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HAFIRS OR DEVELOPMENT BY SURFACE WATER SUPPLIES IN THE SUDAN

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Hafirs or Development by Surface Water Supplies in the Anglo-Egyptian Sudan

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THE OUTLINE OF THE PROBLEM

About one-third of the area of the Anglo-Egyptian Sudan—or some 300,000 square miles, just over three times the size of the British Isles—withholds its potential of pastoral and agricultural wealth for the primary reason of shortage of drinking water. Roughly two-fifths of this area are predominantly sandy country suited for cattle; two-fifths are clay plain suited for rain-dependent agriculture; and one-fifth clay plain suited for rain-dependent agriculture only if the severe flooding from storm water during the rainy season can be controlled. The rain dependence of agriculture in these plains is contrasted with the irrigation-dependent agriculture that at present forms the backbone of the Sudan's economy, but which takes place outside and to the north of the areas under consideration. Irrigated agriculture is limited in potential expansion to a maximum of 16,000 square miles, even if all the water ever likely to be allotted to the Sudan from the Victoria Nile is harnessed, plus the water at present wasted in the swamps taking the drainage of the north-eastern slopes of the Nile–Congo watershed.

Were the 300,000 square miles unbroken plain, little development by surface water supply would be possible because the rainwater would be absorbed where it fell; but the plain is broken at wide intervals in the east and centre by inselbergs and in the west by weathered sand dunes. Exploitable water catchments are formed by the inselbergs and their plinths and by the clay–sand mixtures formed round the sand dunes by the washing out of their clay fraction by rainwater. Natural catchments give rise to scanty water supplies that support some permanent and many seasonal settlements over the large areas lacking underground aquifers.

The nomadic outlook sees the earth's resources as illimitable. This has resulted in heavy unplanned pressure upon natural water supplies, and as a result each is the focus of an area of exhausted soil and, where slopes are steep enough, of actual erosion. To cure this condition by planned pastoral and agricultural works is one aim in the development of surface water supplies. This is now vitally important because the rapid national development is unbalanced in disfavour of the land and the demand for rural products will outstrip a supply which depends upon what Sir Philip Mitchell has called an ' African and his hoe ' economy. This weak economy must be bolstered to meet expanding demands until the new techniques of rational pastoralism and mechanized agriculture—which alone can grasp the opportunities offered by such vast areas—have been perfected, otherwise this weakness might be the source of an economic collapse, leading perhaps to a political one, in which all that has been gained since Sir Herbert

Kitchener's time might be lost. It is believed that much can be wrung from the old peasant economy by the elimination of the distances between the field and the water point.

Existing water supplies allow the use of three per cent or less of the agricultural land and the pastoral land to be used at a low efficiency. Until just after the second world war practically the entire effort to improve water supplies was devoted to tapping underground sources, but for reasons of non-water-bearing rocks and shortage of geophysical survey equipment, this yielded meagre results. No large-scale effort to exploit surface storage methods was possible, because the heavy earth-moving equipment needed was only developed in America just before the war started. Towards the end of the war there arose a determination among those responsible for the welfare of the Sudan to attempt the development of the rainlands, partly for their own sake and partly to broaden the basis of the country's economy by farming which did not have cotton as its mainstay. Cotton had always been the main revenue producer and the fear—perhaps less than was justified—that it would one day be supplanted by something else and leave the coffers empty, inspired the venture into the rainlands, a venture which is still not proven but lies in the realms of promise.

EARLY WORK

The noun ' Hafir ' is the Arabic word for a hole in the ground excavated for the storage of rainwater. Hand dug hafirs have been used in the clay plains of the Sudan probably from time immemorial and their outlines are visible over a wide area, the denuded banks still holding shallow pools after heavy storms. Hafirs are the obvious means of water storage in areas of impervious clay without underground aquifers. It seems that the majority of the old hafirs were dug in an era of greater rainfall when the flooding of the land by rainstorms was a regular occurrence, for they consist simply of horseshoe shaped excavations with open mouths and no special arrangement to obtain water from torrents or rock catchments.

In 1946 six Caterpillar D7 tractors and six Le Torneau 11 cubic yard scrapers to match, were procured by the then Department of Agriculture, through the para-military organization the Middle East Supply Corporation, for the purpose of mechanical hafir excavation. Though they had not been tried for this specific purpose Dr. J. Smith, then Deputy Director of Agriculture, was convinced that they would work. The machines were based upon workshops at Wad el Huri near Gedaref, started a few years earlier for other lines of rainland development, which were expanded to deal with servicing problems.

The purchase of the machinery was the expression of the desire to produce surface water supplies on a large scale, but at that time staff and experience were limited. It was soon realized, after a successful trial, that the output of such a collection of machinery would necessitate the services of a body of civil engineers with supporting junior staff, both for preparatory work several years in advance of its field operations and currently for essential completion works. Several years passed before this need was fully appreciated and recruitment started. In the meantime excavations were made at a number of sites obviously suitable for hafirs both from social and hydrological angles, which enabled the machinery to be used to advantage without too serious mistakes being made. The need for a full establishment of qualified staff became urgent as the machines moved to new country where no existing information was available about hydrological conditions and the nature of soils, and where social problems arose involving new settlement and changes in the grazing routine of nomads. By now the staff of the Department of Agriculture and of the Forestry Division, who had so generously lent their help in the early days, were fully engaged with post war programmes of their own.

THE PRESENT ORGANIZATION FOR CREATION OF SURFACE WATER SUPPLIES

The present organization of the Soil Conservation and Surface Water Supplies Section was set up to deal with hafir programmes and other works which, since 1949, have meant the disposal annually of some 800,000 cubic metres of excavation in from 50 to 60 hafirs, and the construction of up to 1,500 kilometres of graded earth access roads. The excavating machinery is actually worked by a Mobile Plant Depot, the manager of which is responsible through the Chief Engineer to the Director of the Ministry of Agriculture. The Mobile Plant Depot acts as a contractor for works planned by the Soil Conservation and Surface Water Supplies Section, and before the beginning of each working season, which starts in mid-October and finishes about mid-June, the Soil Conservation Officer passes to the manager of the depot a plan of work, so that the latter may make his dispositions involving rail or river transport and fuel oil supplies.

The Soil Conservation and Surface Water Supplies Section consists of a headquarters unit based in Khartoum, and four regional offices at Kassala, Sennar, Malakal and El Obeid. The headquarters section co-ordinates plans, orders supplies, and maintains an execution team that reinforces the small permanent staff of the regional offices in the seasons when they are visited by machinery. The function of the regional offices—staffed by a civil engineer, a foreman of works and two surveyors—is to carry out permanent reconnaissance and maintenance of works already completed. For maintenance work the regions also have a watchman or two on each hafir and a maintenance foreman for each group of about 20 hafirs.

For hafir excavation the Mobile Plant Depot—now with its workshops just outside Khartoum—uses two fully mobile excavation teams each based upon six Caterpillar D7 tractors with a Carryall 11 cubic yard scraper to match, and two other D7 tractors, one pulling a rooter for loosening the subsoil, and one fitted with a bulldozer blade for clearing sites. In addition each team has adequate road vehicle and tanker transport for fuel oil and water, and sufficient repair equipment to keep the team working long distances from its base for seven months each year. Shelter for crews is provided by tents; the mechanical engineer in charge of the team has a caravan.

For access road grading there are two self-contained road teams, one with a capacity of about 12 miles per day of nine-metre-wide graded earth road, and the other with a capacity of about five miles per day.

The output from all machinery, considering the conditions of utmost remoteness, is gratifyingly high, and this must be attributed to the keenness and ability of all staff involved. The excavation teams work a 24-hour day in three shifts: a long shift from 0700 hours to 1800 hours, followed by another long shift up to 0500 hours, followed by a short shift of two hours by greasers completing the 24 hours. Drivers on the long shifts make their own arrangements for short stops for feeding, which is usually done communally in local tradition. The establishment of staff of both excavation and road teams is now completely Sudanese, and the only European supervision is that of an engineer who tours the four units—sometimes widely dispersed—during their field season, and of the manager of the depot who makes occasional tours during the same period. The workshops and stores at the base have a small European staff.

In addition to seven-and-a-half months of arduous field routine the staff of the excavation teams have to cope with any incidents that occur, from the heavy job of replacing broken tracks and clutches on the tractors and changing steel cables on the Carryalls, to dealing with attacks by wild bees. On one occasion whilst clearing an hafir site the bulldozer demolished a tree containing a bees' nest, the occupants of which at once attacked the interloper. The driver fled precipitately. A brave volunteer, covered in sacks, tarpaulins and other sting-proof apparel, returned to turn off the engine of the tractor, but the whole job of digging that hafir had to be done by night, as the bees returned to the attack each dawn and held the field till dusk.

THE SEQUENCE OF FIELD WORK

The plan received at the beginning of each season by the Manager of the Mobile Plant Depot is in the first place the result of the five-year plan agreed to by the Rural Water Supplies and Soil Conservation Board, and in the second place, of a number of years of preparatory work by the Soil Conservation and Surface Water Supplies Section. So far as the latter is concerned, hafir programmes involve the following sequence as a basis for amendment:

First year	...	preliminary reconnaissance
Second year	...	reconnaissance track clearance
Third year	...	clearance of access tracks
Fourth year	...	site investigation and grading of access tracks
Fifth year	...	excavation and completion of hafirs.

This sequence must be regarded as the one that would be followed were there absolutely no knowledge of the country in which hafirs were needed and if there were ample time for preparations. Always there is some knowledge and never is there ample time for preparations, and this means that some of the steps may be omitted or may have to be sandwiched into one year. In extreme cases in the days of early operations barely one season's reconnaissance work was done, but here at least there was a fairly detailed knowledge of the country and a willing staff of helpers from the Ministry of Agriculture and from the Forestry Division.

Preliminary reconnaissance has as its object the determination whether the country proposed is in fact suitable for development by hafir water supplies, that is to say, whether conditions of hydrology and soil are suitable and compatible, and administrative conditions favourable. It may, for instance, be clear that soils over a particular area are too thin for surface storage or too pervious, or the difficulties of access and supply of the weighty machinery may be too great and expensive. Some areas may have too short a working season owing to late drying out after the rains or the late abatement of annual floods.

Should the preliminary reconnaissance show that an area is generally suitable for hafirs, the existing road system—if there is one—is examined to see what additional tracks may be needed for reconnaissance parties, and the general lines and extent of these decided upon before the next season's work. When the next season, that is year number two, begins, field parties scrape temporary tracks with medium tractors and scrapers and where necessary clear lines through the bush, though clearance is avoided as far as possible until the following season when definite commitments for the future are undertaken. From these tracks a better knowledge of the country is gained, and the main hydrological features and distribution of soil types, so far as they concern hafirs, are charted sufficiently to shape the excavation programme.

Before opening the third working season the lines are chosen for the permanent access roads which will be needed for the passage of the excavating machinery, for the maintenance of the finished hafirs, for the extraction of new produce resultant from the new water supplies and for the inward movement of consumer goods. During the season these lines are cleared to a width usually of 12 metres. The work is preferably done by contract and costs anything from £E.20 to £E.60 per mile. With the contractor's men are road trace foremen from the Soil Conservation and Surface Water Supplies Section who have been trained in setting out such traces for long distances on compass bearing or upon landmarks.

During the fourth season the access traces, previously cleared, are graded by the two road teams, and this costs about £E.16 per mile. While this is going on survey parties are levelling and soil-testing prospective hafir sites. The degree of levelling necessary depends largely upon the way in which the hafir is to be filled.

In general filling sources fall into the following categories, though they are not watertight compartments, and in practice one source may have the characteristics of more than one category: inselberg catchment (close), inselberg catchment (remote), seasonal torrent, swamp, gardud, and artificial catchment.

(*i*) *Inselberg catchment* (close) is used in the case of small inselbergs which are too small to form torrents with their surface run-off of storm water. Since the Sudan has a large number of inselbergs in its clay plains, and as these are often the only means of concentrating the storm water sufficiently to make it usable, much attention has been given to this form of catchment, particularly in the Blue Nile Province. Basically the method involves putting a canal at a suitable slope just above the line at which the inselberg merges with the cottonsoil plain. An estimated figure of three per cent of the average annual rainfall falling upon the inselberg and its plinth is collected. This is a safe figure and it is usually exceeded. The water from the catchment canal is led away to the hafir site in a lead-in canal, and the site is usually perforce some distance away from the inselberg in order to obtain sufficient depth of soil, which is seldom required to be less than six metres and may be up to ten. A snag in this method is the expense involved in preventing scour in the lead-in canal which in most cases has to run at a fairly steep slope. If possible, though lack of time and the difficulty of transporting materials often prevent it, this is done by the installation of weirs in masonry or gabions. If this is not possible and scour cannot be avoided a silt trap of about one-tenth the size of the hafir may be interposed before the hafir.

(*ii*) *Inselberg catchment* (remote) is used where an inselberg, or a group of linked inselbergs, is sufficiently large for its run-off to form local torrents. Hafirs may then be sited to fill from these torrents using short intake canals of a 100 metres or so in length and the expense of collection and long lead-in canals is avoided. Sometimes an hafir may be needed some distance out in the plain where there is no annually occurring water source: in this case the tail of a torrent may be extended using a suitable machine to form a canal. Carryalls have been used most successfully for this purpose and in one instance, using a natural depression as a line, a cut of 20 kilometres was made, which now brings more than enough water to fill an hafir of total size exceeding 300,000 cubic metres.

(*iii*) *Seasonal torrents* vary considerably in usefulness as hafir fillers according to their size and characteristics of velocity, silt content, regularity and proximity to impervious soil. The ideal torrent is one which brings clear water at a non-scouring velocity and just enough of it to fill the hafir. The further this ideal is departed from, the greater the expense in completion works to ensure maximum life between major maintenance operations and filling, in a season of small flushes, and to defend the hafir against heavy spates which overflow the normal bed of the torrent. Large torrents often have beds of pervious silt along their banks with the impervious clay retired at awkward higher levels; carefully levelled canals are then necessary as lead-ins and their banks may give trouble through cracking in the dry season. The faster the torrent, the greater the amount of silt and debris carried, and the more likely it is to make local changes of course which may leave the offtake point high and dry or cut off from the hafir from behind. Whatever the nature of the torrent the general rule followed is that in securing an offtake point local hydrology is interfered with as little as possible: offtakes are sited on the outsides of gentle bends so that the mainstream impinges directly on to a radius of the curved downstream pitching of the canal head. This method has been found successful over a period of trial and error in the Gash delta, where some 50,000 acres of cotton and grain growing land are irrigated by floods from the Gash river torrent each year.

Two main classes of torrent are distinguishable with many intermediate examples. At one extreme is the torrent which only flows with one heavy flush for a few hours in the season, and at the other, the torrent which flows with reasonable regularity. With the former a large volume of water has to enter the hafir in a short time and carefully thought out designs have to be made and executed. Where there is ample water the best answer to inlet works is to be found in the use of steel pipes, provided there has been time to get the pipes ordered from supplying countries. Where time is very short and an hafir has to be filled in a very few hours, masonry works of very ample section have been used. These are satisfactory in actual performance but they are expensive to construct and maintain, as building sand, stone and aggregate are usually remote from sites.

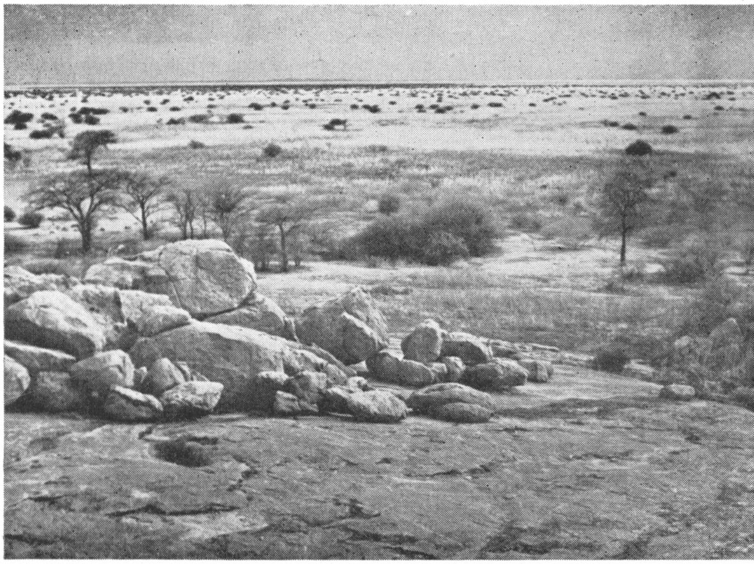

Figure 1. Jebel Meleisa, or ' The Smooth Jebel ', a small inselberg between the Blue and White Niles

Figure 2. An aerial view of Abu Sana hafir of 25,000 cubic metres capacity

(*iv*) *Swamps*, with their clear water, are the best fillers of hafirs, and small diameter and therefore cheap pipes can be used for inlets. The only downward limitation to the size of pipe is the necessity for it to be large enough to avoid choking with debris and this can be prevented by the use of suitable screens. If filled from swamps, care must be taken not to plan hafirs too near the water's edge, for the site must dry out sufficiently for the machinery to work as soon as it arrives.

A variation of the swamp as a source which is very useful, is the small swamp formed in the S bends of an old bed of a large torrent. These S-bend swamps are well known and have special native names; they act as excellent silt traps and obviate the need to take special precautions in the construction of canal offtake heads.

(*v*) *Gardud* is an Arabic word which means an area of non-cracking clay or clay and sand mixture. It is usually slightly elevated above the surrounding plain and on a slight slope and therefore productive of a run-off of storm water. Two features commonly give rise to garduds: denuded or vestigial inselbergs where a plinth only shows above the ground and small sandhills at whose edges the sand had been washed down and mixed with the clay of the surrounding plain, or whose clay fraction has been washed out and mixed together with some of its own sand to form a non-cracking apron with run-off propensities. Hafirs filled from gardud catchments use the same system of catchment and lead-in canals as those filled from inselberg (close) catchments.

(*vi*) Because of expense and shortage of staff *artificial catchments* have up to now been avoided, with one exception. Various forms of artificial catchment have been considered for use when necessary and they are mostly based upon the use of bitumen in making impermeable a clay area which would not normally have a run-off. But in the one case where an artificial catchment has been made about 750 acres of heavy clay forest land have been drained by a herringbone system of ditches made by a road grader. The slopes in the area do not exceed one in a hundred and there would seldom be free surface water for collection. Observations of run-off from the roadside drains on earth graded roads under comparable conditions showed that about 50 cubic metres of water could be collected per acre drained. It is hoped at least to half fill an 80,000 cubic metre hafir in this way. Preliminary reports, received as this is being written, show that the herringbone drainage system seems to be working better than was expected.

The problem of settling the details of catchments and the collection of water therefrom, goes hand in hand with that of finding suitable soil for the hafir. Here the two most important qualifications are clearly depth and impermeability. Certain surface signs give a good indication of both these attributes: black soil as opposed to red or brown; even cracking as opposed to pot-holing or no cracks; level ground as opposed to sloping; absence of surface pebbles and the absence of trees other than *Acacia mellifera* and *Balanites aegyptiaca* are, taken all together, good indicators of soil depth and impermeability. Sites thus shown to be favourable must be checked by soil sampling, which is done by the tedious but so far irreplaceable method of digging test shafts. To start with three test shafts are dug at the corners of an equilateral triangle of side length 60 metres, with the centre of the triangle over the centre of the proposed hafir. Should one of the shafts strike unsuitable material it is abandoned and another dug to make another triangle on the opposite side of the other two shafts; this manoeuvring is continued until a satisfactory triangle is found. Should the area as a whole be promising for suitable soil, the triangle of three sound shafts is taken as a sufficient proof of a good site, but in the case of difficult areas further pits must be dug at the corners and centre of the hafir to make sure.

The degree of departure from the ideal of pure impermeable clay that may be tolerated in cases where hafirs are urgently needed in particular sites depends upon the way in which imperfections occur. Impermeable clay mixed evenly with quite a large amount of sandy material will pass, but bands of pure sand in pure clay are difficult to deal with, especially if they are at low levels or through the bottom of the hafir. The only thing which can be done is to cover sand on the bottom with clay brought in by the machines at the time of digging, and to dig away bands of sand in the sides, causing the clay from above to collapse and seal them off.

During the fourth season of preparation the question of the sizes of the future hafirs must be decided. Because the Sudan is still largely a country of nomads, tribal communities and shifting populations—particularly in the areas where hafirs are dug—precise calculations are not possible as to future demands for water. A fair division of the season's work amongst the various claimants in an area is a major factor influencing size; so are the degree of hardship already suffered from shortage of water, the probable speed and extent of resulting development, the most economical size for the excavating machinery and any other local factors.

For *agricultural purposes* hafirs are usually needed for either *permanent settlement* or for *seasonal cultivation only*. In the case of permanent settlements water must also be allowed for domestic animals, and an allowance is made of a minimum of three cubic metres per month per family with domestic animals. This may seem small, but it is generous compared with previous standards. The smallest hafir used for permanent settlement is of 30,000 cubic metres size and the largest about 80,000 cubic metres. These sizes—allowing for half the water being lost by evaporation and some loss of capacity from silting before maintenance—are estimated to support 500 and 1,300 families respectively; to date this capacity is not fully taken up though demand increases each year. The effective offtake period is taken as 300 days per year as during the remaining 65 days loss will be made good from direct catchment of rainfall and reduced by animals drinking from pools. The larger of these two hafirs represents about the maximum size desirable. If an hafir is still bigger it means that cultivators will have to walk too far to their furthest land. A big hafir supporting 1,300 families and that number of cultivators, on a three course bush/bush/cultivation rotation at 10 acres of cultivation, will need 39,000 acres. This area represents a square of side just over eight miles and diagonal just over 11 miles. If the village were in the centre of the square, which cannot always be arranged, a villager might have to walk five-and-a-half miles to his land; if the village were not central distances would of course be greater.

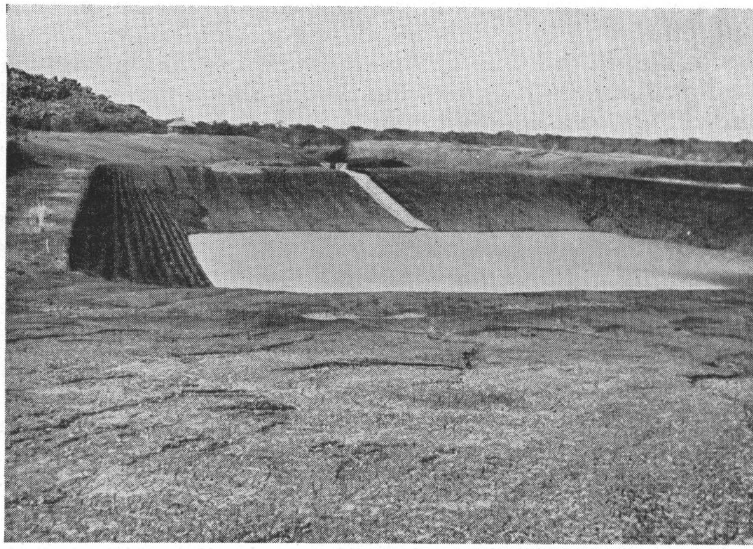

Figure 3. A finished hafir in the Blue Nile Province of about 20,000 cubic metres capacity just after the first water had entered

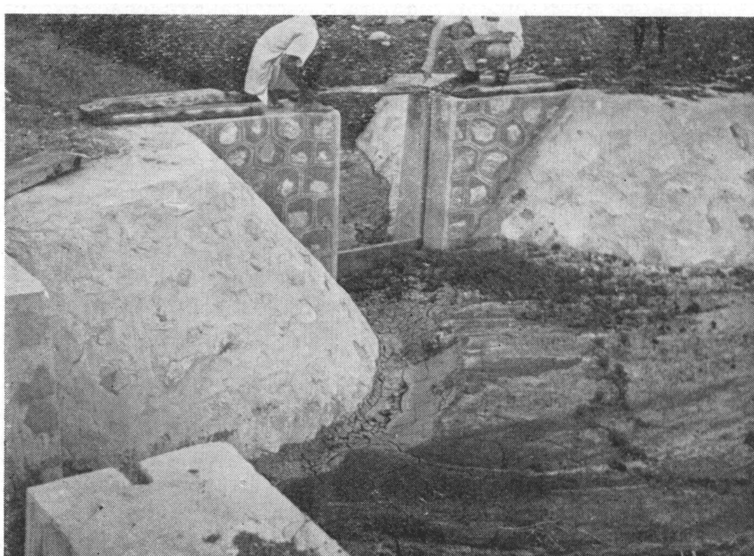

Figure 4. Typical arrangement of two stop log gates, one for inlet water and the other for surplus water

A note on village land layout is not out of place here. African rainfall and growth conditions are notoriously uncertain and it is necessary to include some provision against the cultivator's misfortune if the rains miss his plot. In the case of higher rainfall areas this is attempted by dividing the village land in long strips rather than squares; in areas of lesser rainfall a chequer board system distributes the season's cultivated land over several squares. Individual plots are not demarcated but allotted according to tribal custom within the blocks.

The allowance of three metres depth of water for evaporation and silting is very generous: in fact, annual evaporation computed from Piché figures varies from just over one metre to just over three metres from an open water surface, but further south, and thus further into comparatively low evaporative conditions, the season of demand for water becomes shorter, and hafirs may therefore be smaller on two counts.

For *seasonal cultivation* not requiring settlements hafirs can naturally be smaller. They do not have to maintain large numbers of animals and demand occurs at a time of year when evaporation is low and losses largely replaced by direct catchment from rainfall. Many successful hafirs have been made for the Dinka tribe, their capacity varying between 6,000 and 10,000 cubic metres. To be fully effective it is important that these hafirs provide water for cultivators who come to prepare their land at the end of the summer, before the new rains make the catchments run. Thus the water must last from the end of one cultivation season throughout the summer for these preparations at the beginning of the next season, and a margin of extra size is necessary to compensate for evaporative loss.

Hafirs in this class are also provided for the utilization of ' harig' land. ' Harig ' is a technique—its large-scale use is believed to be unique to the Sudan—whereby accumulations of old grass are used to rid the land of new weeds by burning off old and new together: it is naturally practised only in remote areas where fires started by human beings are not all-pervading. Harig areas are also, of their nature, waterless, and in the past they have been worked by hardy peasants coming long distances by camel and existing on the barest minimum of water, taking great chances that water from puddles will enable them to stay long enough for the establishment of their crops. Often unfavourable rains have resulted in the loss of crops through a shortage of drinking water. Small hand dug hafirs, even at wide intervals, have helped to increase the yield of this form of cultivation, and the bigger mechanically dug ones should ensure this increase.

For *stock* the size of hafirs must be correlated with the nature of the grazing, with existing water points, water potential which can be developed from other sources, the number of animals and the time they are intended to graze the area, and with any other local factors. To assess the importance of these things, study by pasture research officers is required. In the early days of hafir construction such study had not been made, and water for stock was provided by siting hafirs at the most convenient places along migratory routes. Now a more refined approach is made. A major object of schemes for improved grazing is the strengthening of good grass species, and this is planned by dividing the country into strips, one of which is rested each year. With water points few and far between, a great deal of grazing is wasted by being trampled to pieces and blown away; at the same time much of the energy obtained from the grass is wasted when the animals have to walk long distances between grazing and watering points. These defects are common knowledge, so common that they seem to be accepted by the nomad as an immutable natural law. A difficulty in improving grazing conditions is that stock are managed on a tribal system which, with the best will in the world from tribal leaders (and some are very co-operative), is difficult to rationalize into anything like the ranching plan one would like to see.

In southern Darfur in the extreme western Sudan, a scheme for grazing improvement based upon hafirs is being carried out. So far 15 of a probable total of 45 hafirs have been dug; their average size is about 7,000 cubic metres, varying from an individual 3,000 to an individual 12,000 cubic metres. This scheme, which is incorporated with the seasonal migration of the Rizeigat tribe, falls into two parts. The area concerned is in the centre of the tribe's annual north to south migration route and the northern half of the scheme involves division of the route into three strips watered by hafirs and a few natural shallow well fields. One of the strips will be closed each year to strengthen the grasses therein. In the southern half no strips are provided but the whole is to be protected from the annual total fires by a system of firelines and fire-guards. It is not intended to hold the tribal animals within the area of the scheme for the whole year, but to delay their passage to their summer grazing grounds to the south by about two months, so that the grazing there will be better able to last out the summer. At present it is very severely punished and in poor years many beasts die of starvation. Another reason for the need of more grazing in these parts is that, in common with other areas in the western Sudan, it has for several years been the scene of an intensive anti-rinderpest campaign. This has resulted in a large increase in the number of animals to be fed.

Before leaving the subject of hafirs used for stock mention must be made of a successful and important operation carried out in the 1950–51 and 1951–52 seasons. This consisted of the provision of water by hafirs along 300 miles of a 600 mile route from stock raising country in the south-western Sudan to a new canning factory recently erected by Messrs. Liebig at Kosti on the White Nile. It was intended to have hafirs on the route at 15 mile intervals, which was considered by the veterinary authorities to be the best spacing, but lack of time for reconnaissance resulted in an average interval of about 30 miles. The hafirs are of 25,000 cubic metres capacity each and are dug as twins of equal capacity. The object of this is to facilitate desilting when it becomes necessary, as one half may be pumped into the other when the levels have dropped sufficiently and clearance work carried out without leaving the point waterless. The two halves were dug in successive seasons, and a strong supporting reason for this action at the time was the very high price of cotton grown in the area of Kordofan Province south of the hafirs. This enabled a considerable extra capacity of hafirs to be given immediately to the cotton industry, which has paid quick dividends. In addition to the hafirs along this route it is hoped to make a group near Kosti which will enable cattle to stay in a holding area to act as a reservoir of animals and stabilize the flow to the factory.

In the fifth year of the programme the spotlight is on the Mobile Plant Depot and its staff and machinery in action in the field. Together they are indeed spectacular and the spectacle is matched by the satisfaction of the staff of the Soil Conservation and Surface Water Supply Section in seeing their long-prepared plans come to fruition. This does not imply that the section is now a looker-on. The field staff from headquarters have to follow the excavation machinery as closely as possible, installing finishing works to each hafir. These works, which cost on an average £E.500 per hafir, comprise masonry flumes or piped inlets with suitable offtake arrangements from feeding canals, weirs to prevent scour where necessary, housing for the watchman, housing for the area foreman, fencing and water extraction plant with water points for human beings and animals.

The question of what kind of water extraction apparatus should be provided proves difficult to answer. The object is to extract the water in adequate quantities in such a way as to avoid completely any contamination by infected human beings or animals. The apparatus provided must do this and at the same time be foolproof and capable of maintenance by the very simplest-brained persons. After much thought a solution has been reached in an outside well connected to the hafir by an underground pipe. The well is fitted with a diaphragm pump—thus avoiding metal valves—and has a sealed cover. If the pump breaks down irreparably the well cover may be removed and dippers used temporarily. The principal snag to this otherwise good solution is the difficulty of installing the underground pipe, which must be laid at a depth of about six metres. For this purpose a thrust boring machine has been bought and is under test, though at present the pipes are laid down in a hand excavated trench—a very tedious thing to dig as it is about 100 feet in length besides being deep.

The principal waterborne disease to be guarded against in the Sudan is bilharzia. So far no hafirs have been shown to carry this infection, but the strictest precautions are taken. (Hand pumps are used on hafirs up to about 20,000 cubic metres and mechanical pumps on larger hafirs. An advantage of the outside well system is that the well itself has some significant capacity and several pumps may be grouped upon it or one mechanical pump substituted for several hand ones.) In addition to the water-extracting apparatus fencing is considered important: this again gave much food for thought before a standard form was decided upon. Five strand barbed wire fences are now installed. They are rather expensive, but attempts to avoid this expense by using local materials for poles and thorn filling failed through the depredations of termites, fire, and the laziness of watchmen.

COSTS

Because of the shortage of accountants no attempt has yet been made to find out individual costs for each hafir. All that can be achieved is a figure compounded of all the various costs of the processes described, divided by the number of hafirs or cubic metres produced. Upon this basis, over a total of 276 hafirs of total capacity with feeder canals of about three million cubic metres of excavation, the cost per cubic metre has worked out at just about seven shillings. This cost comprises the following:

		s.
Hire charges on excavation machinery	...	3
Clearing and grading access roads ...	...	1
Completion works	...	1
Establishment charges	...	2
	Total	7s.

The establishment charges refer to the cost of regional and headquarters offices and therefore include reconnaissance work.

Actual costs of individual hafirs may vary greatly from the average figure of seven shillings per cubic metre: probably they would be as low as five shillings or as high as 10 shillings. The figure for hire charges on excavation machinery includes the fees paid for rail and river transport which run into £E.3,000 to £E.4,000 a year with both teams, and it includes all idle running time between sites, during which each team covers between 1,000 and 1,500 kilometres a season.

The above remarks apply to capital costs. In planning hafir schemes for the future account must also be taken of day to day running costs. Each hafir costs about £E.200 a year to maintain: about half of this sum is taken by the watchman's wages, about one-quarter by a repair contingent which may be spent not annually but when necessary as a greater sum, and about one-quarter by an annual contribution to access road maintenance of which the major part is the removal of grass after the rains and the filling in of pot-holes. Access roads must be regraded about every five years, though in favourable circumstances the interval may be longer. In a handier form these figures of capital and maintenance costs work out at two shillings per cubic metre of water to the consumer, assuming a depreciation of the hafir in 20 years. In practice water is not generally charged for because of the opportunities for peculation in the collection of many small sums in divers remote places.

It is the policy of the Sudan Government to hand over all hafirs as they are constructed to local governments for day to day running and maintenance. This is not easy as in some places local governments have not yet emerged, and where they have emerged their resources of skilled supervisors are too small to meet this demand. It is considered best, however, to press on with the handing over, so that local authorities may learn by seeing their own mistakes.

As a result of hafir operations during the last six years some nine million acres have been put within reach of the cultivator, to be exploited by his ancient methods. Before the full resources of the rainlands can be released much remains to be done to develop practical new agricultural methods suited to African conditions: meanwhile by the provision of simple surface water supplies the ' African and his hoe ' economy may be enabled to carry on, supporting the demand of development in other fields until this release is achieved.

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حكومة السودان

مذكرات قسم الغيـط

نمره (٧)

الحفـــائر او التعمير باعـــداد مستودعات المـــاء السطحيه في السودان

تـــاليف
ج. هـ. ك. جفرسن

لجنـــة النشر الزراعيـــه
الخرطوم ١٩٥٤