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THE IMPACT OF THE JONGLEI CANAL IN THE SUDAN

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A one-day conference was held at the Royal Geographical Society on 5 October 1982 on the development and potential effects of the Jonglei Canal in the Southern Sudan. Eight experts involved in different aspects of the work on the canal spoke on planning, problems of irrigation in the Sudan, the canal's construction and its probable impact on the local population, the land and wild life. Dr Paul Howell, who had been Chairman of the earlier Jonglei Investigation Team studying the proposal for the canal in the 1950s, has collated and, in some cases prepared, summaries of the papers read at the conference. It is hoped that a book will be published containing the full papers and details of more recent developments.

The speakers at the conference were, in the order in which they spoke, H. E. Sayed Yahia Abdel Magid, former Minister of Irrigation in the Sudan; Dr Paul Howell, Fellow of Wolfson College, Cambridge; Sayed Kamal Ali and Sayed M. A. Mohammedein, both of the Permanent Joint Technical Commission for Nile waters (PJTC); H. E. James Ajith Awuol, Chairman of the Executive Organ, National Council for the Development of the Jonglei Canal Area; Jonathan Jenness, Adviser to the Jonglei Executive Organ (JEO); Steven Lawry, Land Tenure Center, University of Wisconsin; Dr John Sutcliffe and Yvonne Parks, both of the Institute of Hydrology, Wallingford, Oxon; and Dr Stephen Cobb, David Jones, Jonathan Kingdon, and Dr Roland Bailey, all members of the Mefit-Babtie team (an Anglo-Italian consulting group) who made ecological studies.

Dr Cobb summarized the discussion which followed the papers.

DR HEMMING, Director and Secretary of the Royal Geographical Society welcomed all those participating in the conference, and invited the first speaker to read his paper:

His Excellency SAYED YAHIA ABDEL MAGID, former Minister of Irrigation in the Sudan, introduced the proceedings with a paper entitled *Conservation projects of the Nile and irrigation development in the Sudan*. Outlining the history of irrigation in those countries, Sayed Yahia referred first to the events leading to the Nile Waters Agreement of 1929 and the control works then envisaged. These included storage behind dams at Jebel Aulia and Sennar, storage in Lake Tana and Lake Albert, and a diversion channel to reduce losses by spill into the *Sudd* swamps. Failure to reach agreement with Ethiopia over the proposed Upper Blue Nile Project below Lake Tana and the construction of only the Sennar Dam led to concentration of hydrological and engineering studies on plans for control of the upper White Nile or the equatorial Nile Project. After protracted negotiations and the recommendations of a Commission established in 1925, the first Nile Waters Agreement was reached in 1929, the most significant feature being that the development of control works should in no way infringe Egypt's 'natural and historic rights'.* Moreover, working arrangements providing for these allocations assured Egyptian claims to almost the whole of the natural flow of the river from the beginning of January to mid-July—the 'timely' period. The Sudan had to meet nearly all its requirements during this period from storage.

After the Second World War Egypt put forward revised plans for further control works to increase the availability of irrigation water in the 'timely' period, these to include a reservoir near Merowe for summer and flood protection storage, a reservoir combined with regulation in Lake Victoria**, over-year storage in Lake Albert, a

* The Nile Waters Agreement of 1929 defined Egypt's 'acquired rights' as 48 milliards (1000 million m^3) per annum, with only 4 milliards allocated to the Sudan—a total of 52 milliards out of a mean flow of 84 as measured at Aswan. The remaining 32 ran to waste in the sea.

** Construction of the Owen Falls Dam at the outlet of Lake Victoria was completed in 1954 with agreement to limited storage and a minimum constant discharge to meet hydro-electric power requirements in Uganda.

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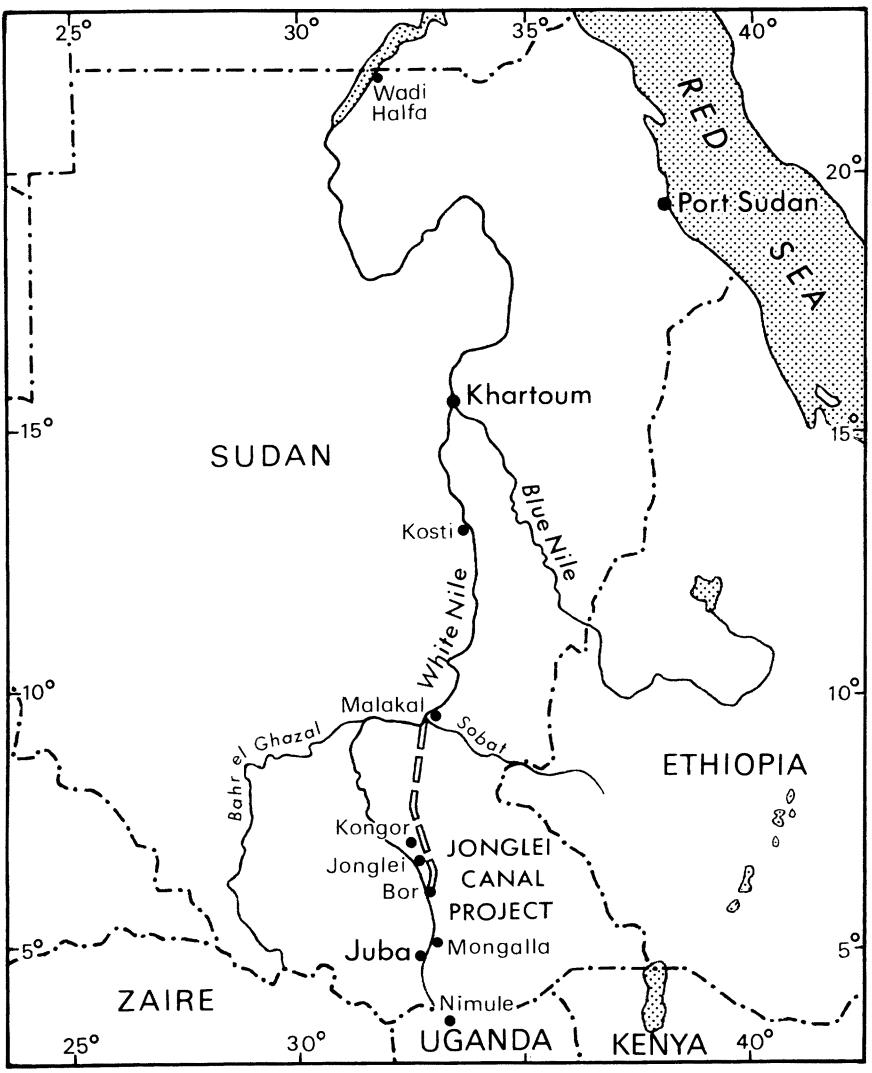

Fig. 1. Location map

diversion canal through the eastern part of the *Sudd* to carry about half the 'timely discharge from Lake Albert, with diminished losses in the Bahr el Jebel, and plans for over-year storage in Lake Tana should agreement be reached with Ethiopia.

In 1946 the then Sudan Government set up the Jonglei Investigation Team to study the Equatorial Nile Project in detail and its effects on the interests of the Sudan in the *Sudd* region and to recommend remedies where necessary. The Team adopted two approaches to mitigate the effects. In the first place they recommended a set of direct remedial measures to maintain the existing form of economy with the least possible disturbance; in the second a revised operation calculated to simulate as nearly as possible the natural fluctuations of the river in order to reduce any adverse effects locally to a minimum, and avoid as far as possible the need for alternative livelihood schemes. 'This clearly manifests the attitude prevailing at the time; agreement to the project to fulfil its main objective for the provision of water downstream and a negative

approach to the problem of the development of the region and the Sudan as a whole. Since both Egypt and the Sudan were still bound by the terms of the 1929 Agreement, the concept of conservation and control projects continued to focus on the need to augment, in the 'timely' period, the low flow of the river, mainly for the benefit of Egypt. No extra provision for irrigation needs in the northern Sudan from additional water made available by the Equatorial Nile Project were included in the terms of reference of the Jonglei Committee* and only limited extra supplies could be provided by raising the Sennar dam (in the early 1950s) and plans for another storage reservoir on the Blue Nile at Roseires.

In the mid-1950s, the Egyptians produced the concept of over-year storage behind a High Dam at Aswan, largely within its own territorial boundaries, thus providing the solution to their three main problems: meagre summer flow, floods, and the occurrence of low years. To the Sudan, the Aswan High Dam offered a solution to their dispute with Egypt over the apportionment of water under the Nile Waters Agreement of 1929. The Aswan High Dam would obviate the need for increased 'timely' discharges upstream, and the net mean saving would be 22 milliards m^3 out of the 32 which then ran unutilized and uncontrolled into the Mediterranean.** Under the Nile Waters Agreement of 1959 which followed the Sudan received an additional 14.5 milliards m^3 bringing its total to 18.5 and was, besides, no longer precluded from drawing water for irrigation from the natural river flow during the 'timely' season. At this point, too, the Permanent Technical Commission for Nile waters (Egypt and Sudan) was established with responsibility for control of the river on behalf of the two governments and for studies leading to future conservation works to increase the Nile flow.

After outlining further irrigation and economic developments in the northern Sudan, H. E. Sayed Yahia turned to the present Jonglei Canal Project (Fig. 1). Studies promoted by the Joint Technical Commission revealed the possibilities of considerably increasing the flow by reducing losses not only in the *Sudd* region, the immediate objective, but ultimately in the Bahr el Ghazal area and the Machar Marshes north of the Sobat River. Agreement was then reached to embark on the first phase of the first of these schemes to provide an additional 4.75 milliards m^3 (3.85 milliards net at Aswan) at the tail of the swamps just above the mouth of the Sobat in order to meet increased irrigation water demand by the mid-1980s. The main features of the new diversion canal, which will now take off from the Bahr el Jebel in the vicinity of Bor, are as follows:

(1) The canal is not dependent on the regulation of the Equatorial Lakes; there will be no reversal of the hydrological regime;
(2) the question of 'timely' releases does not arise since this requirement is controlled by the Aswan High Dam;
(3) the diversion of over 20 million m^3 of water per day down the canal will relieve many areas down-stream which over the last 20 years have been subjected to severe flooding, and at the same time 'increase the potential for riverain grazing to be uncovered during the dry season';
and (4) the cost of the project and water benefit are to be shared equally between the Sudan and Egypt.

What needs to be stressed is that, while the approach in the 1940s was to ensure that the Equatorial Nile Project did not disturb the existing economic and social structure of the area, in the 1970s the approach is 'development without destruction'. The canal will provide an important infrastructure for economic and social mobilization of the vast human, land and animal resources of the area.

In a paper entitled *The Equatorial Nile Project and the Jonglei Canal*, Dr Paul Howell, Fellow of, and Director of Development Studies at Wolfson College,

* 'Additional' water—that is water made available by control works such as the Jonglei Canal—is now to be divided fifty-fifty between Egypt and the Sudan under the 1959 Agreement.

** It was calculated that 10 millards m^3 would be lost by evaporation in the High Aswan Lake.

Cambridge and former Chairman of the original Jonglei Investigation Team,* highlighted three main points of difference between the earlier Equatorial Nile Project and the current Jonglei Canal Project. First, the Jonglei Canal as then proposed was of more than double the capacity of the present structure, and was part of a much larger complex and ambitious scheme, including control of the river upstream and storage in the Great Lakes of East Africa. Secondly, though ecological effects similar to those expected under the present project were then forecast, the reasons were quite different; relating as they did to a new artificially regulated river regime, they would have been far more extensive and almost entirely adverse. The new river regime was then designed, not only for over-year storage, but with seasonal control to release water in order to reach Egypt in the 'timely' season when the Blue Nile flow dropped away. The 'timely' season coincided with the dry season in the southern parts of the Sudan when the natural channels of the river were at their lowest. The 'untimely' season, when the water would be held back and stored, was just that time of year when the river was normally at its highest. The general effect would therefore have been the reversal of the natural seasons.

Between Mongalla and Jonglei, land along the river that by January was normally fully exposed to provide dry-season grazing was to be under water, while in the rainy season inundation of the floodplains would not take place at all, with consequent effects on the grass species and the disappearance of valuable *toich*land.** In the zone between Canal Head and a line roughly from Buffalo Cape on the Bahr el Jebel to Fangak on the Zeraf River, approximating to the area that is nowadays often referred to as the 'Jonglei area', the floodplains would not be inundated at all, with similar reductions in valuable dry season grazing. Further north the river would remain permanently at a relatively constant high level, discharges being increased to coincide with 'timely' requirements, while in the rains the level would be supplemented by high discharges from the Sobat River coming in, uncontrolled, from a different catchment.

The economy of the region was then, as it is now, very largely dependent on animal husbandry, supplemented by rain-grown crop production, an essential but hazardous enterprise because of the erratic distribution of rainfall and the incidence of both drought and flooding. The Project, as then designed, would have caused serious adverse effects from Mongalla to Renk, resulting, according to the calculations of the time, in an unavoidable decrease of about 36 per cent of the total livestock population and not less than 20 000 tonnes of fish per annum, also a very valuable potential resource.

The Jonglei Committee was not directly concerned with the broader issues of negotiations over river control throughout the Nile system or the proportions of the flow to be allocated to the countries of the Nile valley. In that regard, the interests of the Sudan were being actively pursued in another quarter. The Committee and the Jonglei Investigation Team were involved only with possible repercussions in the Southern Sudan, a matter of genuine concern to the government of the time. The conclusions of the investigation were that losses would have to be met by 'direct' remedial measures either in the form of artificially irrigated pastures in the dry season—a necessarily costly and probably uneconomic undertaking—or in the form of irrigated agricultural alternatives as well as the development of rain-grown crop husbandry and other economic activities. Whatever the form, the remedies had not been adequately tested. The region then, as now, presented massive problems in terms of development. 'Direct' remedies, which in concept and purpose were synonymous with what others may now refer to as development projects, were either technically difficult to implement or seemingly uneconomic to operate, to say nothing of the

* *The Equatorial Nile Project and its Effects in the Anglo-Egyptian Sudan*, 1954.

** *toich*: a common Nilotic term for the floodplains seasonally inundated by spill from the rivers and watercourses of the region. The annual grass species thus produced, largely determined by the depth and duration of the flooding, are of crucial value for grazing when the water recedes and they are exposed and accessible at a time of year when pasture is not to be found elsewhere. *Toich*land is therefore an essential resource in the local economy.

complex problems of an abrupt change in economic circumstances and hence new forms of livelihood to which the people would have had rapidly to adapt. Proposals for so-called remedial measures were in fact very little different from the type of development projects proposed and in some cases under trial today, including the introduction of organized markets for cattle and agricultural produce, grain storage facilities, the promotion of the fishing industry, and a whole range of other possibilities. The Team also had its own experimental irrigated agricultural station at Malakal, where the soils and other conditions were identical with those to be found in the Jonglei area, and many types of crop, including some 200 varieties of rice, were being tried out. Time was needed for further research, trial and training.

It was not, therefore, a negative approach at all; it was a cautious approach to untested development possibilities which prompted the Team to recommend a revised operation of the project in such a way as to limit local hydrological and hence ecological effects as much as was feasible, while in fact reducing the net benefit in much needed additional water emerging from the *Sudd* by only 4 per cent. These proposals were logical, and represented great savings in the costs of remedial measures, the efficacy of which was yet to be proved but which were in no manner of means inconsistent with the objectives of economic and social development that are quite rightly the concern of the Jonglei Executive Organ today. It must not be forgotten, too, that on the completion of the Jonglei investigation work, the team, which had by then gained much experience of the area, was immediately transformed into the 'Southern Development Investigation Team' whose instructions were to examine all aspects of development potential in the southern provinces as a whole.* Since then, of course, plans for upstream control works have been abandoned at least for the time being, and, as Sayed Yahia explained, the need for 'timely' and 'untimely' discharges in Egypt has been met by the construction of the High Dam at Aswan.

Dr Howell explained that there was a third very important point of difference, this time in physical circumstances rather than design or method of control. This was the great hydrological change in the natural river regime since the first Jonglei Investigation had been completed. The high discharges of the 1960s and 1970s and the build-up of water in Lake Victoria had vastly increased the area of permanent swamp and flooding from the river. Combined with heavy precipitation in the region and consequent rain flooding and creeping flow**, this had resulted in great human hardship and loss of animal stock. It followed that if this cycle of heavy annual discharges continued, the present Stage I Canal might do much to alleviate these adverse physical conditions, though such a benefit might not occur if a cycle of dry years were to follow.

An all-weather road along the Canal, more direct river communications, more certain and varied means of crop production accompanied by efficient facilities for storage, increased animal disease control, the evolution of new techniques in both animal and crop husbandry, the stimulation of better market incentives and facilities, the provision of water supplies inland during the dry season, good public health and education services and other social benefits, all these were sound objectives. Measures already undertaken and others in the planning stage would be described by other speakers; it was evident that the National Council for the Development of the Jonglei Area and its Executive Organ had all these things in mind and were vigorously tackling the problems involved.

The effects likely under the present Canal Project should above all not be confused with the catastrophic impact of the earlier scheme had it been implemented without revision. However, for those who had surveyed the area in the past, while acknowledging the differences mentioned above, there were nonetheless some lingering anxieties about the hydrological and hence ecological effects of the project

*Their initial survey, though crammed by circumstances into a very short period of time, suggested many development possibilities which have subsequently been initiated in the Southern Sudan. See *Natural Resources and Development Potential in the Southern Provinces of the Sudan*, 1955.

** Creeping flow, Creeping flood: rain flooding which accumulates after heavy precipitation and creeps slowly over the flat 'intermediate' grassland plains of the area.

and the feasibility of some of the measures suggested, whether they were called remedies or development. The extreme harshness of the environment, poor soil conditions, inadequate natural drainage, and other adverse factors inevitably made the development of the area a more daunting prospect than in many parts of Africa. The potential was there, though there were some who remained sceptical of the year-round grazing value of the perennial grasses in the vast areas of intermediate land so often cited as a major resource. The exploitation of the potential demanded long years of trial and experiment *in situ*. That was essential to determine the crops best suited to the soils, to establish optimum water duties in the case of irrigation, and to breed suitable disease and pest resistant crop varieties. The same applied to the improvement and increase of animal stock as well as complementary systems of pasture management to suit different circumstances and methods of animal husbandry and to make the best use of grassland resources without subsequent environmental deterioration. The work of the Jonglei Executive Organ and of the Mefit-Babtie team, whose papers were to follow, would doubtless throw much light on considerations of these kinds.

In papers, entitled respectively *The Design and Construction of the Jonglei Project* and *The Objective of the Jonglei Canal Project*, SAYED KAMAL ALI MOHAMMED and SAYED MOHAMMED A. MOHAMMEDEIN of the Permanent Joint Technical Commission outlined the main features of the design, construction, and objective of the Canal. The capacity will be 25 million m^3 per day on average, the total length 360 km, with slopes varying from 7.0 to 12.5 cm/km. The bottom width will vary between 28 m with berms and 50 m without berms, while the depth will range between 4 and 7 m. The Canal will be a navigable waterway, with berthings and greater width at various points to allow for the manoeuvrings of river craft. The navigable route between Malakal and Juba will be shortened by 300 km. Crossings will be provided for people, animal and motor traffic at predetermined points. These will consist of bridges at four points and a number of motorized ferries. Canal structures comprise a regulator, navigation lock and training work at the offtake, and training works at the exit. Cross drainage works will be provided as required to cope with side stream flow and sheet flooding.

The estimated costs (at 1978 rates) will be in the order of £92 million, made up of £14.7 million for structures and training works, £43.5 million for canal excavation, £18 million for local development works and £15.8 million for contingencies. A Jonglei Canal Authority will be established to supervise the maintenance of the structure and associated works, ensure the operation of the canal for navigational purposes, and determine and control the intake of water into the Canal.

Apart from saving water for irrigation purposes downstream, as explained by Sayed Yahia, the Canal offers several benefits in its own locality. It will enhance opportunities for agricultural, livestock and industrial development in this part of the country. The diversion of 25 million m^3 of water per day through the Canal will reduce discharges in the natural channels of the river, but will not alter seasonal fluctuations, a reduction of about 10 per cent during the flood period and 20 per cent in the low flow season. The Canal itself will be a source of perennial water supply in its vicinity, relieving the population of the need to drive their cattle to the fringes of the swamps. It will prevent flooding of the plains between its alignment and the Bahr el Zeraf, including the Fangak area which has been surrounded by floods since 1964. It will provide a more direct route for steamers between north and south, and, besides, make available a compacted road traffic route on the eastern side of the Canal for the greater part of the year, thus accelerating development in the southern region.

In a paper entitled *The Role of the Executive Organ, National Council for the Development of the Jonglei Canal*, the Chairman, His Excellency JAMES AJITH AWUOL, said that their commission was to investigate the local impact of the project, maximizing the benefits it would bring, mitigating any adverse effects, and implementing plans for the economic and social development of the area.

The emphasis of Executive Organ's responsibility is on local development, while the construction of the Canal was the concern of the Permanent Joint Technical Committee for Nile Waters. The scheme would provide much-needed water for irrigation further north and, while the people of this underdeveloped region would forgo for ever that water which was a valuable natural resource, they would have a chance to gain

immediate and otherwise unplanned benefits. The Canal itself would provide water in an area at present lacking supplies during the dry season, thus promoting a more stable and settled way of life. The all-weather road along the canal bank would provide year-round communications from north to south too, and act as a base for feeder roads extending east and west. The shortening of the river route from Malakal to Juba would serve to promote trade in the south in general as well as in the vicinity of the Canal itself. The Canal embankment would also afford some protection from excessive Nile floods, halt the movement of creeping flow from the eastern plains, and serve also as a refuge for people and livestock in periods of heavy flooding such as had occurred in the 1960s. Lower water levels, the result of canal offtake, would lead to increased access to areas which in recent years had been almost permanently under water, thus increasing rather than diminishing dry season pasture land, and providing easier routes for the marketing of fish from the permanent swamps and open water beyond.

The Council recognized that there would be costs as well as benefits. The construction of the Canal itself would obliterate a limited number of habitations, but this loss would be very generously compensated. The Canal would be a barrier to east-west movement of people and livestock, but four conventional bridges and 12 motorized ferries would be provided. The only known feasible method of overcoming the barrier effect on wildlife migrations would be gently sloping embankments now planned for 270 km of the alignment. The embankment would in some parts itself disrupt the natural channels draining the eastern areas of the region and cause flooding at the height of the rains, but where necessary this problem would be solved by planned resettlement.

The diversion of water, by-passing the *Sudd*, would have its effects in reducing what is a natural irrigation system. Conclusions on this aspect were necessarily generalized and not definitive, but the main determinant would be unpredictable discharges from Lake Victoria and areas upstream of the Canal. Two major features also needed to be recognized. First, that the effects of the present project under Phase One would be much less than those that would have occurred under the earlier scheme; secondly, that proper understanding of the effects on the *Sudd* would require a long-term programme of detailed study and general monitoring of Canal operation, land use and the natural system. Much had already been done in these respects, including epidemiological and nutrition surveys which revealed a high incidence of water-borne diseases and much seasonal malnutrition. Far from a picture of 'the Noble Savage' confronted by 'the threat of modern technology', the area was one in which people were demanding the benefits of development in the provision of communications, clean water supplies, human and animal health facilities, and education, as in other parts of the country.

The Executive Organ had several other studies under way, financed by the EEC, including soil surveys, studies of the *toich*land and grassland plains, animal production and disease control, and investigations of open water and permanent swamp with a focus on the biology of fish resources. Moreover three pilot development programmes had been implemented: The Kongor Integrated Rural Development Programme; the *Sudd* Fisheries Development Programme; and the Bor Area Development Programme, the first two financed by UNDP/FAO, the third by the Netherlands Government. The National Council had, besides, now begun to supplement Regional and Provincial Development programmes by the provision of, for example, schools, medical clinics, veterinary dispensaries, and water supplies in the form of deep bore wells. The construction and operation of the Canal would have a positive effect on the economy of the Jonglei area.

Mr JONATHAN JENNESS, Project Manager, land use planner (UNDP) and Adviser to the Executive Organ, read a paper entitled *Planning for the Development of Land Use in the Jonglei Canal Area.* Though for planning purposes the area is taken to include land 30 km on either side of the Canal, geographically it lies within an extensive alluvial basin, the main channel of the river—the Bahr el Jebel— entering and leaving it as a single stream but fanning out into many twisting channels with parallel lakes and permanent swamp of reeds, bulrushes, and papyrus. This is the *Sudd*, the 'barrier', covering an area of about 18 000 km^2, bordered by and intermingling with seasonally inundated floodplains, the *toich*. From May to December, the *toich* is flooded, but

during the height of the dry season, from January to March, it is more or less accessible to herdsmen, livestock and wild animals. It is then of vital importance to the existing local economy since the rest of the area lacks surface water for drinking and green grazing. On the edge of this basin, the *toich* merges gradually outwards into plains flooded only by rainfall and extending for some 200 km to the edge of the Ethiopian hills, most of it unused by man or domestic livestock. The flatness of this area is well illustrated by the prevailing gradient, which averages 10 cm/km on the plains and only 5 cm/km within the *Sudd*. Above the levels of the *toich*, there are scattered areas of 'high' land, relatively flood free and rarely more than 1 m above the rest of the land used for permanent habitation or as a rainy season refuge for people and livestock.

The soils in the area are mostly cracking clays which shrink and open when dry or swell and seal when saturated. They are poor in nutrients and organic matter and have a low moisture holding capacity, and being rock hard when dry or soupy paste when wet, they are extremely difficult to farm with heavy machinery. For half the year from mid-October to mid-April, the whole of this area is dry, and during the other half more than 85 per cent of the total annual rainfall (800–900 mm) falls. The distribution of rainfall during this period is, however, very variable, and crops are subject to excessive amounts or alternatively to drought. High, but not extreme temperatures, combined with the rainless dry season and low moisture carrying capacity of the soils leads to an annual desiccation and loss of surface water, while, in the rains, water tends to accumulate on the soils after they have sealed and to move across the plains after heavy storms in a uniform mass, like drink spilled on a well-waxed table, a phenomenon known as 'creeping' flow or flood, which is also a particular hazard to crop production.

Water level in the *Sudd* is critical to the ecology and economy of the area. Water comes from three main sources: the East African Lakes; the so-called seasonal torrents (upstream of Juba); and locally precipitated rainfall. The first produces a fairly steady base flow, which, however, varies from year to year and over a cycle of years. From 1905 to 1960 this input was on the average relatively low in contrast to the sudden increase which occurred in the 1960s and which has been largely sustained until now. This increase in discharges caused widespread flooding and consequent havoc among the people and their livestock, much of the *toich* in the interior of the *Sudd* becoming permanent swamp, although the total area of the *toich* increased.

Low discharges from upstream catchments coincide with the height of the dry season (December to March) and during this period of the year the Nile is largely contained within its channels. In May, when floods from the torrents begin to come down, water spills from the channels into the swampland, up the flat depressions and watercourses and across the flat landscape. This spilling increases and reaches a peak in September or October, and then quickly begins to decline. Return flow from the side channels is limited and the *Sudd* retains within itself much of this water and, given that open water evaporation is nearly double the rainfall, the water so retained (on the average about 14 milliards m^3 or nearly half the inflow) simply vanishes into the air, producing in the process the extraordinarily exuberant aquatic plant-life characteristic of the area. The flatness of the Jonglei area; the impermeable clay soils; the rise of the Nile coinciding with the rains; the large long-term changes in the input from Lake Victoria; the insidious spread of creeping flow after heavy rainfall, all link together to make flooding the annual event, and disastrous flooding a periodical event. The annual flooding from the Nile and the rainfall, alternating in serious drought and desiccation, is the outstanding dynamic difficulty of the physical environment.

The Jonglei area is inhabited mainly by Nuer and Dinka, with some Shilluk in the north. The former are segmentary societies of similiar language and culture. Both Nuer and Dinka have diffuse settlement pattern based on individual households, with larger communications confined to administrative centres.* Their main food crop is sorghum, but local production consistently falls below requirement. There is almost always a

*An accurate census is not available, but from sample aerial surveys carried out between 1976 and 1980, in an area of 65 000 km^2, there are 65 000 dwellings, 27 000 cattle byres, 1000 seasonal cattle camps, 500–800 000 cattle, 20–30 000 ha of cultivation, and a population in the order of 200–300 000 persons.

deficit in the early to middle rains, when imported grain is paid for by the sale of cattle, and from remittances and government salaries. Small amounts of maize, melons, pulses and tobacco are planted by hand in the early part of the rains. The people regard cropping as onerous and risky, but essential for survival. Flood, drought, pests are risks the people expect and accept as normal, and in consequence annual yields fluctuate markedly. Cattle keeping is second to crop production as a source of food, but is unquestionably the prime economic interest of the people. The cattle are milked and eaten when sacrificed or die of natural causes. Some are sold to acquire a limited range of consumer goods, to pay taxes, fines, and school fees. Beyond such uses, cattle occupy a central place in the culture, are the preferred capital store, and are a means of establishing marriages and settling disputes.

The enthusiastic husbanding of cattle means that the people have to follow a transhumant way of life. In May, with the rising flood, the people abandon the dry season cattle camps and trek to the areas of permanent settlement, or temporarily to plains camps where the cattle graze until the end of July. From August through September all cattle graze around the highlands, being housed at night in barns or byres (*luak*) for protection from biting insects. From October to December they again graze on the plains, making use of the succulent regrowth from the perennial grasses after burning, which continues until soil moisture dries out. Then, in January, the bulk of the population trek down to the *toich* again, leaving behind only some of the old people and children supported by the odd milch cow and a few goats and sheep so long as drinking water holds out. Jonglei cattle are regularly subject to a variety of diseases. Milk production and calving rates are low; and animal sales, estimated at a guess at about 5 per cent, tend to be local in effect, animals being circulated within the area. The people's diet is supplemented by fishing, which provides a useful source of protein and, apart from the activities in this field by most of the population at certain times of the year,* diet is also supplemented by meat from wild animals during their seasonal migrations.

Speaking of the way forward, Mr Jenness pointed out that the Sudan was among the least developed countries, and, within the Jonglei area development had been retarded more than in many parts of the Sudan owing to its isolation, low level of marketed production, the effects of civil disturbance between 1955 and 1972, and recurring calamity in various forms—flood, drought, epidemics, tribal raiding, and low local expenditure by government. On the positive side, however, government-led development has accelerated. An all-weather road has been built from Juba to Kongor about half way up the canal alignment. The nature of the terrain makes the construction of feeder roads difficult and nearly all parts are impassable to motor traffic in the rains. There is the beginning of a network of other services in the form of police posts, primary schools, public water supplies and clinics, which are being built or are planned. As had been explained by the Commissioner, other material benefits could be expected from the Canal.

On the negative side, growth in the productive sector, agriculture, is not significant, and it is doubtful whether it is even keeping pace with population increase. Grain imports are higher, and, while cattle sales are increasing, it is debatable whether a significant proportion is exported rather than being circulated within the area. Less fish appear to be being marketed than before the civil disturbances. The limited forestry resources were badly damaged by floods in the 1960s and growth is not keeping pace with extraction for building poles, charcoal, and firewood. The growth of the government sector, itself not directly productive, is creating jobs (but mainly in the administrative centres) and is leading to rapid urbanization. The consequent loss of manpower from a labour-deficient agricultural economy during the critical period of

*There is here some diversification of livelihood, and there are isolated communities of full-time fishermen (*monythany*), but lack of access means that little is known about canoe fisheries of this kind. Aerial survey suggests some 6000 canoes engaged in this industry, but the indications are that this is a resource which is underutilized, partly owing to the difficulties of transporting dried fish and lack of organized markets.

land preparation is disturbing. Agricultural extension is largely limited to mobile veterinary units, and no organized system of markets yet exists.

The main approach to development adopted by government in the area is twofold: to install a basic network of infrastructure and social services; and to increase agricultural production. The constraints on the first objective are funds, both capital and recurrent, and trained manpower for operation. The means for agricultural production are less certain, though the first priority must be to overcome seasonal hunger and to establish self-sufficiency. Mechanized agriculture, after a major, well-funded research undertaking of seven years' duration, has not so far proved successful, though the most promising line for mechanization is rice, a crop new to the area. Attempts to improve the output of small farmers has only just begun, including rice, the use of cattle for manure fertilizer and traction, and the use of light hand-pushed cultivators and direct seeders. Small-farmer cattle production appears promising, the principal requirements being effective veterinary care and organized livestock markets. Opportunities may arise in the relatively unexploited eastern plains, given public security and dry season water supplies. Fish offer the greatest immediate economic promise, and endeavours have already started to research the potential of this sector and to provide the means to develop it.

The building of the High Dam at Aswan has made the timing of the river regime less critical. However, studies of the *Sudd* have revealed the unique importance of the *toich* to the past, present, and future economy of the Canal area. Dr Sutcliffe and Ms Parks have argued that the regime of operation of the Canal could be made to minimize the reduction in *toich* resources by larger offtake in the lower water season and smaller offtake in the higher season. This important observation reintroduces the notion of 'timely' supply, though in this case 'timely' for natural irrigation of the immensely valuable *toich*. This allows us to approach closer to the deepest aspirations of the original Jonglei Investigation Team, namely, 'the best form of river control for the benefit of all inhabitants of the Nile Valley'.

Mr Steven W. Lawry of the Institute of Environmental Studies, University of Wisconsin-Madison, in a paper entitled *The Jonglei Canal and Endogenous Change: a New Framework for Policy Analysis* referred to aspects of social and economic change not directly attributable to the effects of the Canal or other development projects in the area. The most fundamental change taking place in Dinka and Nuer society is a slow but steady shift from economic relations based largely on kinship to production and distribution regulated by market forces. Other changes, he argued, include first, the move away from subsistence to commercial production of livestock; secondly, expanding networks of economic activity reaching beyond dependence on livestock, though the role of crop production should not in any case be underestimated in Nilotic societies; and thirdly, the tendency towards a more sedentary way of life resulting from the effects of increased reliance on local markets for essential household goods, fixed water supplies for humans and livestock and improving social services. Such processes of change are central concerns of development policy in the Jonglei area.

Thus, for its implications to be fully comprehended, the Jonglei Canal must be seen not simply as a public works project with ecological implications and attendant development schemes, but as a vehicle for the more rapid diffusion of largely exogenous influences into already rapidly changing societies. On this premise the concerns of public policy will be substantially different in character from those obtaining at present.

After reviewing a range of attitudes towards development in the area, notably two conventional currents in policy analysis, ecological disruption and social transformation, Mr Lawry suggested that a new perspective was needed the better to influence the direction of change. On his interpretation there are really only two relevant considerations in this context: the social and economic welfare of the people and the well-being of the resource base. There are, however, major obstacles of interpretation often influenced by criteria which do little to reveal the local consequences of change, including failure to ensure the widest possible distribution of benefits which should be the first aim of policy. The second should be to ensure that new strategies and technologies do not lead to the degradation of the environment, and

that, for example, appropriate pasture management systems must accompany measures which tend to reduce the need for the existing transhumant cycle.

After detailed speculation upon the future course of change and development in the region, the speaker suggested that livestock production would be oriented more to the market than social exchange, that this would have major implications for the social order, and that the evolution of livestock markets, extensive expansion of migrant labour, and a tendency towards a more settled way of life are all part of the integration of the local into the national economy. These changes are occurring for the most part without the stimulus of development projects, and this suggests the need for a reassessment of strategy on the part of the JEO, which is well suited and well placed to cope with issues of this kind requiring new or continued policy emphasis on land-use planning, careful study of the effects of new technologies both in terms of adaptation by the people and to preserve the natural resources available to them, as well as to make a realistic reappraisal of the potential of crop production and the problems likely to be encountered.

It is suggested in the paper that the JEO should define its interests more broadly than the typical development agency. Its concern for ecology and social services indicate that its leadership sees the development process as something additional to growth in aggregate output and market integration. At the same time, these latter factors are much further advanced than suspected, and will eventually become dominant, whatever the attitude of the JEO, or other Sudanese government agencies. For this reason the JEO should take the initiative in assessing the implications of inevitable economic change for the distribution of economic rights and wealth in society, and in determining what a new local economic order implies for resource management.

Dr John Sutcliffe, formerly of the Jonglei Investigation Team and now of the Institute of Hydrology, read a paper, prepared in collaboration with his colleague Ms Yvonne Parks, on *The Effect of the Jonglei Canal on Areas of Flooding*, describing their conclusions from recent studies of the hydrology. In this they pointed out that at present only half the inflow of the Bahr el Jebel at Mongalla emerges from the *Sudd*, and the remainder spills from the river into permanent and seasonal swamps and evaporates. The Jonglei Canal will save water which is currently evaporated by decreasing the areas flooded, but there is an important distinction between the permanent swamp and the areas seasonally flooded and uncovered which provide dry season grazing. The aim of this study has been to estimate the effect of the canal on the areas flooded.

The analysis was based on a simple reservoir model, using measured values of hydrological inputs and outputs wherever possible. The analysis has covered the historical period 1905–80, when variations in river inflow from the East African lakes have caused considerable variations in the areas of swamp. The effects of the Jonglei Canal must be compared with these natural variations. The inflow to the *Sudd* combines the damped outflow from the East African lakes, which has alternated between periods of high and low flows, and the seasonal and variable discharge of the torrents above Mongalla. Below Mongalla, the channel capacities are less than high flows and the alluvial channels are above flood plain. Excess flows inundate wide areas through spill channels during the rainfall season when evaporation is low; flooding is limited by high ground only in the south. Thus varying areas are inundated 'permanently' or 'seasonally', with the 'permanent' swamp reflecting variations of lake outflow and the seasonal swamps depending on torrent inflow. Although a succession of basins act as reservoirs in series between Juba and Bor, the river banks are lower further north and flooding extends further away from the river. The oscillations of inflow are damped to a fairly steady outflow from the swamps.

River flows at Mongalla (average 33 $m^3 \times 10^9$) and outflows from the swamp (16 $m^3 \times 10^9$) are available from 1905–80, and direct rainfall (average 870 mm) may be estimated from eight stations near the swamp. Evaporation should not vary much from year to year, and Penman's* estimates of monthly open water evaporation totalling

* Penman, H. L. 1963 *Vegetation and Hydrology*. Farnham Royal: Commonwealth Agricultural Bureau.

2150 mm/year were tested and proved to give a reasonable evaporation rate from the swamp area. Historical measurements of flooded areas are available including one of 8300 km^2 below Mongalla from air photography in 1930/31, compared with 22 000 km^2 from satellite imagery in February 1973. Areas of permanent and seasonal swamp were mapped in 1954 and 1980, and give corresponding total areas of 13 900 km^2 and 30 600 km^2.

The hydrological model, when based on inflow and outflow records, starts from an initial area and provides monthly flooded areas for 1905–80 from rainfall, evaporation and soil moisture recharge using an assumed relationship between area and volume. These monthly areas correspond with gauge levels measured over this period, and also show a reasonable fit with measured areas. There are considerable natural variations over the period, which are greater in the permanent swamp than in the seasonal swamp. If the canal is to be introduced into the model, deduced outflows must be substituted for measured outflows, and these were based on inflows with a 3-month lag; the introduction of deduced outflows did not affect the reproduction of flooded areas, so that it was thought possible to transfer this inflow-outflow relationship to Bor to estimate the outflows from the swamp after diversion of the designed flow through the canal. The inflows after diversion and the predicted outflows were then substituted in the hydrological model to provide estimates of the areas flooded if the Canal had been in operation during the period 1905–80.

The effect of a steady canal flow will be to reduce the total area flooded by about one-third, and this corresponds with the predicted benefits in water saved. The reduction in flooded area is likely to be rather greater in terms of permanent swamp than seasonal swamp, and would have been a greater proportion of the natural swamp in the dry years 1905–60 than in 1961–80. However, the seasonal pattern of flooding must be compared with the natural variations. A trial with canal flows varying seasonally suggests that it could be possible by selecting operating rules to deflect somewhat the impact of the canal from seasonal to permanent swamp if this were considered desirable.

The effects that the Jonglei Canal may have on aspects of the terrestrial ecosystem was the subject discussed in three presentations by JONATHAN KINGDON, DAVID JONES and DR STEPHEN COBB. All three were members of a team belonging to Mefit-Babtie, an Anglo-Italian consulting group, that had been in the field studying this matter since 1980. Their studies, conducted at the request of the Sudanese Government, were financed by the European Development Fund. They were directed towards understanding the ecology of livestock production in the area, in relation to the availability of water, the productivity of the grasslands, the role of wild herbivores and the needs of the people who depend on them.

The climate of the Jonglei area is typical of its latitude, consisting of a relatively cool wet season, with a rainfall averaging some 850 mm between May and November, and a much hotter dry season between December and April, in which shade temperatures regularly exceed 40°C. The wet season coincides with the season of high river flows, which causes inundation of the floodplain. At this time virtually the entire surrounding landscape is also inundated, though less deeply, by rainwater. The extent of river-flooded land, including both the true swamp and the seasonal floodplain, has more than doubled since the floods of the early 1960s. Defying adequate explanation, the river flows have remained high ever since that time.

Those who are likely to be most affected by the operation of the Jonglei Canal are Nilotic pastoralists of the Dinka, Nuer and Shilluk peoples. Their way of life is a carefully balanced response to the demands of their environment, depending, as they do, on unpredictable sorghum crops grown in the wet season and on the rather more reliable year-round supply of animal products. The need by both people and animals for water and by the animals for more nutritious grazing, necessitates a migration in the dry season to the seasonal floodplain and the edge of the permanent swamps.

Detailed monthly measurements were made of the productivity of six major grassland types. These showed that the floodplain, dominated by the grasses *Oryza longistaminata* and *Echinochloa pyramidalis*, is typically much more productive than the rain-fed grasslands, which are dominated by *Hyparrhenia rufa*, *Sporobolus*

pyramidalis and *Echinochloa haploclada*. Of further great significance is that, in the dry season, the nutritive value of the dryland grasses falls below the maintenance level necessary for cattle, whilst that of the floodplain grasses does not. This is important because the Jonglei Canal will lead to an increase in the area of dryland grasses and a decrease in the area of the floodplain. Even those areas opened up for dry-season grazing by the advent of year-round water in the Jonglei Canal itself will in fact be marginal grazing lands, dominated by nutritionally impoverished grass species. It is the exploitation of these differences in grass quality that renders migration by livestock, by the people who depend on it, and by wild animals, such an essential strategy. Neither the Jonglei Canal, nor other development plans, should be allowed to diminish migration.

There are wide differences in the productivity of Dinka, Nuer and Shilluk cattle. The age at which they first calve, the inter-calf interval, calf growth rates and the daily milk yields all show that the Shilluk cow is the most productive, the Nuer intermediate, and the Dinka the least. This can be partly attributed to environmental differences in the critical dry season months, when the cattle density in the *toich* occupied by Dinka cattle is twice that in the Nuer *toich*. Despite these internal differences in livestock performance within the Jonglei area, the cattle, sheep and goats of the region, compare very favourably with the performance of the same species in comparable areas elsewhere in Africa. This is important, because it demonstrates that there are limits to the capacity of pastoral production systems, which have probably already been reached in the Jonglei area. They can only be bettered at the expense of the true interests of the people. This has implications for government aspirations, currently rising on the tide of the development thrust provided by the construction of the Jonglei Canal, to transform the local livestock economy. Cattle have long been recognized as the backbone of the Dinka and Nuer economy and thus, of their whole lives. Although this is essentially true to this day, other animals prove to be surprisingly important. The local sheep and goats are astonishingly fecund. The goats, in particular, are managed by women and children (while the cattle are looked after primarily by men and boys). For reasons of youth, infirmity or pregnancy, these groups of people may not migrate in the dry season unless they are compelled to do so. Goats provide twice as much milk in the dry season as they do in the wet, the exact converse of the pattern in cattle. Goats thus play an important role in sustaining women and children, without interfering in the traditionally important role ascribed to cattle. It is estimated that about 10 per cent of the annual human milk intake comes from goats.

Wild animals, too, play an important role in the annual nutritional economy. Hunting is largely confined to the dry season months, when the migratory wildlife is thrown into much closer contact with both people and cattle. This is particularly so among the Twic and Bor Dinka tribes, for daily hunting then occurs. It is quite opportunistic but, at its most effective, nevertheless involves the cooperation of three or four people (usually youths, though no age or sex is exempted) and as many dogs. In this way, wild animals provide one-quarter of the year's meat intake. There is no evidence that this level of offtake has an adverse effect on the existing populations of most wild herbivore species. The same cannot be said, however, for the lion, crocodile, hippopotamus and elephant, all of which suffer from more sustained and sophisticated hunting techniques. One of the adverse effects of the Canal will be that it will concentrate wild animals along its length owing to the water supply there and to their uncertainties about crossing it, while at the same time allowing access, both along the Canal and along the road on its embankment, to an endless flow of traders, soldiers, police and government officials, all carrying guns, both because of, and in defiance of, the law. The traditional relationship between people and wildlife will be rapidly thrown out of equilibrium, to the detriment of both.

Studies revealed that the role of wildlife as a reservoir of animal disease seemed to be insignificant. Extensive surveys of the incidence of disease among the livestock showed that poor condition, a result primarily of seasonal nutritional stress, is the major complaint in the local cattle population. Respiratory problems and abortion are extremely common. Animals are infected by a wide range of helminth parasites and are challenged by infections of trypanosomes, rinderpest and other contagious diseases.

The care lavished on their animals by the Dinka and Nuer herdsmen is certainly an important factor in suppressing the degree of parasite infestation. This care includes the daily rubbing of the skin with ash, which inhibits ectoparasites such as ticks; the nightly burning of cattle dung in the cattle camps (where concentrations of as many as 4000 cattle may be tethered each night), which breaks the life cycle of some parasites, whose eggs are passed in the faeces; the smoke from these fires which also repels biting flies; the tethering of the cattle indoors at night during the wet season, which also protects them from biting insects; and the sequential use of pasture, which prevents parasite accumulation. All of these are wise strategies, which unwise development could easily throw into disarray.

The Jonglei Canal will without doubt have the effect of reducing the area of swamps and of floodplain. The probable extent of this reduction is described in the paper presented earlier by Dr John Sutcliffe and Ms Yvonne Parks. It is apparent from their predictions, based as they are on the known behaviour of the river over 75 years, that the potential effects of the Canal are not as great as the effects of the natural variability of the river. Evidence for this comes from the doubling of river discharges in 1961 and thereafter, with the consequent more than doubling of the swamp and floodplain areas. But should the river return to its pre-1961 levels (which is the most probable outcome), the combined effects of this and of the operation of the Canal will be to produce serious shortfalls of suitable grass at the time of year (the dry season) when cattle are already critically stressed. Although no integral part of the Jonglei ecosystem will be lost as a result of the Canal, all elements of the wetland system will decrease. This must stress populations of all organisms dependent on those wetlands. Dry season grazing, in particular, will be affected and the increased stress on cattle (and wildlife) is unlikely to be truly compensated by alternative developments.

On the positive side, the Canal will enable many people to rebuild their homes, destroyed in the floods of the early 1960s, while they and others from the area, together with their livestock, will be able to exploit traditional grazing lands that have been inaccessible for two decades. Communications, health, education, the water supply and trade should all improve, with consequent benefits for the people, if the services are sensitively provided. All of these could have been achieved without the construction of a Canal however.

The Sudanese and Egyptian Governments are contemplating the construction, in addition to new canals to abstract water from the Machar marshes and the floodplain of the Bahr el Ghazal, of a Phase Two Jonglei Canal that would more than double the quantity of water abstracted from the Bahr el Jebel. The effect of this would be the virtual elimination of the critical dry season floodplain grazing, in addition to other adverse effects on wildlife and fisheries. For the wildlife, the livestock and the people of the Jonglei area, this would precipitate the complete disaster which the Phase One Canal will fortunately just avoid.

Dr Roland Bailey, also of the Mefit-Babtie team, spoke of the swamp ecology survey which they had undertaken in the Jonglei area. Although it contains one of the most extensive wetlands in Africa, this part of the Sudan has received scant attention from hydrobiologists. Its size, remoteness, and inaccessibility have restricted activities to occasional forays into the main channels and lakes of the Bahr el Jebel. Moreover, since the most detailed studies of the White Nile in the early 1950s two important events have occurred—the increased discharges and higher levels already mentioned, and the massive incursion of water hyacinth.

The present survey is intended to cover one year of field study with varying inputs in the disciplines of limnology, botany, zoology and socio-economics. Simply stated, its objectives are to characterize the different aquatic environments, to identify specific associations of plants and animals within them, and to explore their ecological basis. Within this framework priority is given to discovering how fish resources and fishing activities are partitioned between different parts of the system, recognizing that a long-term *Sudd* fishery development programme has already been initiated. The swamp survey began later than Mefit-Babtie's other investigations with the advantages that an established base-camp and reliable maps of the study area and its vegetation were immediately available. A series of more or less distinct ecological zones extending

from river channels through permanent swamps to seasonally inundated grasslands were promptly defined, around which the scientific work could be organized. The distribution of open-water and plant communities between and within the swamp and grasslands results from an equilibrium between wet and dry season conditions. Mefit-Babtie researchers have demonstrated that as a consequence of increased Nile flow since 1961, a shift in this equilibrium distribution has brought about marked changes in vegetation zones in a comparatively short period of time. Fieldwork to date has concentrated in those ecological zones within easy access of the base-camp, well located in the southern part of the system. Air, land and river-barge based activities were employed to investigate spatial variation over the study area as a whole.

The main permanent system at present covers 1600 km^2 and comprises (a) braided channels, lakes and lagoons with open water and variable qualities and quantities of hydrophytes, and (b) a broad border of papyrus and extensive *Typha* swamps. Ubiquitous fishes of lakes and lagoons forming the basis of the perennial fishery are *Distichodus*, *Citharinus*, *Heterotis*, *Mormyrus*, *Lates*, *Tilapia* and catfishes. Rain-filled pools at the edges of adjacent grasslands may develop populations of 'annual fishes' before seasonal flooding from the river ensues. This begins in July and may bring about the inundation of some 1400 km^2 of *Echinochloa* and *Oryza* grasslands. Clariid catfishes, *Polypterus*, *Protopterus* and a number of smaller fishes invade the flooded pastures, whilst *Heterotis*, and probably *Gymnarchus*, penetrate as far as open and marginal areas of the permanent swamp. The larger fish provide valuable catches for a seasonal opportunistic fishery as they become stranded in sometimes extensive hollows left by the receding and evaporating flood waters.

The ecological basis for the partitioning of fish resources relates to differing requirements for food, cover, breeding and nursery grounds. Several major species are shown to breed successfully within the permanent aquatic system which also provides suitable rearing areas. Water hyacinth fringes have an important role in this. The necessity of a floodplain in the provision of rearing habitats for these species is doubted and only a minority of species use flooded grasslands for spawning and juvenile rearing. One conclusion to emerge from investigations in the southern floodplain is that there appears to be very little return of water, materials or fish into the permanent system.

Data from all ecological zones is gradually becoming available, but inevitably some will be better researched than others. The survey will undoubtedly raise more questions than it answers, but a groundwork will have been prepared for assessing the probable effects of subsequent changes in water management of the *Sudd*.

Summary of the Discussion which followed the conference, by Dr Stephen Cobb.

The meeting attracted a large and varied audience which included journalists, academics of many disciplines, retired professionals and civil servants from the era of the British Administration in Sudan and southern Sudanese students and former politicians. There were two periods in the meeting set aside for questioning the speakers and for public discussion of the many issues posed by the Jonglei Canal. Southern Sudanese speakers from the floor reminded the audience of the misgivings of large numbers of people from that part of the country about the Jonglei Canal Project. These had first been voiced during disturbances in Juba, the southern regional captial, in 1974 and despite years of public information about the purpose of the Canal since then, it was clear that doubt and suspicion still linger on. These stem partly from confusion of the present 25 million m^3 per day canal with the one previously planned of 55 million m^3 per day, and the serious adverse local effects then forecast. The rest of the audience was, in the main, more conscious of and more concerned with the potential environmental repercussions of the Canal than with the political ones. Points discussed included general problems of Nile control; variation in the East African climate; the groundwater resources of Egypt and future Egyptian water demand; and the problems of aspiring to develop pastoral economies in Sudan, with particular regard to water resources.

The meeting reached no conclusions and passed no resolutions. But it did give the opportunity for the exchange of a variety of differing views on an important (and controversial) subject.