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Original report


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Finalisation of report


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Aqueduct to link Central Africa with Southern Africa?

A brief outline*

It is generally accepted that at some time in the comparatively near future – say between 2025 and 2055 – it will be necessary to supplement the water supplies of the Republic of South Africa, as well as those of some other water-scarce countries in the SADC region. As it would typically take 30 to 40 years to bring a major international water transfer scheme to fruition, it is not too early to start looking at various possibilities. The authors suggest that the rivers of Central Africa could possibly serve as one of the future sources for water supplies for the dryer south. If a scheme to transfer water from the water-rich rivers of Central Africa southwards to Botswana, Namibia, Zambia, Angola, Zimbabwe and South Africa were to be tackled on a sufficiently large scale, considerable royalties could be generated for the benefit of the northern-lying countries

ALTHOUGH THE WHOLE of Central and Southern Africa is rich in natural resources, development has generally been skewed. To the south, particularly in South Africa, massive economic and structural infrastructure development has taken place whereas in the north, which is richly endowed with natural resources, the infrastructure needed for growth is spread thinly over the land.

Water resources, in particular, are very skewed, with large volumes of untapped water lying dormant in the north or being discharged fruitlessly into the sea while in the water-hungry southern-lying areas of SADC, water is being and will be used and reused to nearly the limit of its efficiency.

One of the keys to engendering a more rapid and even spread of development over the southern portions of the African continent would appear to be to market resources such as food, water and hydropower throughout the region with cross-royalty payments from the consumers of the resources being used to stimulate growth in the infrastructure-stressed areas of the region.

In the light of the possible effects of climate change, it is urgent that consideration be given to the long-term destiny of Southern African countries. Thought must also be given to the potential for a massive migration of people.

In the future, as growth takes place, it may also become necessary to supplement the water supply to the southern-lying water-hungry lands of Zambia, Angola, Botswana, Namibia and Zimbabwe and, at the same time, transfer royalty funds to stimulate growth in the northern-lying lands.

Over the years, a number of schemes for transferring water southwards have been conceptualised. Most of these schemes have involved the use of large canals that passed through windswept arid areas and also through areas rich in wildlife. Associated with the canals were massive pumping systems with transfers along existing minor and major rivers and dry watercourses. Canals do, however, present major environmental and maintenance problems. In particular, the barriers and dangers that canals present to animal migrations and to local animal movements generally, and the ever present problems in the dryer areas of windblown sand being swept into canals have in many cases tended to negate the use of canals for large inter-country water transfer facilities. Furthermore, canals tend to exacerbate erosion by concentrating stormwater flows and animal and vehicle crossings with their approaches and generally to present a barrier to natural movements.

We propose an alternative type of water transfer facility or method that for all intents and purposes would eliminate animal migration problems and windblown sand threats. At the same time, it demonstrates that water transfers can be effected economically at a price consumers will be able to afford.

THE PROPOSED SCHEME

The scheme envisaged would typically be to abstract the proposed water supply from the Zaire River in the Democratic Republic of Congo (DRC) and to convey it to the upper tributaries of the Zambezi (see map). The Zambezi would be used in turn to convey this supply down to Chobe, whence it would be conveyed across Botswana and be pumped up to near the Hartebeespoort Dam area in South Africa. Obviously other routes could be considered and the most effective and environmentally advantageous route would ultimately be selected.

The special means to be used to effect this transfer in the gravity sections (non-pumping sections) would be an above-

**The four authors of the original report, a copy of which has been handed to the President of the Republic of South Africa, have had extensive experience in water engineering.*

ground flume. Although, at first sight, this method may appear to be strange, we hope to demonstrate that the above ground flume would be an economical means of conveying large volumes of water over long distances. Above-ground flumes have been used for many centuries in many parts of the world. Obviously, the actual construction shapes, details and methods used for the flume would have to be optimised at a later stage.

The proposed scheme would naturally have to be developed in phases. Phase 1 would be say to abstract a 50 m^3/s supply at Lac Nzilo (an existing hydroelectric scheme dam) in the DRC which lies only 80 km from the watershed separating the Zaire and Zambezi rivers. Further phases using water from Lake Kabwe and Lake Lukanga respectively would follow and would involve abstracting water from further down the Zaire River as its catchment increases in size. It is anticipated that, ultimately, of the order of 450 m^3/s might be transferred by this type of facility and from these sources.

The transfer of royalty funds to the Central African region – to Zaire in particular – for the use of this water would have a dramatic effect on development on the northern region. The availability of water along the transfer route would also stimulate local development and work opportunities, while the supply of such a large volume of water would stimulate the economies of the dryer southern lands.

ZAIRE AS A WATER SOURCE AND THE ZAMBEZI RIVER FOR CONVEYANCE

Although it would be possible to use an above-ground flume to convey water over the whole length of all the gravity sections, the use of a large length of the Zambezi River as a transfer mechanism has been proposed to reduce the total cost. (It must be stressed that it is the intention to use the section of the Zambezi River only as a transfer mechanism and not to use the river itself as an actual source. In fact, the transfer system could even to a certain extent be used to supplement the flows in the Zambezi River.)

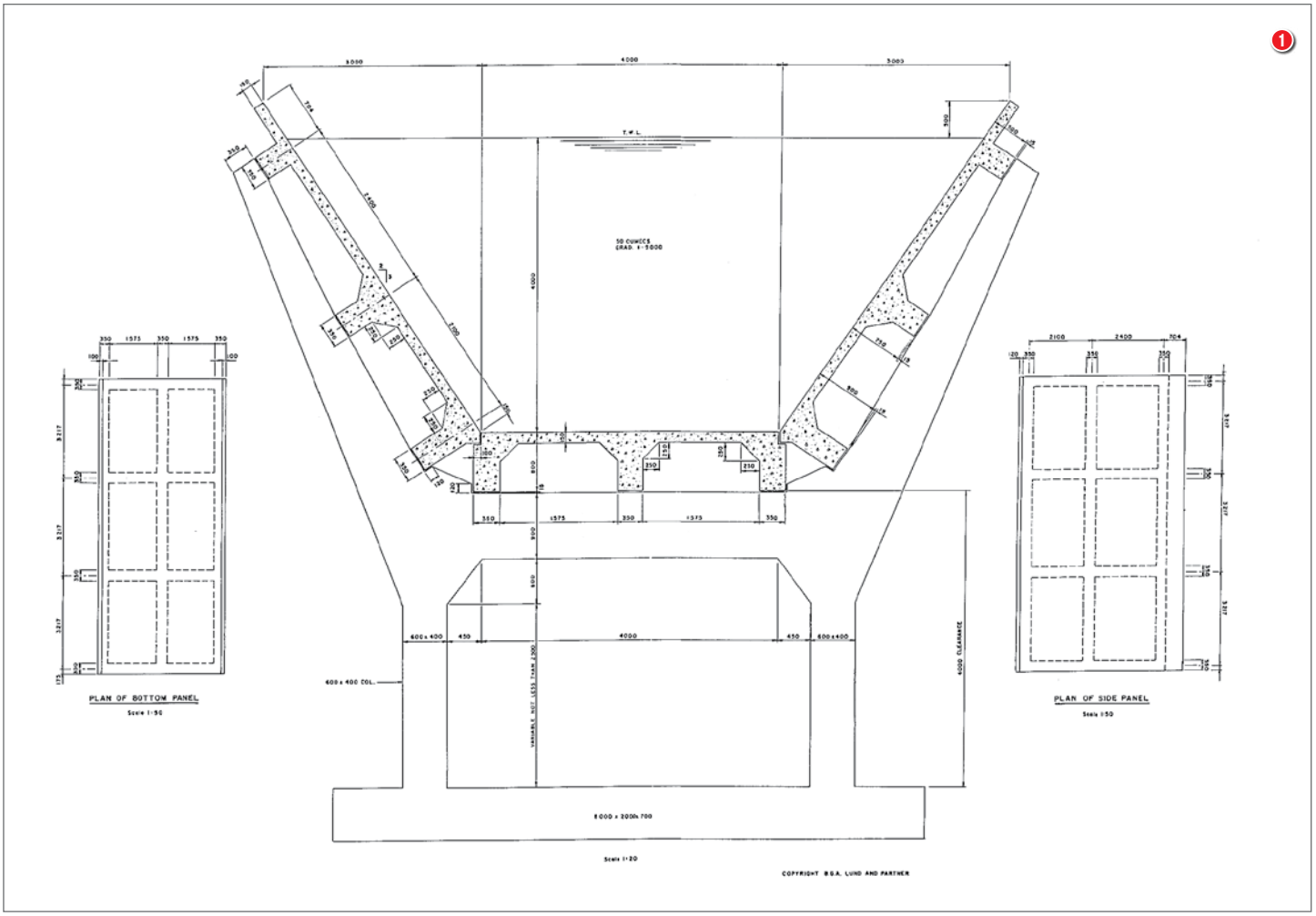
The main plan would, however, be to use the Zambezi only to convey water from Zaire via Chobe, for use in Botswana, Zambia, Zimbabwe, Angola and South

Table 1

Item	Lac Nzilo	Lac Kabwe	Lac Lukanga
River	Zaire/Congo	Zaire/Congo	Zaire/Congo
Catchment area (m^2)	16 000 m^2	54 000 m^2	140 000 m^2 (1)
Estimated mean annual runoff (million m^3 per year)	3 200 (4)	12 500 (5)	28 000
Estimated yield (million m^3 per year)	2000	6 000	15 000
Available yield (million m^3 per year)	1 500	6 000	15 000
Available yield (m^3/s)	50	190	500
Direct distance to Zambezi tributary	80 (3)	260 (6)	300 (2)
Lift	60 m	790 m	810 m

1 Excludes Lac Nzilo, includes Lac Kabwe
2 495 km by flume with 22 km rising mains
3 115 km by flume with 20 km rising mains
4 3 270 million m^3 per year (1921–1938)
5 Includes spillage from Lac Nzilo
6 330 km by flume with 21,3 km rising mains

1 *Cross section of proposed flume*



2 *Route of flume aqueduct*
3 *Proposed ultimate scheme in the DRC*

Africa. It could also be arranged therefore that additional flumes or pipes from Chobe be provided to convey water from Zaire or from the Zambezi for the cities of Bulawayo in Zimbabwe and Gaborone in Botswana. The Zambezi River is already subject to intensive development and is unlikely to be suitable as a basic source of water for transfer to the south. Accordingly, for the purposes of this article it was decided to examine the possibility of obtaining a supply of large volumes of water from three large Zaire River catchments further north in Zaire, where there is an abundance of water. Incidentally, these Zaire River sources are located close to the source of the Zambezi River.

ZAIRE AS A WATER SOURCE

The details of the proposed three main sources in the DRC are given in table 1.

It is fortunate that runoff figures are available for Lac Nzilo, so that this will give added confidence to estimates further down the river. The rainfall at the watershed is of the order of 1 200 mm per year whereas further north at Lac Lukanga it would be approximately 1 400 mm per year.

THE ZAMBEZI

It is proposed that the Zambezi River be used only as a conveyance. As any water extracted from the Zambezi is likely to have a negative effect on the generation of hydroelectricity downstream, it is obvious that it cannot be considered as a basic source of water for transfer to the south.

THE DEMOCRATIC REPUBLIC OF CONGO

It is suggested that the various phases in the Democratic Republic of Congo (DRC) would be as follows:

Phase 1 (50 m³/s)

This phase would comprise a flume from Lac Nzilo (a hydroelectric scheme at Kolwezi – a copper mine), where the water would be pumped into the flume from the powerhouse tailrace. The flume would gravitate from its head works southwards to near Kayeye, where water would again be pumped to the water shed in a series of parallel pumping mains.

The evaporation in a 50 m³/s flume has been estimated to be 1,2%.

This phase would have a capacity of approximately say 55 m³/s. The variation in the discharge from the existing hydro scheme outlets is not known at present, but the authors have assumed that about 55 m³/s would be available at all times. In order to achieve this, alternative outlet facilities may be required. The total elevated flume length would be 115 km and there would be a 20 km rising main. The total lift would be approximately 60 m.

Phases 2 (a) and (b) – each 100 m³/s

This phase (of 200 m³/s) would comprise a flume from Lac Kabwe, where the Lubidi River joins the Zaire River. It would, however, probably be found to be more

economical to provide a 100 m³/s flume, which could be duplicated at some time in the future.

It has been assumed that the water would be stored in the lake, but if this storage is found to be insufficient, a dam on the Lubidi River near Bukama may be required.

Phase 3 (200 m³/s)

This would involve moving 100 km further north along the Zaire River to near Lac Lukanga, where the Lufira and Bungari rivers add to the discharge. If required, a dam could be built on the Lufira to balance out the flow.

This phase would have a capacity of 200 m³/s making a total of 450 m³/s for all phases – the target draft (400 m³/s plus ± 10%).

CHOBE TO HARTBEESPOORT

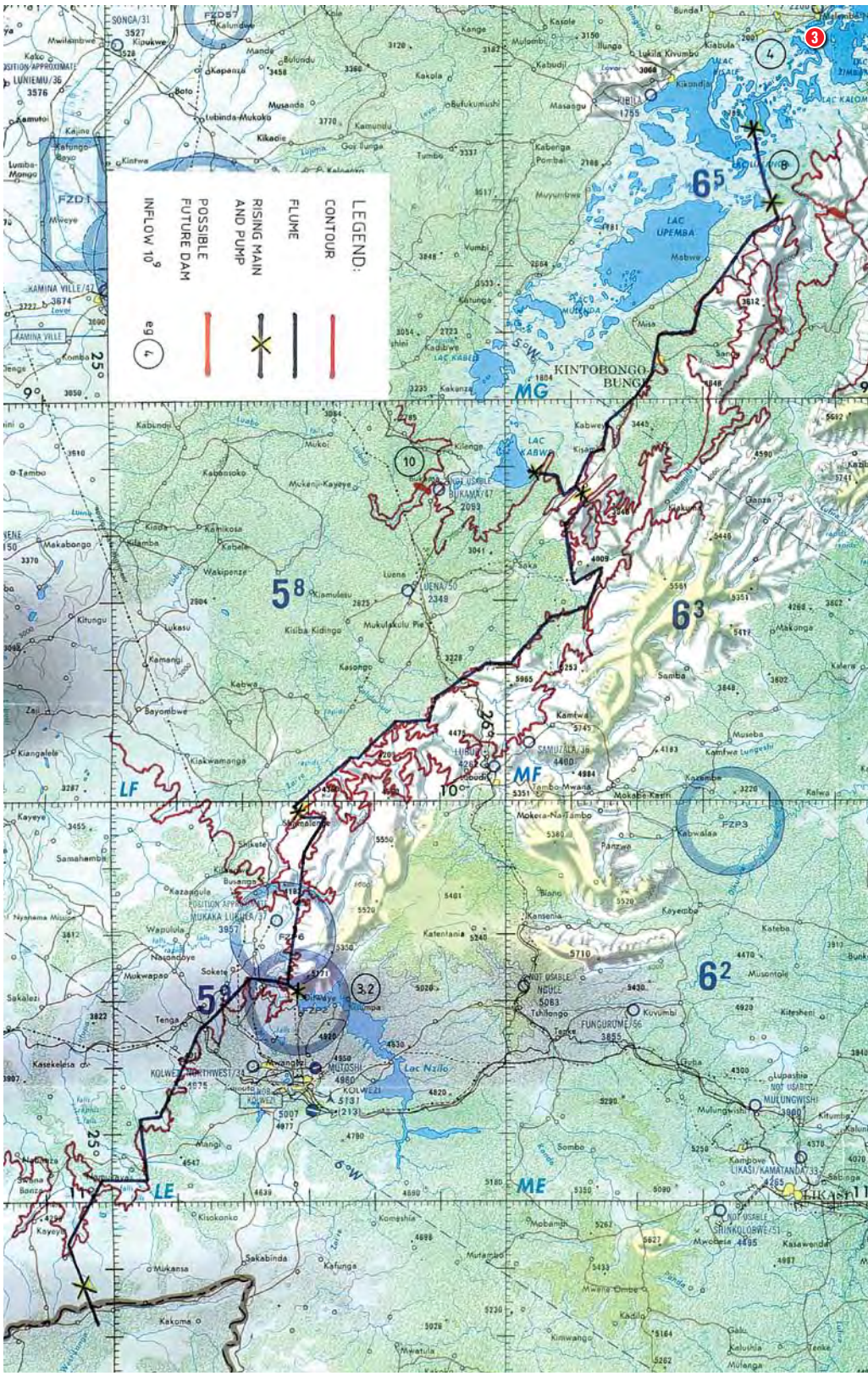
After initial extraction pumping, an elevated flume would run south from Chobe, then southeast and finally south again to arrive at a low point east of the Makgadigadi Pans. At Makgadigadi, 38 km rising mains would be required to deliver water to the top of the escarpment in eastern Botswana. From the escarpment, the flume route is relatively straightforward down to the Crocodile River. Particular care would be required in planning the crossing of the Serurumi River valley. The balance of the route would be up the Crocodile River valley where a number of pumping stations and pumping mains would be required. The total length would be about 1 400 km, the pumping lift about 758 m and difference in level between the beginning and the end about 250 m. Branches could be provided to Bulawayo and Gabarone, if required, and to other areas.

CONVEYANCE STRUCTURE

It is proposed that an elevated flume of the required capacity be used for the gravity sections. The proposed flume investigated would be manufactured in precast yards located, say, 100 km apart along its length.

The flume clearance could be increased at little extra cost. This high clearance has the advantage that animals in game reserves and other areas would be able to pass freely underneath the flumes. Furthermore, road and rail transport corridors could be passed beneath the flume and storm water passage could easily be effected without concentration and associated erosion. Outlets would be provided at intervals to provide drinking water for animals inside and outside game reserves and the possibility of water supplies for local food irrigation could be considered.

For details of the flume, see figure 1. It is not our intention to providing definitive and accurate total costings for the whole scheme, as this would depend on actual site conditions and myriad of other factors. As an illustration, however, the costing has been based on a 50 m³/s flume at a slope of 1 in 5 000. Of interest is that a 100 m³/s flume at a gradient of 1 in 2 000 is roughly the same size as a 50 m³/s flume at a gradient of 1 in 5 000. Accordingly, the cost of water at 100 m³/s would tend to be approximately half that of the 50 m ³/s flume and in any event a 100 m³/s flume would deliver water at a lower unit cost (unit reference value) than would a 50 m³/s flume.



ESTIMATED COSTS

The feasibility of this project would obviously depend on the delivered unit cost of the accompanying water.

At first glance the above-ground flume as a concept would appear to be unattractive. It would, however, tend to be 10% to 15% shorter in length than a conventional canal and furthermore it would have much

lower environmental costs. For example:

- It would not need fencing
- It would not need stormwater diversion embankments with associated culverts or superpassages and it would not be vulnerable to sedimentation
- It would not need farm and road bridges
- It would not need animal escapes and crossings
- It would not need special river crossings of minor streams
- It would not need under drainage installations and long weirs also to prevent uplift
- It would not need large embankments for access roads along its length
- Its spillways could easily be facilitated using frequent air regulated siphons
- It could easily be shut down for cleaning and maintenance as this would be relatively simple process
- It would have intrinsic safety and inspection facilities
- Rock excavation would not be a particular problem and would in fact be an advantage
- Its pumpstation costs would be reduced by providing extra NPSH and lower excavation costs
- Mass production would be facilitated
- It would generally have a lower environmental impact and would sterilise less ground

It would, however, have a higher visual impact and would of course be more vulnerable to sabotage.

COST OF WATER

We have been able to estimate the cost of bringing water from the DRC to South Africa to typically be of the order of R4 to R5 per cubic metre (These are basic costs and do not include royalty payments or payments for servitudes, transfer, transfer costs in rivers or other non-physical costs.)

We must emphasise that the costs have been based on a typical 50 m^3 per second flume at a gradient of 1 in 5 000. Many sections would be at 50 m^3 per second flume at a gradient of 1 in 2 000, which would require a smaller flume. No allowance has been made for this saving given the many physical unknowns and environmental concerns along the route.

A detailed costing of the flume, of the pumping mains, of the pumpstations, and of the total cost of operation, including pumping and electricity, was carried out by a costing expert using resource-based costing. The original report, which contains full details of the calculations including rainfall, run off evaporation, hydraulics and routing, also contained a full section on the costing. This full report may still be published in a scientific journal.

CONCLUSION

The scheme briefly outlined here envisages abstracting water from the Zaire River in the DRC and transferring it to some point near Hartebeespoort Dam. The basic method proposed would comprise the use of an elevated flume over long stretches of the DRC and Botswana, but would include pumping mains and the use over a certain length of the Zambezi River – this section being used as a conveyance and not a source.

The indicators are that if a scheme could be developed with a large enough flow capacity, water could be delivered at a competitive cost, The implementation of such a scheme would stimulate development in the northern-lying areas through royalty payments and the availability of more water supplies would allow further growth in the dryer southern-lying countries.

Acknowledgement

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Please contact Erlyn Snell on 072-491-6996 or ErlynS.ssi.co.za for more details. Obviously, we could only touch on the descriptive background of this interesting proposal. References are available on request – Ed