and water permits heretofore issued and granted shall for the period and subject to the conditions therein appearing be deemed to be of full force and effect as if the same were issued and granted under these Rules until determined or cancelled pursuant to the provisions therein contained, or by process of law.

4. The prescribed officer may by license or other authority on such terms and subject to such conditions as to him appear reasonable and proper permit any person to do any of the matters and things mentioned in Section 152 of the said Ordinance.

By command of His Excellency the Governor-in-Council.

Nairobi.
The 20th day of October, 1919.

C.B. Sponner,
CLERK TO THE EXECUTIVE COUNCIL.

Though these may not have been the sort of rules that the Ordinance contemplated, they appear to be in accordance with the Ordinance and have the full force of Law, and they are the only rules that have been published

up to date under the Ordinance.

176. If we put on one side the few rights which remain to an owner under the English Common Law, as indicated above, the law boils down to this: That no person shall use any water of the country except with the consent of the Director of Public Works, who may, by license or other authority (verbal ?) on such terms and subject to such conditions as to him appear reasonable and proper, permit any person to do anything with the water.

This is probably the most autocratic law in the world. The whole law is confined within the breast of a single administrative official. He can sit like an eastern despot within the gates and deal with every case according to the impression of the moment, recognising no rule at all. Such a law can hardly be called a law at all. The essence of a law is that it should be a rule, not a transient particular order from a superior to or concerning a particular person, but something permanent, uniform and universal, for the perpetual information and direction of all individual citizens, in order that every man may know what to look upon as his own and what he may look upon as others.

Without any definite rules laid down, an owner is entirely in the dark as to what his rights are. If he feels aggrieved, he has no means of redress, no grounds on which he can appeal, for there are no principles laid down establishing his right. The sole principle is the will of the Director of Public Works, and he can exercise his will in whatever way he pleases. He may vary his principles to suit individuals or circumstances as he chooses. One Director of Public Works may have very different ideas from another as to what is reasonable and proper. One D.P.W. or another may allow their views to range over a variety of principles, sometimes conflicting, embracing priority of position, priority of time, proportional

division of the water, use by natives as against Europeans, irrigation in preference to power or industrial use, or the opposites.

177. There are possibilities of the law as it stands, though I hasten to add that, since the rules have been published, the present Director of Public Works has exercised extraordinary discretion in using his powers and has followed consistent principles, which are fairly well known to the public generally. He has always been careful to make known to those who apply for water permits what general considerations guide him in coming to a decision. It would be as well, before proceeding to further consideration of the law as it is, to see what are the considerations which guide the present D.P.W. in issuing permits. These can be gathered from the printed forms used in applying for and granting permits. The forms, of course, have no specific legislative authority and can be varied from time to time, as indeed they have been since 1919. The only conditions which are binding on a permitee or licensee are those which actually appear on his individual permit, and these conditions may vary in any two permits. The forms which give most information are P.W.D. Form No. 73 (a) "Form of Application by a Landholder for a Water Permit", and P.W.D. Form 137, "Water Permit".

178. The three notes on the former and the thirty general conditions on the latter are as follows:-

P. W. D. FORM NO. W3. A. 558

FORM OF APPLICATION BY A LANDHOLDER FOR A WATER PERMIT.

NOTE I - DOMESTIC USE - No permit is required for the obstruction of water from a river or stream for the domestic use of the applicant's establishment, or watering of cattle, if such obstruction is not proposed to be made by means of a dam, weir, machinery or other works. If it is, this form should be filled up by the applicant.

NOTE II - DRY FARMS - Permits are not issued for the transmission of water from a stream to a farm having no water frontage on such stream unless it is clearly established to the satisfaction of the Director of Public Works that the discharge of the stream during the time of dry weather flow is in excess of the reasonable requirements of all landholders having a frontage on the stream.

NOTE III - OTHER INTERESTS AFFECTED - The attention of the applicant is directed to the importance of a full statement of the names of other parties (and the Land Office numbers of their farms) who might be affected by the grant of the desired permit. If any portion of the proposed works is intended to be situated on the property of other landholders a letter authorising the construction of such works must be obtained from each landholder concerned and all such letters must be attached to this form before forwarding it to the Executive Engineer.

P.W.D. Form 137

WATER PERMIT

GENERAL CONDITIONS.

550

... for ... ing and using water must be constructed with the provisions of the permit therefor and maintained ... to the satisfaction of the Director of Public Works ... by him. No alterations in design or construction of said works may be made without the consent in writing ... thereof.

... canal is authorised the cross sectional area of its ... the gradient or slope of its bed shall be such that the ... convey more than the stipulated quantity of water when ... normal depth. The design of any artificial channel in earth ... that the velocity of water flowing therein shall not exceed ... unless it is lined with an impervious coating of concrete ... or unless specially authorised in the permit. All earth ... as short as economically possible to effect the purpose ... avoid undue loss of water.

... dam is authorised it shall be constructed in a sound ... manner and all works necessary for the passage of ... the delivery and control of compensation water or other ... in the public interest shall be constructed by the applicant ... before the right to divert water conferred by a ...

... liability attaches to the Public Works Department or any ... for the failure of any works constructed by the applicant ...

... power must be ... except in so far as ... and absorption ...

... Public Works ...

... wastes or otherwise ... sediments ...

... right to the enjoyment of the privileges granted ... permit ...

... earlier date ...

19. Properly protected crossings shall be constructed and maintained across channels in the Native Reserves at the permittee's sole expense at such places as the District Commissioner may consider necessary for the movements of natives and stock.

20. Natives will not be liable for damage other than wilful to works in a Native Reserve.

21. Natives will have the right to draw water from channels in the Native Reserves and in the event of Natives in their Reserves being deprived of access to watering places for cattle or if, in the opinion of the Director of Public Works or the District Commissioner, shortage of water is caused by the diversion, the permittee shall construct such watering places or provide such access to water as the Director shall prescribe and to his satisfaction.

22. Whenever, in the opinion of the Director of Public Works there is a shortage of supply, the permittee, on being so required by the Director, shall cease to divert water or shall reduce the quantity diverted for such period and in such manner as he may determine.

23. A power permit which does not bear the heading "MAXIMUM POWER PERMIT" is a "PARTIAL POWER PERMIT," ... authorises the development of part of the power available from the power reach of the river for which it is issued and is subject to the following condition:—

A power permit authorising the diversion of water at a point between the upper and lower limits of a power reach of a river ... subject to the condition that (a) the permittee may ... be required in the public interest to develop and make ... the maximum power of the power reach ... matters pertaining to which power ... the Director ... Director of Public Works ... entrusted to a person or body of persons ... the permit may be cancelled by the Director of Public Works and such development permitted ... person or body of persons shall give an ... give to the permittee a supply of power of an amount equivalent to that developed by the said permittee and taking ... consideration ... greater than that which such power had been or was being produced or not greater than that at which any other person is being given a supply of power ... under similar conditions by such person ... shall be the lesser, or, at the option ... amount of compensation, if any, to be awarded to the permittee may be decided by arbitration.

... Section 103 (2) Electric Power Ordinance, 1932 ...

Except ... the building in which ... or premises adjacent thereto ... factory, plant, business or ... where no electric ... energy generated ... purposes ... of electrical energy ... standard system ...

179. The above forms were printed only towards the end of 1924, being the result of development by gradual stages through previous forms the first of which was printed in 1919. 56)

The very important Clause 16, for example, which states that no guarantee of right as to quantity of water goes with the permit, was not in the earlier forms. Another important Clause (32), which also makes a right under permit uncertain, used formerly to apply only to yearly permit forms, which are no longer separate. Clauses 4 and 29, purporting to protect the Government, were also introduced only recently. On the other hand, a statement in previous forms, to the effect that permits granted were liable to cancellation by the Governor-in-Council, has not been included.

180. Let us look more closely into the forms to find out what general considerations influence the D.P.W. in granting permits:

A. The applicant must apparently be a "landholder" (title to Form 73.A). Landholder is not defined. Possibly "lessee" of the Ordinance or "owner or occupier" of Ordinance 21 of 1920 might be a better expression. No provision is made for township supplies.

B. The principle that riparians have prior claims as against non-riparians is laid down in Note II of Form 73.A. "Transmission" is used instead of "diversion" of the Ordinance. Does a subdivision of a grant, originally riparian but now cut off from a river frontage, have equal consideration?

If the riparian doctrine is to be followed strictly, have the river farms been laid out with a view to their possibilities in the way of irrigation or power for example? Along some of the bigger rivers, the State has reserved a strip of about 100' of river frontage. Are the farmers adjoining this strip to be considered non-riparian?

Then, in considering "the reasonable requirements of land-holders", are those to be limited to existing landholders or are future landholders or natives and future possibilities of the river to be considered? Query whether riparian doctrine need be followed strictly?

C. Note I of Form 73.A gives the D.P.W's interpretation of the existing law in regard to ordinary use of water. Only "streams and rivers" are mentioned, not "springs and lakes". The "damming" and "diversion" prohibited by the Ordinance is interpreted to be "abstraction by means of a dam, canal, machinery or other works". Other abstraction is permissible without a permit "for the domestic use of the Applicant's establishment, or watering

of cattle". This raises the common law rights very restricted. Possibly "livestock", as defined in the Ordinance, should have been used instead of "cattle". At any rate, some right of common law is left to a riparian owner, and his position and that of Government should other permits interfere with those rights, requires consideration.

D. In Form 137 -
The works must be constructed and maintained to the approval of the D.P.W. (1 & 2).
The amount to be diverted is to be determined by the D.P.W.

(2) There is to be no waste (2 & 5), no diversion to other catchments (6), no pollution (7).

The Permit is cancelled by change of ownership (8, 9, 10, 15) by failure to fulfil conditions (3 & 29) and on failure to make effective use (3) and full use (23). It is a question whether it is desirable to provide for cancellation on change of ownership, if effective and full use is properly inserted on. Otherwise 3 & 29 are essential.

E. Irrigation is not mentioned and there is no indication as to whether it has any preference over power and industrial use. Power is dealt with in Clauses 3, 23, 24, 29, the main object of 23 being apparently to safeguard the full water power possibilities of the country by preventing frittering them away by revision of limited scope. The D.P.W. has very wide powers of cancellation.

F. Apart from cancellation (see D above), no period of time is given for the duration of ordinary permits. Yearly permits are granted and lapse at the end of the calendar year (20 & 27).

G. Servitudes or easements (11, 12, 13 and 17) are not provided for positively. Agreement with owner of servient tenement is necessary.

H. Clauses 18, 19, 20 and 21 provide for protection of the interests of natives, but there are no Clauses providing for surveyance against natives. The word "drain" of Cl. 21 is very wide. Does it include drawing by furrow for irrigation? Is 21 not in conflict with 152 of the ordinance?

I. The two Clauses 16 and 22 are very important. They indicate that there is no guarantee against reduction in the quantity of water (stated in the permit and for which works have been constructed) by reason of use by upper owners under permits subsequently issued. There is no certainty that the principle of priority of time is to be followed. In Note III of Form 73.A a statement is required of the names of other parties who might be affected by the issue of a new permit. Possibly this has in view chiefly the previous permittees and people who have Common law rights for domestic use, but there is no indication that previous permittees will get prior consideration. A point to consider is whether it is possible to acquire prescriptive rights under a permit, or even without a permit, and whether the D.P.W. can apply Clauses 16 & 22 in these cases (see Clause 144 of C.L.O. 1915).

J. The D.P.W. in Clauses 4 & 28 protects Government and its officers against liability for failure of works or for any acts of permittee. Would protection in latter

could be valid if an upper permittee interfered with Common Law rights of a lower owner for ordinary uses.

181. As to procedure, the D.P.W. at present through his executive officers investigates any application for a permit and before deciding on it, refers it to a local district Committee presided over by the Civil officer of the District, or, if there is no such District Committee, to a local body, such as a farmer's association, for their views, and where natives are concerned, to the local Civil officer in charge of native affairs. Objectors are given every opportunity to state their views.

As a guard against granting a long permit unwisely, in cases where it is thought possible that other interests are likely to be affected, only yearly permits are issued, which can be converted into permits for longer periods after experience of their working.

In the early days the permits were exceedingly vague as to the purposes and nature of the works and as to the quantities of water allowed to be diverted. Many different units of measurement were used. Thus we find permits simply "for an irrigation furrow" without any size or quantity of water fixed, and the units were litres per second, gallons per day, hour or minute, ounces, cubic feet per minute, "to feed a 6 inch pipe", "sufficient for 60 acres", etc. Recently these matters have been reduced to a method and the quantity of water to be diverted is specified as "so many ounces or such per cent of the flow of the stream at the point of diversion at the time diversion is taking place (whichever may be the lesser)", and the minimum quantity to be returned to the river is specified.

182. The total number of issued permits recorded and uncancelled in the office of the D.P.W. at the time of my visit (October, 1938) was 657. I am sure that the record does not include all the diversions taking place to-day. Moreover, of those recorded I am equally certain that a num-

ber are not in accordance with the conditions and should be cancelled, as for example, when farms change hands. This state of affairs is inevitable under a system of state Licence of the use of water for which sufficient staff is not provided to make it effective. So far as I could ascertain, no permits have been issued to natives.

The number of permits issued for irrigation purposes in small and they are generally for very small schemes. There are probably not more than one or two Europeans irrigating in one block more than 100 acres in the country.

183. Reference should be made to correspondence which took place in 1915 and 1922 in regard to the value of a permit in guaranteeing a supply of water to works, so that a person who wishes to spend his capital on works may know what risk he runs of being deprived of the full water supply required and granted in the permit. In 1915 a question was put to the Director of Public Works enquiring as to the extent of the guarantee conveyed in a permit. The reply was as follows:-

> "Effective utilisation is regarded as the basis and the limit of any landholder's right to the use of water granted to him by a permit issued under the Irrigation Rules. These rules distinctly state that any permit issued under them is revocable in the public interest. Such revocation would under no ordinary circumstances be exercised except for public requirements of an urgent and imperative nature. The fact that adjacent landholders might see a possibility of increasing their area under cultivation provided a neighbour were deprived of water which he was effectively using, that in to say without waste and in accordance with Gazetted Regulations, would not be held to be an urgent and public reason necessitating the reduction of the latter's privileges enjoyed under an existing permit. Short of the Government grant of an inalienable right to a stated quantity of water, effective utilisation in a Government permit provides the utmost security for the continued enjoyment of privileges which a landholder can possess."

\- - -

D.P.W.

This seems to lay down the doctrine of priority of time fairly strongly, the only type of work which would be permitted to interfere with the rights enjoyed under previous

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permits being those for public requirements of an urgent and imperative nature in the public interest.

Again, in 1923, a power company, before embarking on large works, requested Government to give it some undertaking that permits would not be granted for diversion schemes above their works, which would interfere with the full development of power by the plant they proposed to put down. The following are extracts from the replies:

> - - - Government will be distinctly averse to creating a situation on that River in any way similar to the conditions which have prevailed on the - - - River under which the - - - Company are in a position to lodge complaints on so trifling diversions of water for domestic and irrigation purposes from the upper reaches of that river.
>
> At the same time I have pleasure in assuring you that your apprehensions as to any power rights remaining proving useless in practical operation are entirely without foundation. As a public supply corporation discharging a service of a quasi-public nature, you may rely upon Government safeguarding the effective operation by Your Company of rights which have now been promised to it.
>
> - - -
>
> D.P.W.

This letter is not quite so strong as the last in stating the principle of priority of time, as it applies only to a public supply corporation and not to the public generally. However, both letters seem to indicate that in 1918 and in 1923 it was the intention of Government to reward the early pioneers in the use of water as against late comers by not allowing any later diversions above them which would make the capital placed into the works an unsound financial undertaking by reason of an insufficient water supply. They seem to point to the doctrine of "first in time first in right", or in other words priority of time. If this is the general view and intention of Government, it seems a pity that something indicating that intention in a positive form should not have been embodied in the Ordinance or Rules.

Indeed, if there is one thing more than another that strikes one in looking through the Ordinances,

the Rules and the printed forms. It is their negative or prohibitive character. Their provisions are, like the Ten Commandments, mostly of the form "Thou shalt not". In them an owner desiring to use the water will find some things which the Director of Public Works and the Government may do, but very little indeed that he himself may do.

184. Summary of water rights acquired to date -

Up to 1910:

Up to 1910 English Common Law practically governed the situation. Two sets of rules were published, but were held to be ultra vires. Under these rules over 800 permits were granted. These were made of legal force as between the owners and the State by Section 3 of the Rules of 1910. It is a question whether, however, the owners of all land acquired previous to 1910 do not enjoy Common Law rights by virtue of the saving clause 3 of C.L.O. 1918 in respect of any works constructed without permit prior to 1915; and in regard to such works, or all any rate in respect of works carried out under permit, whether the owners have not the Common Law remedies against diversions, even under permit, which affect them adversely.

Between 1915 and 1919 over 150 permits were issued, although no one prescribed and no rules were made as provided in Section 182 of C.L.O. 1915. These permits were also made of legal force by Section 3 of the rules of 1919. Any dammings or diversions made after 1915 without permit are illegal.

The 1915 Ordinance definitely introduced the principle of State licence, without, however, providing the necessary machinery. The only common law rights remaining are those which can be exercised without damming or diverting. The right to domestic use by direct drinking from a public stream certainly remains, and this is important to remember, as it may give to a lower owner a claim

against an upper owner who is diverting for extraordinary use (say irrigation) even under permit. It establishes no claim against an upper owner, who is similarly using the water for domestic purposes, because on we have seen, priority of position holds for such uses. A riparian also has his common law remedies for flooding of his land or prevention of the free flow-off of river water.

After 1910 the only difference was that machinery for carrying out the principle of use by permit or licence was indicated in rules. There can be no damming or diversion of water from streams, rivers, lakes, or springs without the permission of the D.P.W. No rules are laid down to govern the actions of the latter officer. He may do whatever he considers "reasonable and proper".

Up to date not more than 600 water permits have been granted (and registered), though possibly a large number of these are no longer valid according to the conditions of grant; there is no adequate staff to scrutinise them all.

PART II.

GENERAL RECOMMENDATIONS.

185. We will deal first with flowing perennial streams. Water law in many young countries has become a very muddled affair owing to a lack of clear thinking on fundamental matters in connection with the measure and nature of a water right in a flowing river.

186. The first essential is that a water right must be definite quantitatively; and to be definite, it must be measurable. Quantitative rights in land are easily made definite, because land is solid and rigid, and can be measured and fixed by two-dimensional survey and by hedges and fences. A quantity of land can easily be apportioned or subdivided.

Water differs from land fundamentally in its lack of rigidity and in its change totally from moment to moment. A quantity of water as a separate entity is a practical conception only when it is at rest and completely enclosed below its horizontal surface. A quantity of flowing water as part of a flowing stream is an impractical conception. A right to talk of the whole quantity of water flowing in a particular length of a stream at a particular instant as being the volume enclosed between the bed and banks in that length, but such a quantity would be exceedingly difficult to measure and is of very little practical use. Suppose we have 10 cubic feet in such a length flowing very sluggishly and 10 cubic feet in a much steeper length flowing very rapidly, the fact that equal volumes are flowing in the two lengths would be of little use to us. Besides, throughout the two lengths, water is constantly entering from above-ground or underground sources and is constantly being removed by furrows, seepage, evaporation, etc. We must, therefore, not make the mistake, which has been made in the water law of some countries, of starting off any law dealing with water

rights from such a vague conception as a quantity of flowing water in a stream.

187. We must start from something definite and measurable, and that is the rate of flow at a point on the river, at an instant. More strictly, it is the rate of flow past a plane across the channel through the point, at the instant. We will call this the discharge at a point at an instant. The whole discharge of a stream, or a portion diverted or passed on, at a point at an instant is easily measured.

188. In relation to people below him on the stream, the right of a person to divert or store water is also easily measured and defined, if -

(1) the point is defined,
(2) the instant is defined,
and (3) the discharge which he can divert or store at the point at the instant is defined.

The point of diversion is an important feature of a water right. For irrigation purposes, for example, the higher the point of diversion, the greater is the land commanded, and for power purposes a point above a waterfall is of greater value than a point below it.

In fixing a water right, a great difficulty is that the requirements of a user generally vary from instant to instant. For example, an irrigator may only require water by day or in summer, and not by night or in winter. If, for a certain period of time T_1, a user's demands are for a constant discharge of D_1, he would extract from the stream in that time a quantity of water equal to $D_1 \times T_1$. His right at a point in relation to lower owners should be defined as a series of constant discharges of D_1, D_2, D_3 etc., over periods of T_1 T_2, T_3 etc., hours. This subject of variable requirements has not received nearly enough consideration by legislators. The simplest course is generally adopted, and the right is given as a single constant discharge D_1 throughout the year and from year to year. This inevitably results in waste. It is an

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if we ran a central tram power station at full capacity night and day without any regard to the regular peaks and hollows of the traffic curve.

100. In defining A's right at a point P_a as a right to divert discharges of D over periods of T, we have settled his right quantitatively in relation to people below the point. In order to protect his right, there is no need to place any restriction on the use by those people, as water cannot flow uphill and they cannot attack him. But the consideration and fixing of A's right in relation to B, C, etc., above the point P_a, is a much more difficult matter. Every diversion or storage above P_a reduces the discharge of the river at P_a. In all arid or semi-arid countries, where irrigation or use of water-power is practised, there is the danger that the discharge at P_a will be so reduced by upper users that it falls below D_1 in a period of T_1, as specified in A's water right. If there is any uncertainty of this sort, A will hesitate to embark on an expensive water undertaking, and this uncertainty will kill enterprise.

100. A's quantitative water right must, therefore, consist of two parts: (1) a right to divert, at P_a, discharges of D, etc., in times T_1, etc., and (2) some right as against people above him, which will ensure that the discharges specified in (1) will be available in the river at the point P_a. This latter is the most difficult part of water rights, and it is chiefly in the means adopted for solving this difficulty that water laws of the world differ from one another. Some countries have shirked the difficulty and have been contented with treating water as a herd of wild animals, which anyone can appropriate in any quantities while on their property. That is the doctrine of priority of position. Water is, however, too valuable a national asset to be treated in this primitive way. The only conditions which justify such treatment are when the uses are small, as in ordinary use, in comparison with losses

in the river, and up to certain limits in the case of intermittent rivers, but at present we are dealing with extraordinary use in perennial rivers. Some solution of the difficulty must be devised.

101. An important point to note here is that whatever system be adopted, it must be carried out in practice by defining the rights of the upper owners, $D_2 D_3$ and D_4 in the same way as those of A, i.e. by discharges at specified points for specified periods, but with certain restrictions. If A is to have any guarantee, it can only be by imposing restrictions on the diversions of B C D etc., above him at points P_B P_C P_D etc., in specified periods. It should also be noted that there can be no dominium in a portion of water flowing in a stream, and there can be no possession of a discharge, which has a dimension of time in it and is in respect of future use.

102. Supposing that we have devised a satisfactory method of imposing restrictions on upper owners, A then has a right of action in the Courts against an upper owner, if he can prove that the latter has not observed the restrictions imposed. This is a right which A will find very difficult to exercise in practice. He may find that the discharge of the river at his point of diversion has fallen below his requirements, but he does not know whether this is due to natural causes, such as, a falling off in the sources of supply, seepage and evaporation in the river channel, or whether it is due to one of the upper owners exceeding his rights. He would have to proceed up the river and check the discharges of the river and of the private furrows. Machinery can be devised to simplify and deal with this sort of police work, and remedies can be provided, but this part of the law should be kept entirely separate from the part which deals with the definition of the rights quantitatively. It should be grouped with the remedies for damage to land by flooding or spilling over it and with all other matters which properly

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in the river, and up to certain limits in the case of intermittent rivers, but at present we are dealing with extraordinary use in perennial rivers. Some solution of the difficulty must be devised.

191. An important point to note here is that whatever system be adopted, it must be carried out in practice by defining the rights of the upper owners, B, C, and D, in the same way as those of A, i.e. by discharges at specified points for specified periods, but with certain restrictions. If A is to have any guarantee, it can only be by imposing restrictions on the diversions of B C D etc., above him at Points P_B P_C P_D etc., in specified periods. It should also be noted that there can be no dominium in a portion of water flowing in a stream, and there can be no possession of a discharge, which has a discontinuity of time in it and in respect of future use.

192. Supposing that we have devised a satisfactory method of imposing restrictions on upper owners, A then has a right of action in the Courts against an upper owner, if he can prove that the latter has not observed the restrictions imposed. This is a right which A will find very difficult to exercise in practice. He may find that the discharge of the river at his point of diversion has fallen below his requirements, but he does not know whether this is due to natural causes, such as, a falling off in the sources of supply, seepage and evaporation in the river channel, or whether it is due to one of the upper owners exceeding his rights. He would have to proceed up the river and check the discharges of the river and of the private furrows. Machinery can be devised to simplify and deal with this sort of police work, and remedies can be provided, but this part of the law should be kept entirely separate from the part which deals with the definition of the rights quantitatively. It should be grouped with the remedies for damage to land by flooding or spilling over it and with all other matters which properly

fall within the jurisdiction of the courts of the land.

103. It is the quantitative determination of the rights which is the most important and difficult problem in framing a water law. Where the water is limited in comparison with the demands on it, there must be some method of apportionment. If the rights could be automatically determined by some innocent physical character of the land, and if some formula could be devised for this purpose, then it would only be necessary to put the substance of the formula into an act and leave it to the judges and the courts to see that the formula is followed. Even the best of mathematicians, however, could not devise such a formula. How, for instance, could a use for power be compared with a use for irrigation? Some water laws have attempted to overcome this difficulty by placing different uses in order of merit. South Africa, for example, has made irrigation the dominating use. But even if this is done, laws have to provide in a formula for the requirements of the land, which vary with the climatic and seasonal conditions, the nature of the soil and of the crops to be grown, etc. Even the areas commanded by the furrows depend on the points on the river from which they start and no formula can fix the positions of the points.

Then, there are the variations in the flow of the river, depending not only on the climatic conditions, but also on upper uses and on seepage from irrigation, etc., and these cannot be reduced to a formula. A method sometimes adopted to eliminate the variations due to climate is to base the quantitative rights on the lowest known discharges at various points along the river, but in this way much useful water of good years or seasons or of seepage is wasted.

In Kenya, too, there are the natives to be considered, and a formula could not differentiate between white and black.

Lastly, in a formula of apportionment

there must be something to be apportioned and, as we have seen, it is impracticable to consider water flowing in a river as a divisible entity. It will be realised, therefore, that it is impossible to devise a formula which will settle quantitative water rights automatically. How then are we to set about the definition of water rights?

104. In considering this problem, I start off with the fundamental assumption that the aim should be to make the maximum possible use of the limited water supplies in the general interests of the country as a whole - "salus reipublicae suprema lex". In a young country, such as Kenya, I hold that this can best be achieved by encouraging sound private enterprise amongst existing owners, whilst reserving so much of the resources as may, from a broad national point of view, be considered necessary for future needs within a reasonable time.

105. If the above view is accepted, we get the final argument against the possibility of a formula. You cannot measure the enterprise of people, nor can you consider national needs, by means of a formula. The first conclusion, therefore, is that the judges and ordinary courts should have nothing to do with the quantitative determination of rights. If this could have been reduced to a formula to be embodied in a law, a judge would be the proper person to interpret it, but if a formula is impossible, then I hold that it is no part of the duties of a judge to decide what is in the interests of the country in any particular case or to make a practical apportionment of water in order to encourage enterprise - "Judicis est jus dicere, non jus dare". It is important to emphasise this conclusion, as in every country, where the quantitative determination of rights has been left to the courts, progress in the use of water has been hampered. In South Africa we have established special water courts, who have to deal with the apportionment of

water, amongst other matters; but their judgments are always liable to appeal in the Supreme Courts and the judges have to struggle with all the impossibilities of a proportional formula. The inevitable result is that, after abundance of evidence has been heard and enormous legal expenditure has been incurred in the water court and then again in the supreme and appeal courts, the parties, who have been rash enough to seek a quantitative definition of their rights, settle the matter by consent, and steady men fight shy of this destructive and risky game of water poker.

166. We are forced to the conclusion that the State must set up some special machinery for determining water rights quantitatively in flowing streams and that in granting water rights it should have the same regard to the interests of the whole country as it has in the granting of Crown land. Before proceeding to discuss this machinery, we should look a little more closely into the two systems of water law which have endeavoured to circumvent the necessity for special State determination, namely, the Common Law and the American law of priority of time. In both of these systems, the quantitative determination is supposed to be automatic.

167. We have dealt with the Common Law in paras. 162 to 169 and in 165 of Part I and need only summarize its defects here -

(1) It involves a formula of proportionality to be interpreted by judges. The impossibility of any method involving a formula has been dealt with above in paragraphs 163 to 165.

(2) It gives no reward or encouragement to enterprise, as a man can sit on his right for all time without using it.

(3) It takes no special account of the best interests of country as a whole.

168. The other system depends on the doctrine of priority of time. This doctrine originated in America and in its crudest form can be summarized as "first in time,

first in right". If a proprietor diverts a certain discharge and makes proper use of it, he automatically acquires a right to that measure of discharge as against all others who divert at a later date. The measure of the right is then automatically fixed by the extent of his diversion, not only against people below him, but also against people above him; i.e. people above him, who have diverted after him, must pass down enough water to satisfy his prior right before they can begin to divert. In this way the second and most difficult part of a water right - the imposition of a restriction on upper users, is automatically settled. This law has resulted in wonderful advance in irrigation in the United States, but in its crude form it has the following very serious defects from the point of view of its adoption in Kenya -

(1) It makes no provision for future national needs. A man can divert the whole discharge of a river at a point if he consumes it all. Proper use is the only limit to the magnitude of his diversion.

(2) It does not provide for variation in the requirements of the user throughout the seasons of the year.

(3) In order that it may be automatic in its operation, the man who diverts only a day before another man acquires a superior right. The priority of rights is determined by the second hand of a clock. It is most desirable that a number of people, who are contemplating development about the same time, should have equal opportunities should have a chance of their respective claims being weighed up; but if that were done, there would have to be a law determining how claims are to be compared, and a machinery to hear and adjudicate on claims. It was largely to avoid the difficulties of such a law and the expense of such machinery, that the bald doctrine of priority of time was adopted, and the clock alone determines priority.

Such a doctrine of rights, determined in time by a clock and in magnitude largely by the extent of the owner's purse, would not suit Kenya with its big native population and large extent of crown land; but the fundamental ideas of encouraging and rewarding enterprise and of letting the right convey a guarantee against diminution by later diversions higher up the river should be followed in every means of determining water rights.

Other methods have been devised in different countries for obviating the necessity for State determination of rights, but I am convinced that none of them are suitable for Kenya and my recommendation is that in the main State determination of rights, already introduced into Kenya, must continue.

300. The machinery, which I recommend for the granting of rights, is (1) a Water Board, whose chief function is the granting of water rights, and (2) an adequate administrative staff under the Director of Public Works, whose function is to make the necessary investigations and to supply such supervision of works and of the use of water as is necessary. As pointed out in paragraph 173 of Part I, the rights are at present defined solely by the Director and I think it highly inexpedient that this important matter should be in the hands of a sequence of individuals. A single individual, charged with great and arbitrary powers, may sway to either of the two extremes of overbearing autocracy or excessive timidity. The Board should consist of several members, in a measure as representative of the public interest as in the legislative council, with the D.P.W. as chairman. I have deliberately refrained from calling it a Water Court, as its functions should be confined to the definition and granting of rights and should not include judicial powers, which properly belong to the Courts.

300. The necessity for an adequate administrative staff is equally important. A system of State determination of rights can never be a success without a proper staff. The importance of the collection of hydrographic data has already been emphasized in Chapter IV. No determination of rights and no reservation of water for future national needs can be made without a knowledge of the discharge of rivers at various points and at different seasons, measured over several years; nor can any proper estimate of the losses and gains in the river [illegible]

without such information. Then, to judge of the requirements of any particular scheme and of its merits relatively to any other schemes, and to estimate the future national needs, requires a large amount of investigation and reconnaissance; and finally, the supervision of works and the use of water requires a considerable staff.

201. As to the principles which should guide the Water Board in granting quantitative rights, there are certain principles which cannot be embodied in an Act. We cannot lay down a proportion of the water to be reserved for future national needs; we cannot lay down a precise division of the water between whites and blacks; nor can we give a means of assessing the relative value of rival schemes, as for example, between irrigation and power. These are matters which must be left to the absolute discretion of the Water Board. But there is one principle which should be aimed at in granting rights, and that is, that they should be sufficiently definite and certain, that enterprise will be encouraged and safeguarded. Although I hold very strongly that the courts should have nothing to do with the quantitative definition of rights, I also hold that they should be so defined and crystallised that an owner may be able to go to court in case his rights are infringed. As previously pointed out, this can only be done by imposing some restrictions on upper diversions and we should decide on some principle to be followed in imposing such restrictions.

202. The principle which I think should be followed is that of priority of time. This is the only way in which there can be conveyed with a right any sort of guarantee that capital expended on works will not be rendered fruitless by later diversions higher up the river. I do not recommend that the crude American method of allowing the second hand of a clock to determine the priority should

be followed. I think that, whenever an application for 577
permit is received, the Water Board should hold a public enquiry. At this enquiry not only owners of existing permits should be allowed to attend and to state any objections they may have, but other persons who propose to develop within a year or two should also be allowed to put in applications for permits, which should be considered concurrently with the application causing the enquiry. The broad principle of priority of time should then be followed, in that existing permittees should be protected against present applicants and the latter should be protected against future applicants.

Amongst present applications, the Water Board must exercise its discretion in accordance with the broad aims of paragraph 104. Some guarantee of bona fides amongst applicants and some penalty for non-fulfilment should be devised. The future national needs can only be provided for by imposing restrictions on diversions, to be operative when the needs, for which reservation was made, actually arise. These needs should be specific and likely to be exercised within a reasonable time. Railway and township requirements within a reasonable time and also requirements for future grants of Crown land or [illegible]natives might be included in national needs.

203. As previously pointed out, the right granted should consist of two parts (1) a right to divert at a certain point, certain discharges in certain periods; but (2) with certain restrictions on diversion which will protect future national needs and the claims of people lower down. These claims should be based on priority of time and the restrictions should be in the form that at certain periods certain discharges must be passed on to satisfy the claims of prior permittees lower down, even if the discharge of the river should fall so low that the upper and later permittee is not able to divert the quantities stated in the first part of his permit.

To fix these restrictions in such a way as will ensure the maximum beneficial use of the water of the river is an exceedingly difficult matter, as they will depend on the variable requirements of users and the variable flow in the river. Notwithstanding this difficulty, a solution must be found in every case and, as previously pointed out, an adequate staff is essential.

204. The decision of the Water Board in granting the rights should in every case be final and there should be no appeal to the Courts. It might, however, be advisable to provide for a special appeal board to consider appeals on the grounds that the general principles laid down above have not been followed by the Water Board.

The important point is that the rights should be granted with such definite restrictions that anyone may know what are his own rights, what are the rights of others and what reservations are made for national needs. A permittee should be in a position to claim compensation if his rights are subsequently curtailed by the Water Board for other national purposes than those for which specific reservations have been made. Above all, he should be able to proceed to the ordinary Courts if others have exceeded their rights to his detriment. I do not suggest that the difficult police work of detecting infringement in diversions should be undertaken by the State. It may be necessary to create some co-operative machinery in the form of River Boards for this purpose. In the permits issued at the present day, however, expeditious construction of works and full beneficial use of the discharge specified in the permit are very properly insisted on, and the State administration must be responsible for supervising matters of this sort; it must also look after the native interests.

205. I see no reason for a threefold division of uses of water into primary, secondary and tertiary, as

in the South African Act and in other Acts, each use becoming permissible only after all the possibilities of the preceding uses have been exhausted. The division into ordinary and extraordinary uses is sufficient, and even in this division I recommend hereafter that the preference of the former over the latter should be curtailed. The three-fold division is a clumsy invention to overcome the difficulties of proportionality as required under the Common Law. The Water Board will have to judge of the relative claims between irrigation and power uses on particular rivers.

200. Nor, having departed entirely from the Common Law doctrine of proportionality, do I see any reason for dividing the flow of rivers into "normal" and "surplus", as in South Africa, or into "normal" "storm" and "surplus", as in Southern Rhodesia and Nyasaland. Such divisions are only necessary if the proportional doctrine of the Common Law is adhered to in part. Nearly all the definitions of normal flow, which I have seen, use the expressions "quantity of water flowing in a stream" or "so much of the flow of a stream". We have already seen that this is an impractical conception and that the practical conception is a discharge at a point at an instant. If there is anything to be fixed as "normal" about the discharge at a point, it can only be in connection with a diversion or storage at the point, which has to be determined by the Water Board, and this body might just as well proceed directly to define rights by discharges and restrictions at certain points in certain periods without introducing any complicated and impractical conceptions.

207. The expression "normal flow" has been invented chiefly in connection with storage dams with the object of defining how much water must be passed beyond a dam in order to satisfy rights in connection with furrow diversion lower down the river.

So long as there are only furrow diversions to be considered lower down, it is generally possible to place pipes and valves in the dam which will pass any quantities likely to be required by the lower furrows. The right of storage should be based on discharges at two points instead of one, i.e. at the point where the river enters the dam and at the point where the water is passed back to the river through the dam. The difference between these two discharges at any instant represents the diversion for storage. The right should be given as a difference of this sort without any maximum, the difference to be zero whenever all the discharge at the upper point is required for lower persons.

The above method is simple enough when there is only one storage dam to be considered. The chief difficulty is when there are other storage dams with older rights lower down the river or other proposed dams competing with this dam for equal consideration. The difficulty arises from the fact that it is generally not economically possible to pass large floods through pipes in the dam (particularly in the case of an earthen dam). The upper dam must first fill up to the brim before it can pass floods over its spillway. The practical solution is that the Water Board should place some restriction on the storage capacity of the dam by limiting the height of the spillway.

Having granted a storage right with restrictions on the storage diversion and the capacity, the guarantee of priority of time should take the form of prohibiting any later storage works in a defined length of the river or its tributaries except on payment of compensation. Naturally, all owners in that length should be allowed to put in permits for dams at the enquiry held by the Water Board.

A storage right of this sort will generally be combined with a right of diversion for direct use which will also have a priority against later direct diversions.

An important problem sometimes arises in connection with storage dams in the bed of the river, particularly in large co-operative storage schemes, when the stored water is allowed to flow down in the bed of the river to be diverted lower down and the headworks of furrows enjoying older diversion rights, which do not rely on the stored water, are passed on the way. In these cases, as the stored water is mingled with the other water, the rights of the older permittees, as expressed by diversions and restrictions in specified periods, will have to be modified by the Water Board in an equitable way.

808. In previous paragraphs I have dealt only with extraordinary rights in flowing perennial streams. We have still to consider the ordinary and private rights of the common law. Generally speaking, I consider that the principles of the common law in regard to private water can be followed.

It may be as well to state specifically in the ordinances that water flowing in the manner indicated in paragraph 31 of Chapter II of this report is not to be regarded as private wa

In the use of private waters of springs and lakes there should be a very broad interpretation of ordinary uses and they should not be narrowed down to "domestic" uses as in Section 75 of O.L.O. 1918, nor should diversion for ordinary uses be prohibited as in Section 102.

On the "dry" rivers unrestricted rights should be allowed to construct stock and other dams of the sort described in Chapter VI paragraph 113, i.e. up to about 50 acre-foot capacity or even up to two or three times that size, and such dams should enjoy priority of position. For larger dams, however, permits should be necessary from the Water Board and priority of time should

then be considered as in paragraph 207 above.

208. As to ordinary rights in what is commonly known as a public stream, the law must presumably stand in regard to rights attached to farms already given out; but in regard to new grants of farms, I think that there should be a careful reconnaissance of the water resources before land grants are made, and certain farms in the better watered lengths of rivers (to be demarcated) should be given rather extended rights for domestic use, watering of stock and even watering a garden of limited size, including the right to divert. The right might be defined in the land grant as a permission to divert a certain discharge, say 0.05 cusec, for the above purposes.

These rights, however, while involving priority of position against all uses downstream, should not have any precedence as against people upstream who have permits for extraordinary use dated prior to the granting of the farm. This seems a radical departure from the Common Law, as interpreted in countries such as South Africa; but, if we adopt the principle of priority of time for all uses and give the ordinary user priority from the date of granting a farm in the demarcated lengths of rivers, they should be sufficiently protected.

For farms in the lower lengths of feeble rivers, which would not be in the demarcated lengths, other possible sources of water supply for ordinary purposes should be investigated before granting them, and, where such sources are discovered, although water may be used from the river for ordinary purposes when the river flows with priority of position, these farms need not be considered in granting water rights for extraordinary purposes higher up the river and should not automatically acquire any rights as against upper farms.

The water rights that are attached to a farm when it is granted should be specifically stated in the

ordinance instead of being left to be inferred from a reservation as in Section 70 of C.L.O. 1910.

210. It is impossible to cover the whole range of water law in a report of this sort, and I have dealt above with what I consider the most important aspects. Two provisions in the water laws of other countries, as for example in South Africa, have led to very great progress in irrigation. One is in regard to the means of overcoming unreasonable obstructions in the acquisition of servitudes in respect of furrows or storage dams, and the other is in regard to the establishment of co-operative irrigation districts for the joint construction of irrigation schemes. I could not detect an urgent demand or necessity for either in Kenya and do not propose to deal with them in this report, though I am convinced that at some future date provision will have to be made for both in the laws of the country.

211. An important matter is the proper recording of rights, so that every person along a stream may find out easily what rights have been granted. A permittee's rights lie partly in the rights granted to others above him, which cannot be specified in detail in his own permit, and the protection of his own rights depe... ...y largely on the strict observance of rights by others above him. Moreover, any programme of development will depend on the extent of the rights already granted. There is room for improvement in the recording of rights and an adequate staff is necessary for the purpose.

212. It is premature to make any particular suggestions as to the drafting of new legislation before the above recommendations have been carefully studied. I should only recommend generally that as much as possible should be put into an ordinance or, failing that, into rules which require legislative sanction. Many of the

important clauses in the existing printed forms should be included in an ordinance or rules (for comments on the printed forms see Part I).