SODA ASH BOTSWANA (PTY) LTD

SUA SODA ASH PROJECT

Phase III Investigations

Memorandum No. 8

PROCESS AND DOMESTIC WATER SUPPLIES FROM SURFACE SOURCES

June 1984
7696/PG

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CONTENTS

SYNOPSIS

In this Memorandum, surface water sources and solar distillation are examined as means of supplementing groundwater sources to provide a reliable long term supply of 26 l/s of water for domestic and process use.

Solar distillation and storage in the river bed sediments do not appear sufficiently promising to justify further investigation.

The Nata, Mosetse and Mosope Rivers are considered as potential sources of supply.

The closest of these rivers to the project area is the Mosetse. Its mean annual runoff is well in excess of demand and a viable dam site is known to exist near Mosetse Bridge. Hence attention has been focussed on abstraction from the Mosetse, either from a dam or via pump-fed off-channel storage.

The former option would be expensive both because of the need to build a spillway to pass high floods and in view of the relatively long delivery line which would be necessary.

Pump-fed off-channel storage would reduce by at least 50 percent the amount of water which would need to be obtained from groundwater sources in the long term. It is recommended that further investigations should be concentrated on the conjunctive use of a wellfield in the Mosetse valley and off-channel storage in the same area.

Careful monitoring of the performance of the Mosetse Wells under sustained pumping coupled with the storage available in an off-channel reservoir would allow time to bring into supply further groundwater sources in the W8/E3 or Dukwe areas should this prove necessary.

2. OBJECTIVES

An interim report on the provision of process and domestic water for the Sua Project from underground sources was presented in Memorandum No.7 on the Phase III Investigations dated May 1984. This indicated that the anticipated demands of the Project could be met from underground sources but found that the long term security of such a supply could not be guaranteed.

In accordance with instructions from the S.A.B. Project Manager preliminary studies have been undertaken on the following alternative potential sources of supply:

a) Solar evaporation of Sua Pan brine.

b) River flow stored either on the surface or in river bed alluvial deposits.

The findings of these studies are presented herein.

It is understood that further potential sources of supply are under investigation by Seltrust Engineering Limited.

3. DEMAND

The latest available estimated demand figures are given in the terms of reference presented to WLPU by the S.A.B. Project Manager on 24th May, 1984, as follows:

Process demand: 25.5 l/s
Domestic demand: 0.5 l/s

The investigations outlined in this Memorandum are accordingly based on meeting these demands on a reliable, long term basis.

4. SURFACE WATER SUPPLY ALTERNATIVES

There are three rivers draining into the Sua Pan from the east, as shown on Fig.1, whose mean annual runoff is substantially in excess of the projected 820 000m^3 annual demand. These are the Nata, Mosetse and Mosope rivers with M.A.R. figures of 185.9, 26.4 and 6.8 x 10^6 m^3 respectively.

Monthly and annual flows covering 14 years of record on the Nata and Mosetse and 13 years on the Mosope are tabulated in Appendix I.

A common feature of the records is the extremely wide variation in annual runoff. This is typical of Botswanan rivers. Over the periods of record presented in Appendix I the annual runoff varies relative to the mean as follows:

Nata:	0.22%	to	433.2%
Mosetse:	2.93%	to	370.4%
Mosope:	Zero	to	249.7%

Runoff is concentrated generally over the period November to April and the rivers are dry for the remainder of the year.

From these observations it is evident that both seasonal and interannual storage will be required for reliable exploitation of the waters of these rivers on a long term basis.

The alternative methods available for providing this storage are examined below. As the Mosope River is further from Sua than either the Mosetse or the Nata and has the lowest runoff, it has been excluded from further consideration.

4.1 Valley Storage

In general the topography beyond the river channels is flat and conventional dam sites are uncommon.

The Nata and Mosetse Rivers were both examined as part of the "Reconnaissance Study for Major Surface Water Resources in Eastern Botswana", undertaken by Sir Alexander Gibb and Partners in 1976-77 and financed by the Commonwealth Fund for Technical Co-operation.

The Nata valley is particularly flat and no conventional dam sites were identified. On the Mosetse, however, there is a relatively good site where the river passes through the Kwana Hills some 9 km downstream of the Mosetse Bridge gauging station, as shown on Fig.2. This site was originally proposed as a source of supply for the Sua Pan Project by B.G. Lund and Partner.

A very approximate assessment based on 1 : 50 000 mapping with contours at 10m intervals suggests a maximum storage volume at this site of about 110 x 10^6 m^3 for a maximum depth of 9m at the dam wall. The corresponding surface area would be some 23.7 x 10^6 m^2.

Using net evaporation figures based on the Class A Pan at the Sua weather station with a Pan Factor of 0.7 and monthly inflow figures as tabulated in Appendix I a series of reservoir behaviour trials have been run on the computer covering the 14 years of record from 1969.

These indicate clearly the combined effects of very erratic annual runoff and high evaporation losses. With the live storage capacity set equal to the mean annual runoff, 10 months of deficit are indicated over 14 years.

Experience elsewhere in arid areas of Southern Africa has shown that evaporation figures based on Class A Pan results are high relative to the evaporation which will occur from a relatively deep expanse of open water. The Sua Class A Pan results multiplied by a Pan Factor of 0.7 and corrected for rainfall lead to an estimated net annual evaporation of some 2311mm. This result is based on only one year of record from Sua and a total of 1800mm per annum is judged to be more realistic. The performance of the reservoir is highly sensitive to evaporation and a second series of computer runs based on this lower figure indicates no deficits over the 14 year record for a live storage capacity equal to the mean annual runoff. Graphical summaries of the computer output for the high and low evaporation cases are shown on Figs.3A and 3B respectively.

It is emphasised that these results are approximate and that further work is required in the following areas to arrive at more reliable shortfall estimates:

a) Estimation of evaporation losses.
b) Depth-storage and depth-area characteristics of the Mosetse Bridge dam site.
c) Use of daily flow data in the simulation.

On the basis of the work carried out to date on a relatively short period of record it cannot be stated with confidence that a dam at this site could by itself provide a secure long term source of supply.

A further disadvantage lies in the transmission distance to Sua site which is some 24 km greater than that from a wellfield centred on the WW8 area.

4.2 Sand Storage

The flash floods which occur on the Nata and Mosetse bring down large volumes of sediment and deposits of sand occur widely in the river beds. Aerial reconnaissance indicates that deposits are confined to a width of some 10 to 20m. However,depending on their depth, these sands could offer significant storage potential.

To investigate this possibility a survey was carried out by WLPU field staff in mid-May 1984 on the sand deposits occurring in the bed of the Mosetse over a length of some 6.5 km upstream from well WW7, as shown on Fig.4.

This area was selected for survey on the basis of observations made during the groundwater investigations and is thought to be representative of conditions elsewhere on the Mosetse.

In addition, storage at this location would give a relatively short delivery distance to Sua and would tend to enhance recharge to the known groundwater sources nearby.

Although no detailed survey work has been done on the Nata sand deposits, low level aerial reconnaissance suggests conditions similar to those on the Mosetse.

The survey was carried out by probing the soft alluvial deposits with a steel rod. At selected locations the results of the probing were verified using test pits.

The results of this work are summarised on Fig.4.

In general,the depth of medium to coarse sand is less than 1.0m and the total volume of sands in the bed of the river over this reach is estimated at 65 000m^3. Much of the water stored in these sands when the river ceases to flow at surface would be within the capillary zone and therefore subject to loss by evaporation. Taking into account the available pore space and potential evaporation losses, the total effective storage volume would not exceed about 13 000m^3 which represents less than 6 days continuous supply at 26 l/s.

Apparently the storage available in the river bed is very limited. Although more favourable storage conditions may exist elsewhere, either on the Mosetse or the Nata, the indications are not considered sufficiently favourable to merit further investigation.

4.3 Off-Channel Storage

Although the annual flows of the Mosetse and Nata Rivers are extremely erratic, both rivers are known to carry relatively high flash floods. Hence, the only dam site identified on the Mosetse would require a substantial and relatively expensive spillway for safe passage of the flood flows.

By constructing a storage facility outside the river valley and fed by pumping, the need for a spillway is obviated, but at the expense of increased fill volume in the confining embankments.

Since the country outside the river valley is fairly flat, an off-channel storage facility may be sited to best advantage free of major topographical constraints.

To minimise evaporation losses the reservoir should be constructed to the maximum practicable depth and to avoid excessive seepage losses a membrane lining would be required.

A substantial perimeter fence would also be necessary to prevent access by large animals which would cause damage to the confining embankments.

It would be logical to site the reservoir close to the WW8 area where pumping from the river could be supplemented economically by borehole supplies in the event of shortfalls in surface runoff. Also an intake structure incorporating a wier would tend to enhance groundwater recharge.

The concept of off-channel storage suggests that the possibility of conjunctive use of ground and surface water resources merits serious consideration.

This possibility is examined further in Section 6.

5. SOLAR DISTILLATION

The Sua Pan offers a plentiful source of brine in an area of high solar radiation. It is therefore logical to examine the purification of the brine by solar distillation as a possible means of meeting process and domestic water demands.

5.1 Incident Solar Radiation

Sua Pan lies 20° South of the equator in an area which, according to Lof (1966), receives incident solar radiation varying from 400 Langleys/d in June to 525 Langleys/d in December.

5.2 Distilled Water Demand

It is understood that a T.D.S. not exceeding 7 000 mg/l is required for process use.

Water from a distillation plant would have a T.D.S. of about 25 mg/l and selective abstraction from recent recharge would yield a brine of S.G. about 1.10, representing a T.D.S. of about 100 000 mg/l.

Hence, to produce water of acceptable quality for process use the output from a distillation plant may be mixed with brine in the ratio 13.3 : 1. The distillation plant would therefore be required to produce some 93% of the process demand plus all of the domestic demand, adding up to a total demand for distilled water of 24.2 l/s or 2 092 m^3/d.

5.3 Still Design and Efficiency

A conventional single effect, greenhouse type still tested for the United Nations in Spain in 1970 yielded 1.1 - 4.5 l/m^2/d of fresh water.

Small conventional still units (approximately 4m^2, for farm use) tested by the Department of Water Affairs in South West Africa in 1970 produced 1.5 - 6.75 l/m^2/d.

A considerable increase in efficiency has been achieved in pilot scale combined solar/multi-stage flash (MSF) desalination plants recently developed jointly by West Germany and Mexico. Improved efficiency was achieved by the following means:

) Pre-heating of the feed water in solar ponds or by the use of waste heat from a process plant.

ii) Using multi-stage flash (MSF) evaporation (e.g. vapour compression or vertical tube evaporators).

iii) Using parabolic solar concentrators to provide thermal energy for the MSF process.

iv) Using an energy storage system to permit 24h plant operation.

5.4 Still Size and Costs

To produce 2 092m^3/d of fresh water a conventional single effect still would need to cover an area of between 75 and 150 ha.

Translucent plastic sheeting has been found unsatisfactory in the long term as a covering material and glass sheeting is required at an average installed cost at 1984 prices of the order of P40/m^2. This suggests a total construction cost of the order of P30 Million to P60 Million.

The size and cost of the distillation area could be reduced by collecting and storing any rain which falls on the covered area. With an average annual rainfall of about 400mm at Sua this source of water could theoretically supply 1.1 l/m^2/d in an average year hence reducing the area and cost of the plant by about 40 percent. In practice this figure would be reduced by evaporation losses and in any event the erratic nature of rainfall in the area is such that this order of economy could not be depended upon.

If interseasonal storage were provided so that excess summer production could be stored in the winter months a reduction in still area of some 13.5% would theoretically be possible. However,the reduction in still costs would need to be offset against the costs of providing reliable collection and storage facilities.

A solar powered MSF distillation plant would require 7 ha of solar ponds to pre-heat the feed water and some 22 000m^2 of parabolic solar concentrators would be required. The cost of such an installation is likely to be greater than that of a simple single effect installation.

It is possible that waste heat from the process plant could be used as the first stage of an MSF process but this possibility would need to be examined in association with the process plant designers. It is understood that the process plant design has not yet reached a stage at which the availability of pre-heated brine can be quantified.

The scale of operation outlined above far exceeds that of any known operating solar distillation plant and hence a comprehensive programme of pilot studies would be required to establish the viability of producing distilled water in the required quantities.

5.5 Operational Constraints

The Pan surface is frequently affected by dust storms which would both reduce the intensity of incident radiation and tend to deposit salt dust on the glazing, reducing its ability to transmit the solar energy to the contained brine.

Neither of these effects can be realistically quantified but it is envisaged that each would significantly reduce still efficiency.

6. CONJUNCTIVE USE

It is evident that surface water supplies, either stored in a dam on the Mosetse or in an off-channel reservoir fed by pumping could contribute significantly to meeting the total demand of the project, but the erratic nature of river flows and high potential evaporation losses mean that these sources are unlikely to offer adequate security of supply in the long term.

Similarly, the groundwater sources identified in Memorandum No.7 in the Mosetse valley, in the W8/E3 area and near Dukwe would meet project demands in the short term but are of uncertain long term reliability.

Conjunctive use of ground and surface water supplies is most attractive where the ground and surface sources occur in close proximity, as in the Mosetse valley in the vicinity of WW8. Two major options exist, as discussed in the following sections.

6.1 Valley Storage

The reservoir trials outlined under Section 4.1 suggest that a dam constructed on the Mosetse with a live storage capacity approximately equal to the mean annual runoff could meet project demands in most years.

A monthly shortfall probability of up to 6% is indicated over 14 years of record. By routing a supply pipeline from a dam on the Mosetse through the WW8 area groundwater supplies could be picked up to make good the shortfalls in surface supply.

Three or four targetted wells near the Mosetse valley would discharge into a holding reservoir providing a minimum of 24 hours storage (2 250m^3). The topography is such that water could be supplied under gravity from here to the Sua site.

Although such a scheme would offer a high degree of reliability it would be expensive as a result of the extended delivery distance totalling some 55 km in all from the dam, via the WW8 area to the Sua site.

The proposed dam site has not been examined on the ground and the cost of the dam would depend to a large extent on site conditions. It is likely that a substantial spillway would be required.

Assuming favourable foundation conditions and ready availability of construction materals, it is estimated that a scheme comprising a dam, asbestos cement pipeline, back-up wellfield in the WW8 area and limited treatment facilities at site would have a capital cost of the order of P20 Million at 1983 prices.

6.2 Off-Channel Storage

The topography along the Mosetse valley outside the immediate river channel is relatively flat and it is likely that a confining embankment would be required around the full perimeter of the reservoir. A simple earthfill embankment is envisaged.

The efficiency of the reservoir would be influenced by the following factors:

i) Storage capacity
ii) Evaporation losses
iii) Seepage losses
iv) River intake efficiency
v) Pumping efficiency

Evaporation losses can be limited by maximising the live storage depth. This is essentially a matter of economics in which capital cost of the confining embankments is weighed against the value of water lost through evaporation. For present purposes it is assumed that a maximum live storage depth of 5m would be attainable using simple compacted earthfill perimeter embankments.

Seepage losses can be virtually eliminated by using a membrane lining. A number of alternative lining materials are available, but for durability and proven resistance to ultra violet degradation it is likely that a butyl liner would be used. The cost of the liner would be a major factor in fixing the maximum feasible storage capacity and it is assumed that an upper limit of 25 ha would be applicable to the reservoir surface area,giving a maximum storage volume of 1.25×10^6 m^3.

Assessment of river intake efficiency is extremely difficult without detailed site investigations. Siltation is a major problem on flashy sand-laden rivers such as the Mosetse and very careful attention would need to be paid to hydraulic design. As a preliminary estimate, it is not considered realistic to think in terms of abstracting, on average, more than 10 percent of the monthly flow of the river. Without daily discharge data it is difficult to estimate the maximum required pumping capacity at the river intake. However,it would probably be necessary to pump about 600 l/s against up to 15m total head.

Using the outline scheme parameters discussed above a computer model of the storage reservoir has been set up to enable operating trials to be undertaken for a range of depths and storage capacities. The input data to the model is as follows:

a) Monthly net evaporation figures derived from Sua Class A Pan figures multiplied by a Pan Factor of 0.7 and corrected for rainfall using average monthly figures from Dukwe for the period 1959 to 1983.

b) Pumped inflows fixed at 10 percent of the monthly flow of the Mosetse at Mosetse Bridge for the period October 1969 to September 1983.

c) Continuous abstraction of 26 l/s.

d) A reservoir square in plan of maximum side length 500m and maximum depth 5m.

The estimated catchment area at the proposed abstraction site on the Mosetse is some 50 percent greater than that upstream of the Mosetse Bridge gauging station. Hence the assumed inflows represent considerably less than 10 per cent of the true monthly river flows at the point of abstraction.

As discussed in Section 4.1, an annual total net evaporation figure of 1800mm is considered more realistic than the figure of 2311mm emerging from the approach under (a) above. Since the surface area of the proposed off-channel reservoir is much smaller than that of a reservoir at the Mosetse Bridge site, the sensitivity of off-channel storage performance to evaporation is relatively low.

The results of modelling for the high evaporation case are summarised below with reliability defined as

$$\left(\frac{\text{Total Months - Shortfall Months}}{\text{Total Months}} \right)$$

To illustrate the effect of assuming lower evaporation losses (1800mm p.a.) selected results based on this figure are shown in brackets.

Reservoir Area (m^2)	Reservoir Depth (m)	Percentage Reliability
250 000	5	73 (77)
202 500	4.5	65
160 000	4	58
75 625	5	49 (51)
122 500	3.5	48
90 000	4	47
62 500	5	44 (49)

Although the computer similation is crude it demonstrates that an off-channel storage reservoir can make a significant contribution to meeting long term demands, reducing considerably the extent to which it would be necessary to draw on groundwater storage. For example,the model indicates that a reservoir 275m square and 5m deep would reduce by half in the long term the volume of water which would need to be drawn from the wellfield. The graphical computer output for this case is shown on Fig.5, asuming evaporation losses based on the Class A Pan results from Sua.

The indicated order of capital cost of a scheme comprising a 275 x 275 x 5m butyl lined reservoir, wellfield in the WW8 area, asbestos cement delivery pipeline and treatment facilities for domestic water at site is P10 Million at 1983 prices.

7. CONCLUSIONS

None of the sources of supply considered in this Memorandum is likely to meet, alone, the demands of the Sua Project in full with long term reliability.

Solar distillation does not appear attractive and the storage available in the river bed sands is very limited.

However, by harnessing the flows in the Mosetse River, either in a dam near Mosetse Bridge or in an off-channel reservoir in the Mosetse valley wellfield area, a significant reduction can be achieved in dependence on groundwater abstraction.

The Mosetse dam site is some 55 km from the Sua demand centres and a conjunctive use scheme based on the dam would be expensive relative to the use of an off-channel storage reservoir some 24 km downstream.

The indications are that a scheme with off-channel storage would reduce groundwater abstraction on average to less than half the full demand figure in the long term.

In order to optimise the off-channel storage facility daily river flow figures are required and it is necessary to refine the estimated evaporation losses.

Since the project demand centres could be fed by gravity from the storage reservoir such a scheme would provide a high degree of security against pumping plant breakdowns and power failures. A reservoir 275m square in plan and 5m in depth would store water sufficient to maintain a continuous suppy for some 4 - 5 months.

In the event of impending depletion of the Mosetse valley aquifer this storage would provide time to prove and bring into production new groundwater sources already identified in the W8/E3 or Dukwe areas.

With careful monitoring of the initial Mosetse wells it would be possible to anticipate the need to explore new groundwater sources hence maintaining security of supply on the long term.

The Institute of Hydrology have put forward proposals for geophysical investigations to firm up on their assessment of groundwater potential. These proposals, incorporated in their letter dated 15th June, 1984, are presented as Appendix II to this Memorandum. It is recommended that a price should be sought for surface geophysics and target drilling to explore further the WW8-WW9 area.

For the reasons outlined above it is considered that, subject to satisfactory results from this work, further exploration in the W8/E3 and Dukwe areas can be deferred until the Mosetse valley aquifer shows signs of depletion.

APPENDIX I

MONTHLY RUNOFF DATA

NATA RIVER - CATCHMENT AREA 22 900 km^2

Monthly Flows in $m^3 \times 10^6$

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Annual Total
1969-70			51.63	0.55	0	0	0	0	0	0	0	0	52.18
1970-71	0	0	0	62.31	1.83	0	0	0	0	0	0	0	64.14
1971-72	0	4.66	5.94	607.8	143.3	22.8	20.8*	0	0	0	0	0	805.30
1972-73	0	0	0	0	2.47	6.88	0	0	0	0	0	0	9.35
1973-74	0	0	39.35	529.59	157.16	47.15	0.71	0	0	0	0	0	773.96
1974-75	0	0	0.51	7.40	44.53	19.92	7.51	0.13	0	0	0	0	80.00
1975-76	0	0	1.50	15.80	5.15	49.40	11.84	0.79	0.01	0	0	0	84.49
1976-77	0	0	0	0	96.78	121.05	2.56	0.07	0	0	0	0	220.46
1977-78	0	0	0	129.97	97.53	57.66	17.91	3.03	0.27	0	0	0	306.37
1978-79	0	0	1.04	0.04	0	2.77	0.03	0	0	0	0	0	3.88
1979-80	0	0	1.00*	5.92*	13.99	28.21	0.20	0	0	0	0	0	49.32
1980-81	0	0	1.39*	4.87*	108.61*		34.51	2.47*	0.004	0	0	0	151.85
1981-82	0	0	0	0.29	0.107	0.013	0	0	0	0	0	0	0.41
1982-83	0	0	0	0	1.598	0	0	0	0	0	0	0	1.598

* Incomplete records - clock stopped some days

MOSETSE RIVER - CATCHMENT AREA 1 090 km^2

Monthly Flows in m^3 x 10^6

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Annual Total
1969-70	0.008	0.002	1.597	0	9.029	0.636	0	0	0	0	0	0	11.272
1970-71	0	0.372	8.204	29.12	0.19	0	0	0	0	0	0	0	37.886
1971-72	0	0.35	0.34	95.91	0.10	1.08	0	0	0	0	0	0	97.78
1972-73	0	0	0	1.105	0.447	0.88	0	0	0	0	0	0	2.432
1973-74	0	1.785	27.793	33.136	3.054	0.967	0	0	0	0	0	0	66.735
1974-75	0	0.28	0.285	0.265	5.827	1.21	0	0	0	0	0	0	7.867
1975-76	0	0	0	0.40	3.535	4.99	0	0	0	0	0	0	8.925
1976-77	0	0	0	0.80	3.81	10.67	0	0	0	0	0	0	15.28
1977-78	0	0.267	11.254	50.242	0	0	0	0	0	0	0	0	61.763
1978-79	0	0	1.632	1.264	0.004	8.776	0	0	0	0	0	0	11.676
1979-80	0	0	0.423	0.963	3.04	0.009	0	0	0	0	0	0	4.435
1980-81	0	2.152	1.908	18.544	11.495	3.703	0	0	0	0	0	0	37.802
1981-82	0	0	0	0.636	0.087	0.051	0	0	0	0	0	0	0.774
1982-83	1.951	2.125	0	0.353	0.208	0.340	0.176	0	0	0	0	0	5.153

MOSOPE RIVER - CATCHMENT AREA 516 km^2

Monthly Flows in $m^3 \times 10^6$

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Annual Total
1970-71	0.24	0.90	1.58	6.10	0	0	0.13	0	0	0	0	0	8.95
1971-72	0	0.95	0.59	13.11	0.33	0	0	0	0	0	0	0	14.98
1972-73	0	0	0	0	0	14.90	2.24	0	0	0	0	0	16.98
1973-74	0	0	1.51	5.84	2.43	0	0	0	0	0	0	0	9.78
1974-75	0	0.12	1.18	1.16	0.113	0	0.26	0	0	0	0	0	2.83
1975-76	0	0	0.03	0.37	0.87	0.14	0	0.15	0	0	0	0	1.56
1976-77	0	0.01	0.025	0.066	2.10	1.78	0	0	0	0	0	0	3.98
1977-78	0	0.37	1.184	4.28	0.73	2.47	0	0	0	0	0	0	9.03
1978-79	0	0	0	0	0	0	0	0	0	0	0	0	0
1979-80	0	0.07	0.21	0	0	0	0	0	0	0	0	0	0.28
1980-81	0	0	0.06	4.86	7.37	0.36	0	0	0	0	0	0	12.65
1981-82	0	0.01	0.03	2.00	3.21	0	0	0	0	0	0	0	5.25
1982-83	1.209	0.614	0	0	0	0	0	0	0	0	0	0	1.823

APPENDIX II

INSTITUTE OF HYDROLOGY
PROPOSALS FOR FURTHER INVESTIGATIONS

Institute of Hydrology
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Your ref

Our ref 33/347

Date 15 June 1984

FOR THE ATTENTION OF MR P GARRATT

Dear

SUA PAN PROJECT, BOTSWANA

I have now discussed with our geophysicist the application of surface geophysics for locating groundwater supplies for the refinery.

There is the possibility of reducing the number of boreholes to meet the refinery demands if high-yielding sites can be located. However, the potential areas are covered by calcretes or other sediments and, consequently, target sites can only be identified indirectly through the use of geophysical methods. This also applies to fault boundary conditions and the fresh-salt water boundary.

SWECO undertook some surface geophysics combined with photo-interpretation to indicate fault zones. Resistivity and magnetic profiles apparently proved more useful than gravimetric profiles. Dolerite dykes and sills were identified, although test drilling (3107) did not confirm such features were favourable for groundwater abstraction (p23 SWECO Inception Report). Details of the survey are unavailable.

We would propose a trial field survey with the following objectives:

- to examine the geology, from which structural zones and boundaries should be identified
- to infill around WW8 WW9 to determine the extent of freshwater.

The surveys would be supplemented if possible by resistivity borehole logs of the new wells and the published aeromagnetic survey maps (lines about 1 - 1½ km apart). Two or three target features could be drilled whilst the ASTE rig is available to test the reliability of precise target drilling.

The field surveys would have to be undertaken by local staff with equipment available locally or hired from UK. Our geophysicist could plan the surveys and interpret the results using our already developed suite of interpretation programmes.

The survey could accomplish three to four Schlumberger resistivity arrays per day for the saline-fresh water boundary investigation, and between 5 and 10 line kilometres (at a station spacing of 25 m on pre-cut lines) with a magnetometer for structural control. Thus a survey lasting one week should be sufficient. A further week of UK planning and interpretation would be required (from our staffing point of view this would have to be before the end of August).

I hope these general notes will assist you in deciding whether a survey would benefit the feasibility study. If so, then we could provide more details and be available for further discussion.

Lastly, if you still wish to see our rig in operation we would be pleased to arrange a demonstration for you.

Yours sincerely

Dick

R B BRADFORD

RBB/SJB

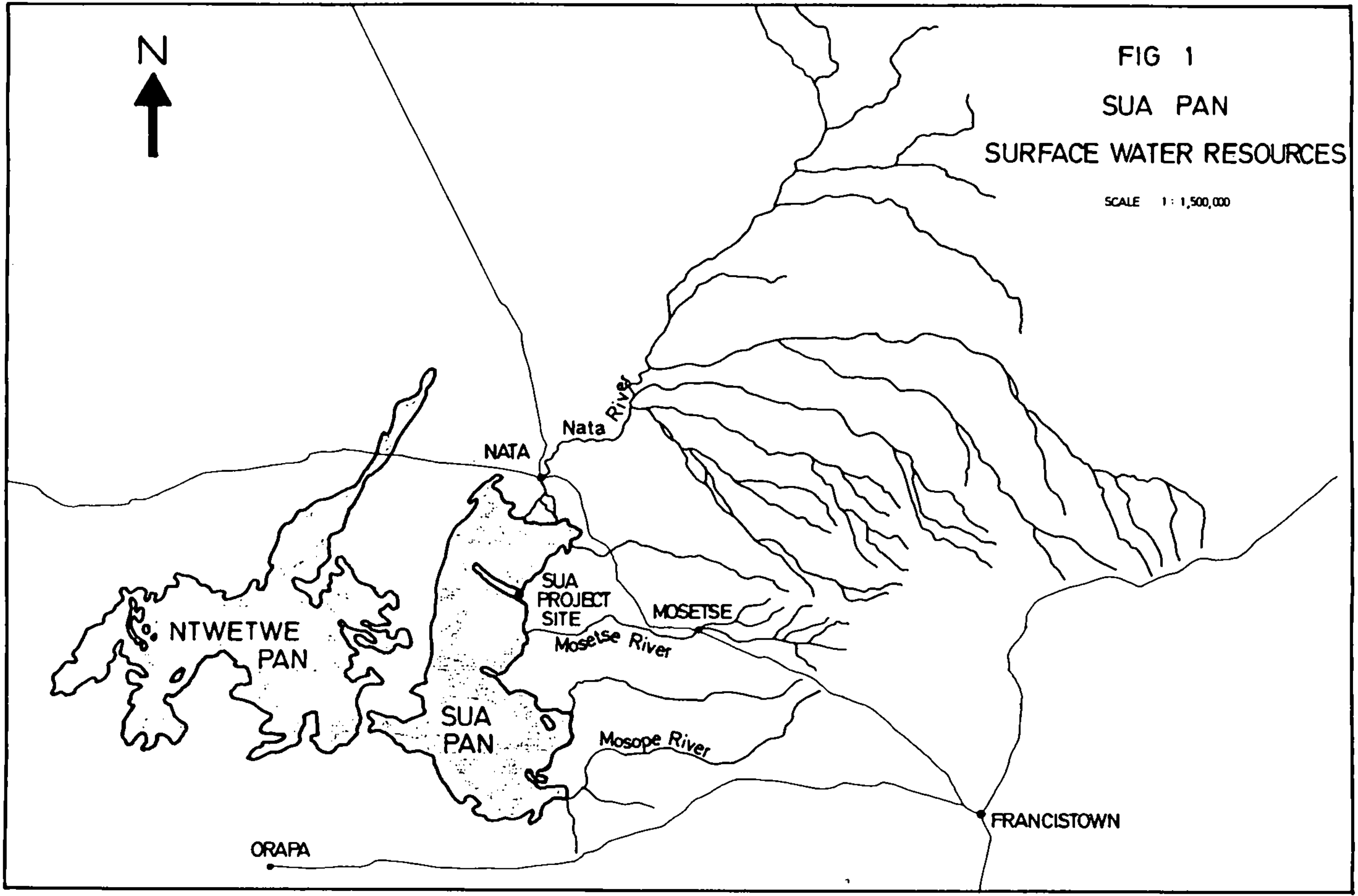


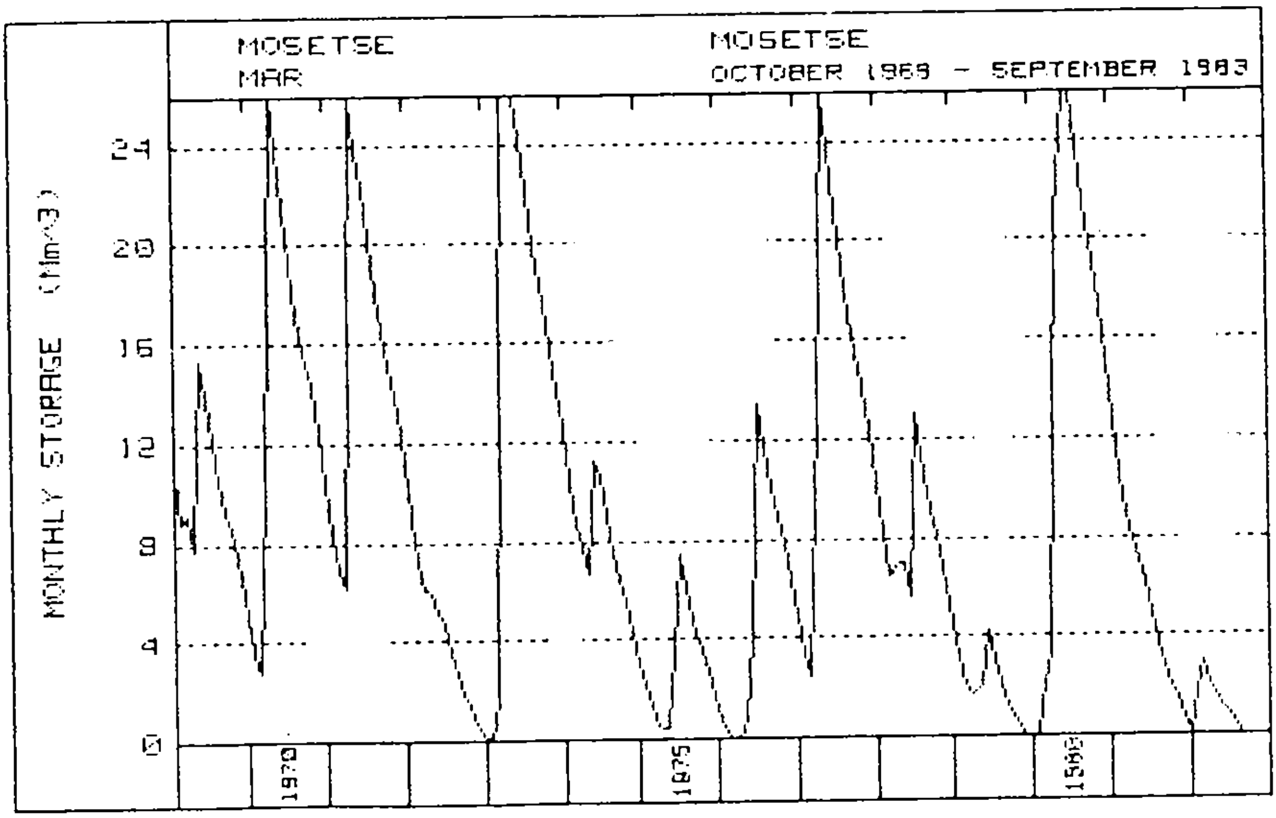
FIG 1
SUA PAN
SURFACE WATER RESOURCES
SCALE 1 : 1,500,000
N
NATA
Nata River
SUA PROJECT SITE
MOSETSE
Mosetse River
Mosope River
NTWETWE PAN
SUA PAN
ORAPA
FRANCISTOWN

FIGURE 2
MOSETSE VALLEY SHOWING LOCATION OF BOREHOLES AND DAM SITE

FIG. 3A
MOSETSE DAM
SIMULATED PERFORMANCE
1969 - 1983

Net Evaporation
2311 mm per annum

19 JUNE 1984



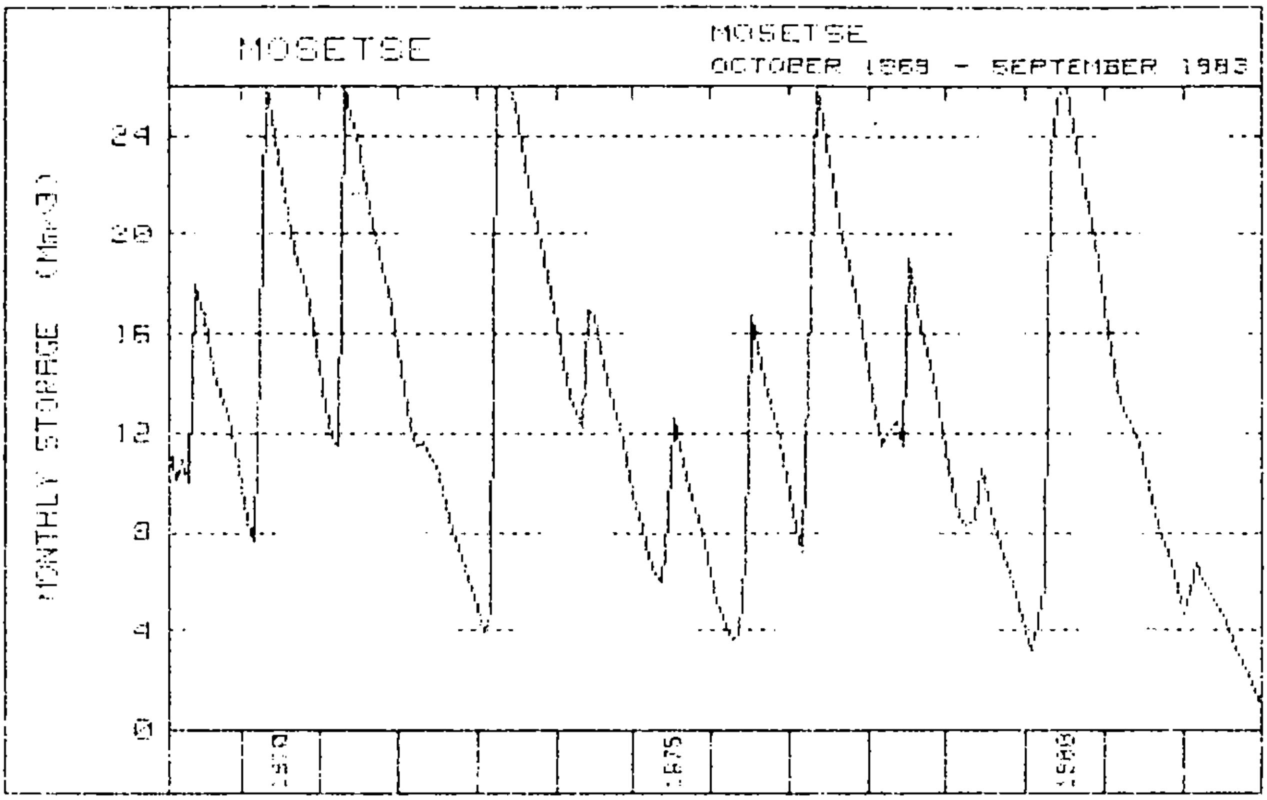
RESERVOIR ROUTING   CAPACITY = 26.00 INIT. 13.00

Constant Monthly Demand =

Volumes, Flows etc. are given in 10^6 * M^3

FIG. 3 B
MOSETSE DAM
SIMULATED PERFORMANCE
1969 - 1983

Net Evaporation
1800 mm per annum

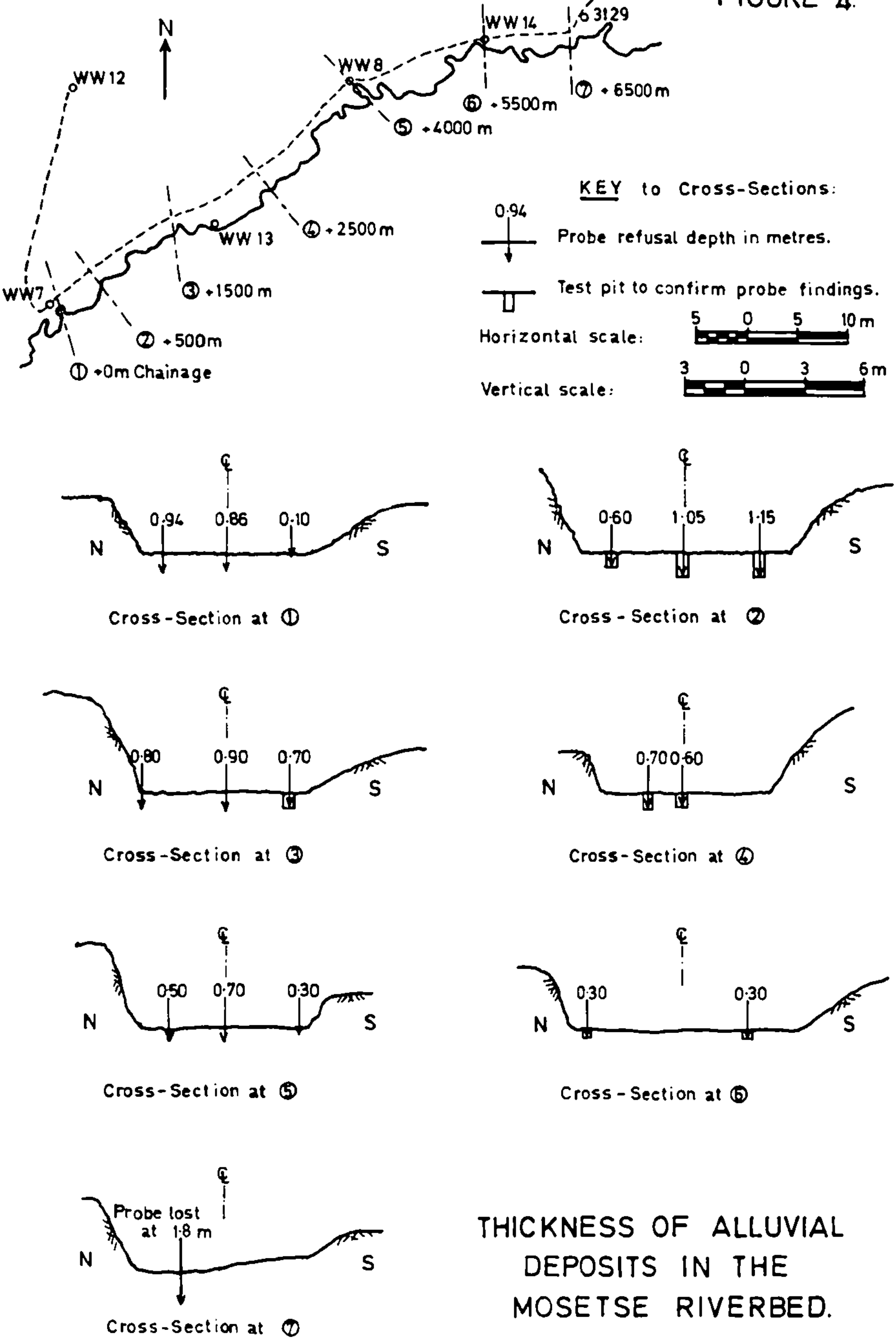


RESERVOIR ROUTING   CAPACITY = 26.00 INIT. 13.00

Constant Monthly Demand =

Volumes, Flows etc. are given in 10^6 * M^3

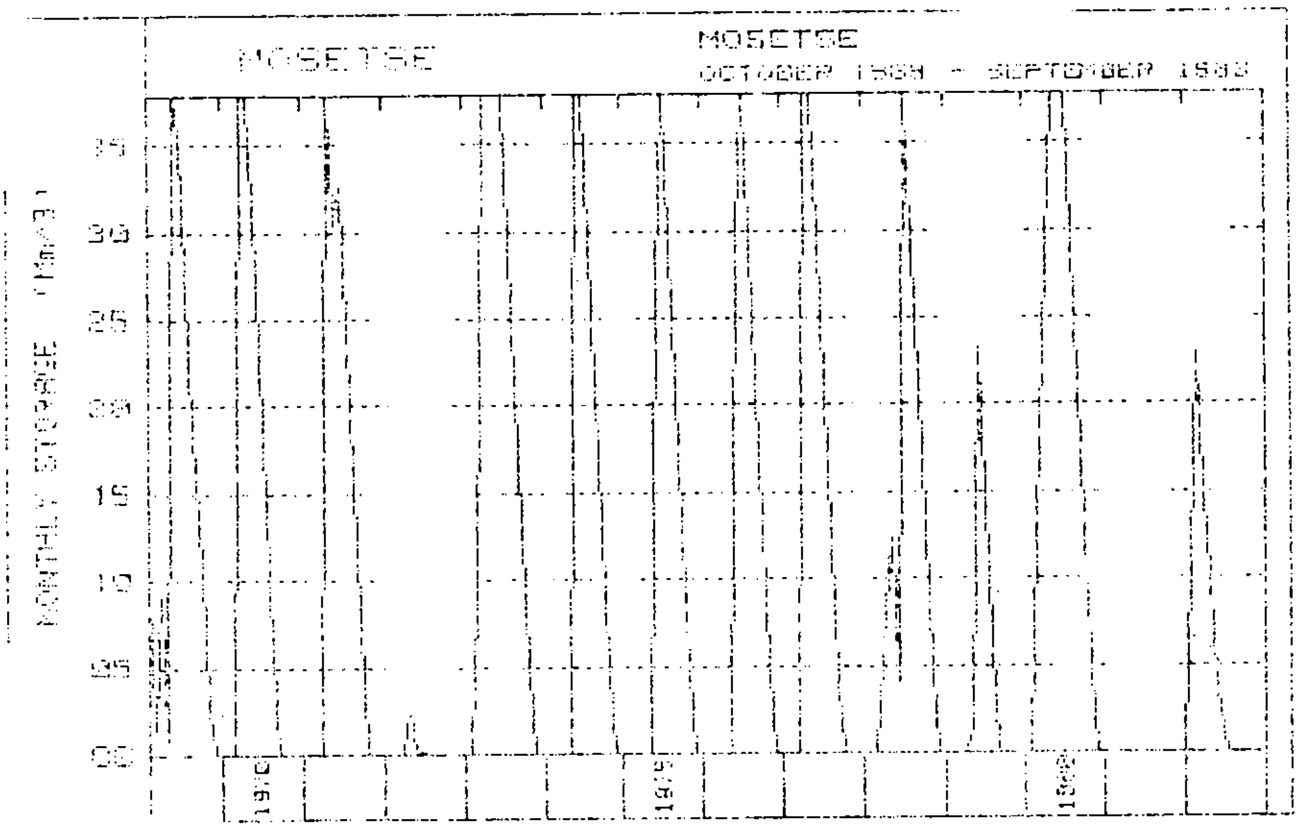
FIGURE 4.



THICKNESS OF ALLUVIAL DEPOSITS IN THE MOSETSE RIVERBED.

FIG. 5
OFF - CHANNEL STORAGE SIMULATED PERFORMANCE 1969 - 1983

Net Evaporation
2311 mm per annum



RESERVOIR ROUTING   ength = 275 Width = 275 Depth

DEMAND = .070   CAPACITY   .379 INIT.   .189

PUMP CAPACITY   5.0   MAXIMUM YIELD FROM RIVER IS 10% OF RIVERFLOW

Volumes, Flows etc are in 10^6 * M^3