PROPOSED MODIMOLA DAM
PRELIMINARY INVESTIGATION INTO THE ENVIRONMENTAL IMPACTS DOWNSTREAM OF THE EXISTING DISANENG DAM

MAY 1994

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1. INTRODUCTION

1.1 Augmentation of Water Supply to Mmabatho

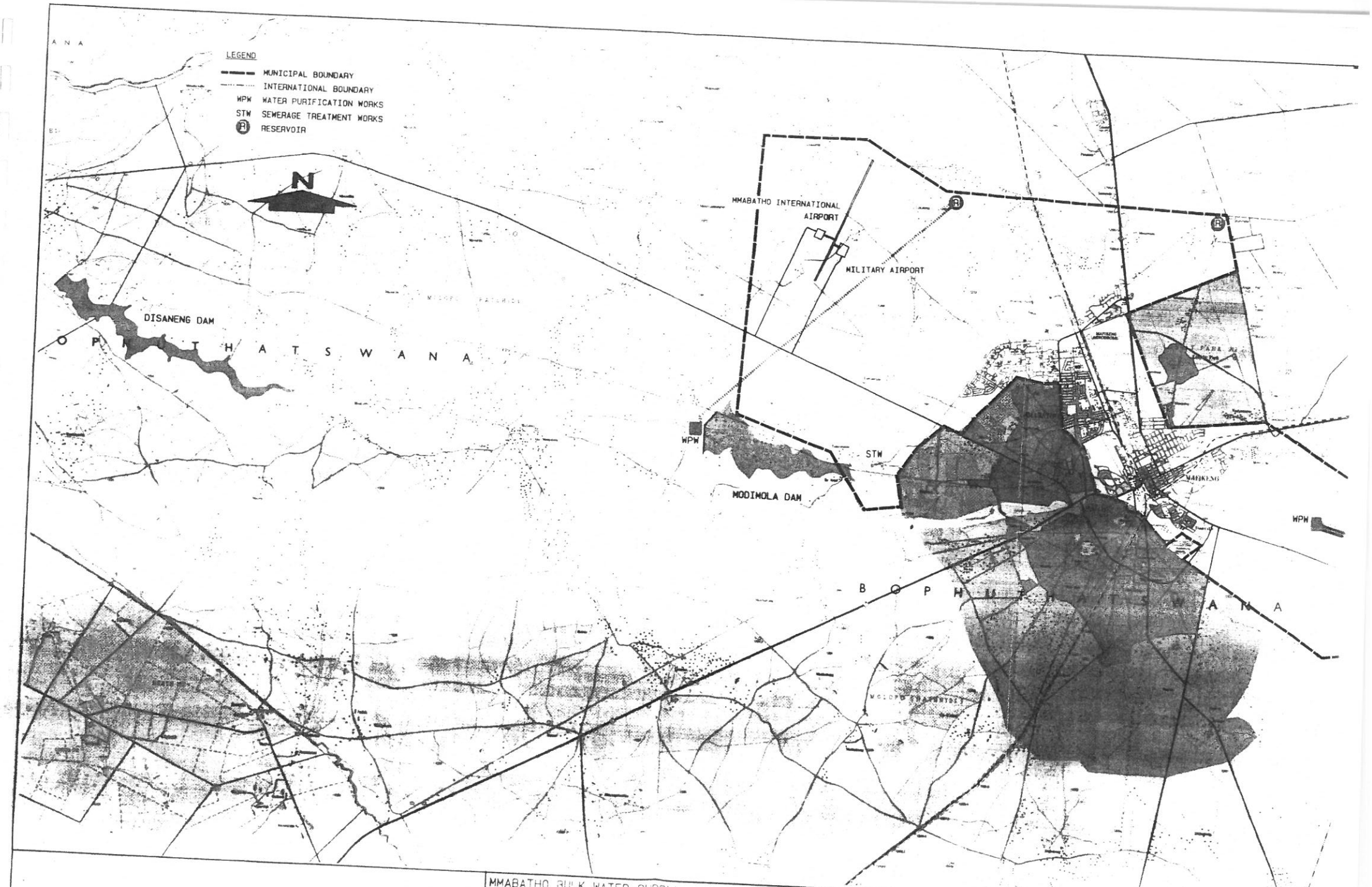
Mmabatho, the capital of Bophuthatswana, is expanding rapidly and the water demand is expected to exceed the supply from available groundwater resources in the east by 1995. An urgent need for water supply augmentation exists.

An intensive investigation into 11 different combinations of water supply options has indicated that the exploitation of the Molopo river resource provides the most appropriate solution in a phased programme of water supply.

The existing Disaneng dam of 17,4Mm^3 capacity has been utilised for the irrigation of some 200 ha over the past decade. The possibility of abstracting water for Mmabatho from this source has indicated that it would be more economical to construct a new dam at Modimola, which is ca. 20kms nearer to Mmabatho and also provides advantages in terms of lower static pumping head. (See locality Map 9066/13). Construction of the Modimola Dam is scheduled to commence in 1994 with impoundment scheduled for the 1995/1996 season.

1.2 Study Extract

The Molopo river is an intermittent international river, rising in the Republic of South Africa (RSA), flowing westward to Bophuthatswana and through Mmabatho to the confluence with the Ramathlabama river from where it forms the boundary between Bophuthatswana and Botswana. The river leaves Bophuthatswana after the confluence with a major tributary, the Setlagole, at Mabule, from whence the river centre is the boundary between Botswana and RSA. Although a single record exists of surface flow in the Molopo river up to the vicinity of Noenieput in the previous century *(van Bladeren pers. comm.)*, the practical furthest extent of surface runoff is Watersend, west of Pomfret. This study considers the environmental impact of the proposed abstractions from the Modimola Dam to feasibly extend no further than the Setlagole river confluence. Nevertheless, developments up to the farm Blackheath are included herein for completeness.



MMABATHO BULK WATER SUPPLY

LAYOUT: WESTERN SUPPLY AREA

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1.3 Other Environmental Studies

An Environmental Impact Assessment has been conducted for the Modimola Dam. *(CSIR 1993)*. No significant impacts were identified, and certain minor impacts are being resolved in terms of the ameliorative measures proposed. For example:
A water quality simulation of the Molopo System indicates that abstraction at the intended supply rates from the proposed Modimola Dam could result in severe salinity problems of short duration in Disaneng Dam.

Indications are that the lowering of the Disaneng Dam spillway or operation of the dam to minimise evaporation volume will result in the water in Disaneng Dam returning to acceptable salinity levels.

1.4 Purpose of this Study

The present study is intended to identify at a scoping level, the potential environmental impacts on the impacted Molopo river reach and dependant environments downstream of Disaneng Dam.

Study Level

This study is intended to be at the scoping level, that is:

- existing information is evaluated in context with the proposed development;
- potential problem areas are defined, and the potential for remedial action discussed;
- areas requiring further study are emphasized.

The co-operation of the Botswana Department of Water Affairs is gratefully acknowledged.

2. DESCRIPTION OF EXISTING DEVELOPMENT

The layout of salient features downstream of Disaneng Dam is indicated on the appended Figure 1.

2.1 Bophuthatswana

Settlements

The Bophuthatswana area is characterized by expanses of grazing land with village clusters decreasing in size and increasing in internodal distance toward the west.

2.1.1 Land Use

Dryland cropping appears to have been practised in the past, but the consecutive 1980's drought years have apparently resulted in a considerable reduction in arable activities.

2.1.2 Irrigation

Disaneng Dam is utilised for the irrigation of 200 hectares of lands some 5km to the north, and a fishery at the dam. Disaneng Dam has become a popular resort for yachting and a yacht club exists near the dam wall.

2.2 Botswana

Settlements

The Botswana area is characterised by ranching activities, with less settlements than in Bophuthatswana (see para. 4.4). A symbiotic relationship apparently exists between neighbouring villages on either side of the border.

2.2.1 Land Use: Ranching & subsistence pastoral farming activities predominate

2.2.2 Irrigation

Irrigation development by the Commonwealth Development Corporation (CDC) to the north of the farm Blackheath comprises 3 centre pivots totalling 104,5ha. Lucerne is presently being grown under the 19,5ha pivot, while the others are fallow. Generally, 2 crops of maize are cropped annually. Water is pumped from 6 boreholes ranging in yield from 23 *l/s* to 43 *l/s*. *(Pers. Comm. Mike Jacks CDC)*. Borehole depth is allegedly 50 to 80m. Developments for at least 50kms downstream of this point are negligible.

2.3 R.S.A

The RSA farms are typically used for ranching. Considerable irrigation development was noted on the farm Blackheath, north of Vergeleë. Two centre pivots, each of approximately 100 hectares in extent, are in operation and a third is under construction. *(K. Carroll Pers. Comm.)* Water is sourced from six deep boreholes (> 100m deep) yielding ca. 120 litres/sec and a dam in the Molopo river of capacity purportedly 1 Million m^3. Preferential abstraction from the dam whenever water

levels permit a reduction in pumping energy requirements. *(Pers. Comm. Karel Carroll)*. Downstream development is negligible.

2.4 Estimated Water Demand

The water demand associated with each of the developments is listed in Table 2.

- Bophuthatswana primary water demands were abstracted from *EVN-1993 "Disaneng West Water Supply Scheme"*.
- Botswana water demands were estimated from dwelling counts estimated from an aerial reconnaissance of the riverine reach as well as data made available in para. 4.4). A unit water consumption of 400l/household/day was used.
- Stock water demands were estimated using a density of 150 Mature Stock Units (MSU) for 1 kilometre on either side of the river. Unit consumption allowance including conveyance and storage losses was taken to be 50 litres/MSU/day.

Irrigation demands were estimated on the basis of 11 000 m^3/annum gross demand per hectare.

3 DESCRIPTION OF PROPOSED DEVELOPMENTS

3.1 Bophuthatswana

The Disaneng Irrigation Scheme will be reduced to 50 hectares in the near future. The proposed Modimola Dam will abstract a target draft of 8,5Mm^3/annum at high risk levels to maximise the conjunctive yield ability of groundwater, treated sewage effluent and surface water.

The growth in water demand of each of the villages referred to in Fig.1 are listed in Table 2 for a design horizon of 20 years.
Primary water demands are expected to increase at a rate of 2% per annum which is essentially due to an increase in affluence since population growth is estimated by physical factors.

3.2 Botswana

The Settlements are expected to remain static since the trend toward urbanisation in the productive southeastern district comprising the Gaborone-Lobatsi axis is expected to counteract natural population growth. *(Pers. Comm. Botswana)*.

The CDC irrigation development may increase in future, but this is dependant on the outcome of a resource monitoring programme to be instituted in 1994. *(Pers. Comm. Mike Jacks CDC)*. In view of the alleged dolomitic character of the substrata, and from experience with related dolomites to the south, we are presently of the opinion that present abstraction rates are in excess of recharge rates *(Partridge Pers. Comm.)*. Further development is therefore unlikely, and it is feasible that a reduction in water use will occur in time. We have illustrated a static trend in irrigation demand in Table 2 over time.

3.3 R S A

Further irrigation development is planned, but we are of the opinion that present abstraction rates are already in excess of sustainable yields considering groundwater recharge rates in this semi-arid area (see Par. 3.2 above). A groundwater study covering certain dolomitic aquifers to the south by the RSA Department of Water Affairs: Directorate Geohydrology is in the process of completion, and this may elucidate this position. We have assumed present abstraction rates to remain constant with time. (Table 2, Fig 4).

4. INITIAL IMPACT ASSESSMENT

4.1 Surface Runoff

4.1.1 Definition of Scenarios

For the purposes of illustration, three upper catchment development scenarios were defined:

- **Status Quo**

  The spatial distribution of Mean Annual Runoff for the existing river system with Disaneng Dam in place, is indicated in Table 3. This "Status Quo" scenario differs from the undeveloped catchment state in that present

irrigation abstraction for 200ha and evaporative loss in Disaneng Dam has been imposed on the "natural" state.

- **Modimola Dam with Disaneng Dam at Present Full Supply Capacity**
  This option assumes the construction of Modimola Dam to a Full Supply Capacity of *21,9 Mm^3* without any changes to Disaneng Dam. As already indicated, salinity levels in Disaneng Dam are expected to rise to excessive levels (greater than 2 000m S/m electrical conductivity for short periods) with this option.

- **Modimola Dam with Disaneng Dam at 25% of Present Full Supply Capacity**
  This option is included in response to the anticipated high salinity levels and can be practically achieved by either lowering part of the present spillway, or else by operating the dam outlets to practically achieve the same result.

4.1.2 Simulation Procedure

The source hydrological data for this report is the HRU 11/81 "Orange River" set of the Surface Water Resources of South Africa. More recent simulations by Dr Pitman on the Molopo River upstream of Disaneng Dam (SSI 1992) include the exceptional dry cycle of the 1980's and this results in a reduction in Mean Annual Runoff of an estimated 15% at Disaneng Dam, as compared with the HRU 11/81 reports.

Reservoir simulation at design draft of 8,5Mm^3/annum was conducted with the simulation time resolution set to 1 month.
Monthly fluctuations in the Mmabatho demand curve were incorporated.
Mean annual rainfall and evaporation data was used.

The Modimola-Disaneng system was simulated as a linked cell model, with both the intervening catchment and Modimola Spillages as inflow to Disaneng Dam.
Effluent inflow was ignored to offset the fact that the present model does not operate on a variable draft rule as would occur in practice to further maximise system yield. In any event, effluent flow is a legitimate dedicated source of supply to Mmabatho, and cannot be brought into the present water supply equation

downstream of Modimola Dam.

While the full simulation was conducted, only the summary of annual values or statistical mean values are included herein.

4.1.3 Discussion of Results

4.1.3.1 At Disaneng Dam

Reference should be made to Table 4.

Status Quo

The present annual spillage distribution is as shown in the second column: "Status Quo" and this indicates a Mean Annual Spillage of 9,36Mm^3, compared to the Mean Annual Runoff at the dam site of 17,4Mm^3. Significant periods of no spillage occur from 1929 to 1932, from 1961 to 1964 and from 1981 to 1987, all inclusive.

Modimola and Disaneng at 100%

The simulated annual spillage distribution is as shown in the fifth column: "Modimola/Dis: Present Disaneng" and this indicates a Mean Annual Spillage of 4,05Mm^3, compared to the Mean Annual Runoff at the dam site of 17,4Mm^3. Protracted periods of no spillage occur from 1934 to 1942, a substantial period from 1946 to 1965 and from 1977 to 1991, all inclusive.

Modimola and Disaneng at 25%

The simulated annual spillage distribution is as shown in the sixth column: "Modimola/Dis: Lowered Disaneng" and this indicates a Mean Annual Spillage of 5,83Mm^3, compared to the Mean Annual Runoff at the dam site of 17,4Mm^3. Significant periods of no spillage occur at roughly the same frequency as the "Status Quo" situation.

In conclusion, it will be seen that the spillage *frequency* at the lowered Disaneng Dam will approximate to that for the present "Status Quo" condition. Annual spillage *volumes* will generally be reduced by approximately one third, but apparently will be sufficient to recharge the riverine aquifers up to the confluence with the Ramatlhabama river and possibly beyond in all cases.

4.1.3.2 Along International Border

The MAR of the Ramatlhabama River at the Molopo confluence is estimated to be 9Mm^3.

The MAR of the catchment between the Ramathlabama River and the Setlagoli River is estimated to be 7Mm^3.

The MAR of the Setlagoli River is estimated to be 33Mm^3. (4RU 11/81)

The tabulation of cumulative downstream MAR with distance will be found in Table 3. The relative reduction in mean flow volumes is expected to be as follows:

Immediately downstream of Ramathlabama River Confluence	: 20%
Immediately upstream of Setlagoli River Confluence	: 14%
Immediately after Setlagoli River Confluence	: 6%

The effect of a hypothetical 10% groundwater recharge is indicated in Figures 3 and 4.

4.1.4 Conclusions

4.1.4.1 The 13km river reach between the Disaneng Dam and the Ramathlabama River confluence will experience the largest reduction in Developed MAR i.e. 38%. No Surface Water Resource development potential exists in this vicinity, and the impact of this 38% reduction is therefore negligible. Although groundwater resources are the primary source of water at present, plans are under way to supply these villages from Disaneng Dam in future.

4.1.4.2 The reduction in mean annual flow volume of between 20% and 14% prior to the junction with the Setlagoli River and only 6% thereafter is similarly inconsequential from the point of view of surface water resource development.

4.1.4.3 The effect of the proposed Modimola Dam on groundwater augmentation may be significant locally up to - say - Makgobistad, but insignificant beyond this point. These villages are in any event proximate to the Disaneng Dam and can be economically served directly from this dam if groundwater resources are adversely affected.

4.2 Possible Effects on Groundwater Resources in the Western Part of the Molopo District

4.2.1 Description of Area

The area in question extends from the Modimola Dam site to the infall of the Setlagole River, a distance of some 80km. Over this distance the Molopo River occupies a shallow valley, which is cut into granite rocks of the Basement Complex, overlain by a thin veneer of Kalahari Group sediments, as far as the vicinity of Makgobistad; it then crosses outcropping banded ironstones and schists of the Kraaipan Formation, after which it is underlain by Kalahari Group sediments. The thickness of the Kalahari Group increases progressively downstream, until it reaches approximately 100m at the western end of the Molopo District. Throughout this area the Kalahari sediments overlie granites and occasional narrow belts of Kraaipan rocks. Deep, sub-Kalahari palaeo-valleys area associated with Pre-Kalahari courses of the Mheele and Setlagole rivers. These buried valleys offer preferential pathways for subsurface groundwater migration. Groundwater quality throughout the western part of the Molopo District is generally good, with some areas along the lower Molopo River having TDS concentrations of less than 500mg/l; elsewhere values are between 500 and 1000 mg/l. A few boreholes show the effects of biological contamination, usually as a result of poor borehole construction.

4.2.2 Groundwater Development

Throughout the western part of the Molopo District boreholes or shallow wells in the end alluvium of the river channels provide the sole source of water for domestic consumption and cattle watering. Boreholes are generally low-yielding, north of the river upstream of Makgobistad yields average 0,5 - 1,5 litre per second over a daily

pumping period of 12 hours. To the south of the river over the same stretch the geohydrological potential is very much lower; in fact, average yields are less than 0,1 litre per second and about 80% of boreholes sited using the best scientific methods are dry. We have previously drawn attention to this area, which contains several large villages, as one where there is urgent need for the provision of primary water from surface sources. To the west of Makgobistad average borehole yields are of the order of 0,5 l/s over a 12 hour period. The water commonly occurs at or immediately below the contact between Kalahari Group sediments and the underlying bedrock. Boreholes are deep (usually more than 100m), and the deep phreatic level makes the use of handpumps problematical. Windpumps or small motor pumps are the preferred types of equipment. No use is made of groundwater for irrigation in view of the low yields. The only area in which irrigation is, in fact, taking place is on the farm Blackheath, located in South Africa some 25km downstream of the Bophuthatswana border and in the adjacent area of Botswana, where a total of some 300 ha has been developed for irrigation by centre-pivot in close proximity to the river channel. The Botswana development is under the control of the Commonwealth Development Corporation. Groundwater is reportedly being abstracted from 13 boreholes with a combined yield of some 130 litres per second; these boreholes tap an aquifer within a belt of rocks of the Ghaapplato Dolomite Formation, which crosses the channel of the Molopo River in this area. These dolomitic rocks contain high-yielding aquifers in the Morokweng and Mothibistad areas to the south, but because of limited recharge, these require careful management to ensure that the resources are not overexploited. It is not known whether the requisite studies have been carried out in the case of the Blackheath aquifer, but the extent of present or intended exploitation is such that delineation of the aquifer and quantification of the water balance should certainly be undertaken. Such a study should obviously include the contribution to recharge from river flow.

4.2.3 Groundwater Recharge

Recharge of the groundwater aquifers present in the western part of the Molopo District is from three possible sources: vertical infiltration of rainwater, slow horizontal seepage along buried valleys, and recharge in proximity to surface channels from episodic river flow. The relative contribution to regional groundwater

reserves from each of these sources is unknown, but research has shown that about 1 - 2% of rainfall (i.e. some 4 - 8 mm) infiltrates from surface to replenish local aquifers. The effects of recharge from occasional flow down channel of the Molopo river would probably be restricted to a zone extending to about 1km on either side of this channel. The average annual natural discharge of the Molopo River west of the Modimola dam site is of the order of 24 million m^3; at its confluence with the Molopo, some 80 km to the west, the Setlagole River contributes some 33 million m^3 annually, on average. The extent of recharge from this source depends on the downstream reach of each flow event and the frequency of events; no quantative estimates are available, *but the contribution to the overall regional water balance is probably very small. Along the valley of the Molopo River it may, however, be highly significant*. Since many of the villages in the western Molopo District and in Botswana are located in proximity to the river, the possible effects of variations in river recharge on rural water supply in this area cannot be ignored. Recharge from lateral seepage originates from areas of higher rainfall and, in some instances, from high-yielding dolomitic aquifers. *Migration rates are slow, averaging about one metre per year*, and contributions to the overall budget are likely to be small and localized.

4.2.4 Initial Impact Assessment

It is these meagre sources of replenishment which sustain the groundwater resources of the area, and, if demand is not to exceed supply, sound management practices must be applied. Reduction of recharge via any one of the mechanisms listed above is likely to have an adverse effect on the groundwater balance, either locally or regionally. Loss of recharge as a result of upstream impoundment of flow along the Molopo River is almost certain to have an adverse effect on the yields of boreholes *in proximity to the river channel*, although this may be slow to become apparent. Another possible adverse consequence is the migration, into the zone of exploitation and reduced recharge, of poorer quality groundwater.

4.2.5 Possible Mitigatory Measures

The adverse effects of reduction of the natural flow regime of the Molopo River between the Modimola dam site and the confluence of the Setlagole river *could be mitigated* by controlled discharge from the existing Disaneng Dam, located a few

kilometers below the Modimola site. We understand that, if the Modimola Dam is constructed, water from the Disaneng Dam will have very limited uses and would be available for this purpose. However, the relative advantages of this form of recharge, in comparison with the provision of surface water of assured amount and quality to the western part of the district through the construction of a pipeline alongside the river, needs to be investigated. Such a pipeline would traverse easy terrain and could supply water under gravity to a major part of the population of the western Molopo District as well as to adjacent areas of Botswana. In this comparison the high cost of drilling new boreholes through the Kalahari sediments, and the not inconsiderable ongoing cost of exploiting small and finite borehole yields from great depth, need to be considered.

The economic viability of such an alternative should be investigated.

4.3 Ecological Impacts

4.3.1 Introduction

Drinking water for Mmabatho is currently supplied from dolomitic groundwater compartments to the east of the city. Predictions are that the increase in demand will exceed the existing annual supply by 1995. The Bophuthatswana Department of Water Affairs is presently investigating possible options to ensure that an adequate supply of drinking water will be available in the future. The options currently under investigation would all impact on the structure and functioning of the Molopo River, especially the reach of river downstream of Disaneng Dam. This report describes a scoping study of the potential impacts on the aquatic environment and grazing potential of the riverine and river bed vegetation.

4.3.2 Methodology

For the impact identification phase (scoping), information on the potential impacts of altered flow scenarios on the Molopo River below Disaneng Dam was gathered using three methods:

- An aerial reconnaissance of the Molopo River was undertaken on 13 September 1993. The survey covered the stretch of river between Disaneng Dam and the small town of Bray, about 260 km further downstream. Characteristics of the river were identified and noted on a topographical map. A video recording was also made of some

of the important features of the river and was later studied in greater detail at the CSIR's offices.

- A search was carried out on the Waterlit national water research literature database for reports or scientific papers which referred to the Molopo River below Disaneng Dam. However, only references which could be found on the database referred to the Molopo River upstream of Mafikeng/Mmabatho.
- A number of publications and reports on the ecological flow requirements of rivers in the Kruger National Park (where most research on ecological flow requirements is currently focused) were consulted.

4.3.3 Description of the Molopo River below Disaneng Dam

A description of the water resources of the Molopo River catchment below Disaneng Dam is given in Section 4.1.

The Molopo River was classified into three categories using information gathered during the aerial reconnaissance of the river. The characteristics of the three categories are illustrated in **Figure 5**:

Class 1 These river reaches can be described as a wide, flat-bottomed sandy channel which is characteristic of many of the rivers of the region (Allanson *et al.*, 1990). The river bed appears to be vegetated with grass which may be an indication of a deep subsurface water table (or recent rains/surface runoff which is unlikely at the end of winter). Few signs of overgrazing were observed although different grazing densities could be inferred from the difference in veld colour on either side of the border fence running down the centre of the river. Class 1 was regarded as indicative of a relatively unimpacted river.

Class 2 The river bed is vegetated with grass but signs of degradation of the river channel were observed. Pools were observed in the river bed, most were dried up and signs of overgrazing were observed in the area around these pools. These pools may be the result of dykes or other geological formations forcing the ground water closer to the

surface. A single incised meandering river channel was observed in the upper reaches of the Mabula and Loporung dams. Class 2 was regarded as a river reach showing signs of degradation.

Class 3 The river bed (or macro channel) is characterized by multiple channels and vegetated gravel, sand and rock outcrops. The vegetated outcrops act as areas where sediment accumulate. Some signs of veld degradation, mainly bush encroachment and overgrazing were observed. These generally occurred in the reaches close to Disaneng Dam and the Setlagole confluence where floods or spates probably occur during the summer months.

The Molopo River below Disaneng Dam was classified as follows (**Figure 6**):

Disaneng Dam to confluence of the Ramatlabama River	Class 3
Ramatlabama confluence to Makgohistad	Class 3
Makgohistad to Loporung Dam	Class 3/Class 2
Loporung Dam to Logagane	Class 2
Logagane to Setlagole confluence	Class 3
Setlagole confluence to Mabule	Class 3
Mabule to RSA/Bophuthatswana border	Class 3/Class 2
RSA border to Molopo River border post	Class 1
Molopo River border post to farm Tennant	Class 1/Class 2
Farm Tennant to Bray	Class 1

These observations seem to indicate that the "condition" of the river improves in a downstream direction. The river reaches downstream of Disaneng Dam and downstream of the Setlagole confluence generally show the characteristics described in the Class 3 classification. This may be the result of short duration high flows in these reaches during summer months and over utilization of the river vegetation.

4.3.4 Potential Environmental Impacts on the Molopo River Below Disaneng Dam

The combined storage of Modimola and Disaneng dams will significantly reduce the frequency of floods down the Molopo River (see section 4.1 on surface runoff and Table 4). According to projections by EVN, the frequency at which spills would occur from Disaneng Dam will be reduced. Long periods, sometimes as long as 8 years, may go by without water spilling from Disaneng Dam. The impact of these reduced flows will probably be restricted to the Molopo River between Disaneng Dam and the Ramathlabama river and to a lesser extent to the confluence with the Setlagole River. The environmental impacts identified in this section refer mostly to this river reach.

It is believed that the construction of Modimola Dam will probably have a major impact on the riverine vegetation but a minor impact on the aquatic fauna.

Riverine vegetation - The multiple channel configuration and vegetated outcrops are probably the result of bush encroachment on the river below Disaneng Dam & the Setlagole confluence. The biotic component found in these areas are generally hardy (drought tolerant) vegetation which can utilize underground sources of water between spates. The projected reduction in the spills from Disaneng Dam will probably reduce the groundwater recharge of the river banks. It is expected that this could have a major negative impact on the riverine vegetation.

The reduction in flows from Disaneng Dam will probably reduce the recharge to the groundwater aquifer. The water demand of the riverine vegetation will also deplete the groundwater aquifer further. The reduction in spills will also reduce the moisture content of the river banks and in turn, reduce the vegetation cover. Such a reduction in vegetation cover will lead to increased erosion rates and general degradation of the river.

Aquatic Fauna - The aquatic fauna of rivers like the Molopo River is not strictly riverine fauna but consists mostly of hardy ephemeral opportunists. When surface flow takes place, flying invertebrate insects such as mayflies and dragonflies utilize

the opportunity to colonize streams and pools. The semi-permanent pools and dams in the river help to maintain some aquatic organisms although the species diversity is expected to be very limited. The aquatic fauna is generally adapted to the intermittent nature of flow in the river and has a variety of mechanisms to survive periods of drought (Allanson *et al.*, 1990). It is predicted that the salinity in Disaneng Dam would increase substantially due to evaporation and spills can be expected to have higher salinities than those currently observed. The organisms would probably be euryhaline, i.e. also adapted to wide fluctuations in water quality. The projected reduction in flow in the Molopo River below Disaneng Dam would probably have a minor impact on the aquatic fauna because they are opportunists.

In terms of larger species, the characteristics of the Molopo River are not conducive to maintaining a healthy fish population and large species diversity. Hardy fish like barbel can probably be found in the dams and pools which form in the river. These species are generally adapted to cope with wide fluctuations in flow and water quality so it is not expected that the status quo would change much.

4.3.5 Impact on Grazing Potential Below Disaneng Dam

In an area like that along the Molopo River, the riverine vegetation and riparian zone offers a resource of nutrients which are generally not available from the surrounding area. It also provides a source of nutrition to animals at a different time of the year which helps these animals to survive dry periods.

From the aerial survey the riparian zone appeared to be narrow and restricted to the banks of the river. The river bed in the Class 1 & 2 reaches appeared to be well vegetated. The areas of the river which are classified as Class 1 & 2, are about 2250 ha (about 150 km by 150m). This area is small compared to the size of some of the farms in the area. In fact, the riverine vegetation contributes no more than 5% of the surface area of farms, to which stock has access.

It should be noted that the border fence between the RSA and Botswana runs along the centre of the river giving farmers on both sides access to the river bed. The border fence between Bophuthatswana and Botswana is on the Bophuthatstwana river bank giving only Botswana farmers access to the river bed.

With the limited information available, it is difficult to determine the importance of vegetation on the river banks and in the river bed as a resource for feeding cattle and game. However, the projected reduction in spills and flows from Disaneng Dam will *probably have a negative impact on the riverine and river bed vegetation, comprising approximately 5% of the total* grazing resource in the reach between Disaneng Dam and the Setlagole River.

4.3.6 Subjects that Need Further Investigation

It is recommended that the following subjects be investigated further:

1. Where appropriate, the aerial observation should be confirmed with ground-truth data.
2. The riverine vegetation as resource for grazing should be investigated in further detail to establish the importance thereof in the regional fodder flow for stock.
3. The possibility of releasing water from Disaneng Dam to maintain the ecological health of the river should be evaluated while recognising the gravity of the water scarcity in the district.

4.3.7 Conclusions

With regard to the river reach between Disaneng Dam and the Setlagole River:

The projected reduction in flows downstream of Disaneng Dam will probably have:

- a major negative impact on the riverine and river bed vegetation, comprising ca5% of the grazing area riparian to the river,
- a minor negative impact on the aquatic fauna.

It is recommended that the present status, extent and significance to local ecosystems and human communities supported by the riverine and river bed vegetation, be investigated in greater detail.

4.3.8 References

Allanson, B.R., Hart, R.C., O'Keefe, J.H. and Robarts, R.D. (1990). Inland Waters of Southern Africa: An Ecological Perspective. Monographiae Biologicae, Vol 64. Kluwer Academic Publishers, Dordrecht. 458 pp.

4.4 SURVEY OF BOTSWANA COMMUNITIES DOWNSTREAM OF DISANENG DAM

Introduction

Settlement Planning Services were instructed by EVN Consulting Engineers to investigate, by way of a "pilot" survey in liaison with the Botswana Department of Water Affairs, the dependence on the Molopo River of the local communities downstream of Disaneng Dam. The purpose of the survey was to determine the physical status of the villages, to identify existing water infrastructure and its condition and to ascertain the attitudes and opinions of the local communities with regard to water supply.

This report is based on interviews and "windscreen" surveys conducted in the villages on the Botswana side of the Molopo River between Mokatako and Mabule (see cover map). The interviews, intended to obtain information on water usage and problems associated with water, were held with the Tribal Authority and members of the local communities.

The report begins with summaries outlining the findings, problems and concerns recorded in the respective villages, viz Mokatako, Phitshane, Loporung, Dikhukhung and Mabule. It concludes by highlighting the main findings of the survey, as well as the principal concerns of the communities with regard to water supply and usage.

The following is a summary, per village, of the main findings, comments and grievances recorded in the field. Population data is abstracted from the 1991 Census. Migrant dependance is estimated from spot surveys done on a seasonal basis.

Population: Stable - 914

Including Seasonal Migrants - 1223

4.4.1 Mokatako

a) Location and Physical Status

- The sparsely settled village of Mokatako is situated on the eastern edge of the "study area", near the confluence of the Ramatlabama and Molopo Rivers.

b) Current Status of Water Supply

- The village has 1 borehole which supplies the community with water, via 6 standpipes, for domestic purposes. The borehole is not coping with the present demand as it tends to dry up during dry periods.

- To alleviate the water shortage problem, the Botswana Department of Water Affairs is constructing a water supply pipeline from Phitshane (in the west) to the village, and will install an extra 4 standpipes within the village. The pipeline, which is approximately 0,5km from the village, is almost complete.

- The water consumption per household in the village is estimated to be approximately 200l per day (approximately 25l per person).

- Due to the drying up of the Molopo River course following the completion of Disaneng Dam and the resultant drop in the water table, open wells along the river, previously used to the watering of cattle, have dried up. Cattle now need to be taken to cattle-pens to be watered and fed.

c) Opinions and Attitudes of Community

- The village has suffered a shortage of water since the construction of the Disaneng Dam, with the Molopo River last having any "trickle" of water in December 1992.

- Future water demands are expected to increase due to the return of disillusioned people, who left the villages in search of work, from the cities. The return of these people to the villages is presumably due to reasons

rather than economic reasons.

- A community, which is dependent on the limited overflow from the Disaneng Dam, is understandably very concerned as to what will happen once the Modimola Dam is constructed.

4.4.2 Phitshane

Population: Stable - 672
Including Seasonal Migration - 940

a) Location and Physical Status

- The village of Phitshane is situated approximately 12 km west of Mokatako and is the second largest village visited after Mabule. The settlement pattern while dispersed, is more concentrated than Mokatako.

b) Current Status of Water Supply

- The village has 4 operating boreholes, only 1 of which has a sustained yield and is therefore the main source of supply for the village. It is also intended that this particular borehole will supply the water for the new pipeline (mentioned in 2.1), feeding the village of Mokatako.

- There are 2 header tanks and 25 standpipes within the village.

- The water consumption per household in the village is estimated to be approximately 200l per day (approximately 25l per person).

- The river bed is used for grazing purposes in the rainy months. The cattle are forced to leave the area in search of water in the dry months.

- There are two communal gardens in the village. These are not productive as there is not enough water for both domestic and gardening purposes.

- All open wells, previously used for the watering of cattle, have dried up. As a result cattle are either taken to a syndicate borehole further away from the river, or to a private borehole where the water has to be payed for.

c) Opinions and Attitudes of Community

- The community believes that the construction of the Disaneng Dam has caused the drastic shortage of water in the village.

- The community sees the Molopo River as a "Common Dish" from which both the Botswana and Bophuthatswana people should benefit, but the local concern is that with the proposed construction of the Modimola Dam, this will probably never be the case.

- Future water demands are also expected to increase due to people returning from the cities, (for the same reasons as mentioned in 2.1).

4.4.3 Loporung

Population: Stable - 558
Including Seasonal Migration - 781

a) Location and Physical Status

- Loporung is situated approximately 15 km west of Phitshane. This is one of the smaller villages surveyed and also has a dispersed settlement pattern.

b) Current Status of Water Supply

- The village has 1 borehole supplying water for domestic purposes via 5 standpipes (see photograph B). There is also a small existing dam, but its water level is very low at the moment as it depends on the limited overflow from the Disaneng Dam.

- Water consumption per household is estimated at approximately 200l per day (approximately 25l per person).

- Open wells (see photograph A), which are used for the watering of cattle, are dry or drying up, with only the wells next to the dam still yielding any water. With a result, large amounts of stock have been lost due to the lower carrying capacity ofthe land.

- The river bed is used for grazing purposes, especially in the early raining season, as the cattle get fatter a lot faster than usual.

- There is a vegetable garden at the Primary School as well as a co-operative garden, within the village, but not much irrigation is taking place due to water shortages.

c) Opinions and Attitudes of Community

- According to the community water availability has decreased drastically since the construction of Disaneng Dam. It is therefore a concern of the community that if Modimola Dam is constructed not only their village, but all villages along the river, will be subject to further water shortages.

- In the opinion of the community, if no water is released from Disaneng Dam to replenish their dam, future development will be extremely difficult and the well-being and livelihood of the community will be threatened.

4.4.4 Dikhukhung

Population: Stable - 340
Including Seasonal Migration - 476

a) Location and Physical Status

- The village of Dikhukhung, which is the smallest of the villages visited, is approximately 11 km west of Loporung.

b) Current Status of Water Supply

- There is 1 main borehole supplying water to 7 standpipes within the village.

- Open wells, used for the watering of cattle, are being dug ever deeper and still very little water is being found. This has also proved to be very dangerous, as the wells tend to collapse and lives have been lost in their excavation.

- There are very few private boreholes nearby and the community needs permission and money to obtain water from them. This, together with the fact that the open wells are drying up, has resulted in a great reduction in the quantity of cattle kept by the community.

- Like the previous villages the river bed is used for grazing purposes during early rains.

- The village used to have 3 small plots, each approximately 1 Ha in extent, for gardening purposes, but these have been discontinued as there is not enough water.

c) Opinions and Attitudes of Community

- It is the opinion of the community that since the construction of the Disaneng Dam water has become scarcer and scarcer, with open wells and the main course of the river drying up.

- The community believes that if the Modimola Dam is constructed the water problems and shortages, presently being experienced, will multiply.

4.4.5 Mabule

Population: Stable - 798

Including Seasonal Migration - 1492

a) Location and Physical Status

- This is the largest of the villages visited and is situated on the western border of the "study area", downstream of the confluence of the Setlagola and Molopo Rivers. While dispersed the settlement is focused on a village centre which is the seat of the tribal authority.

b) Current Status of Water Supply

- The village has 1 borehole which supplies water for domestic purposes, as well as having 2 syndicate boreholes further inland for the watering of cattle. There are 15 public standpipes as well as private yard connections at the teachers housing, clinic and tribal office.

- There is a large dam, constructed in 1959, which at capacity can supply water for approximately 5 years (see photographs C & D). No water has been fed into the dam from the Molopo River for many years, the main water volume coming from the Setlagola River.

- There are no permanent open wells, but in the dry season, due to the 2 syndicate boreholes drying up, wells are dug in the river bed near the dam, to water the cattle.

- Cattle use the river bed for grazing purposes all year round.

- There are 4 vegetable gardens in the village each with its own pump, headertank and sprinkler system.

c) Opinions and Attitudes of the Community

- It is the opinion of the community that the construction of the Disaneng Dam has caused the Molopo River to stop flowing, resulting in the village having to rely on local rains and the Setlagola River to replenish the dams water supply. The failure of such rains to fall will therefore result in the dam eventually drying up.

4.4.6 Conclusion

All the villages surveyed have a traditional subsistence farming base which supports a fairly stable rural population. With no commercial or industrial economic base very few people are attracted to the villages. The main increases in population is therefore due to people returning from the cities - more for traditional rather than economic reasons - and natural population growth. No large influx of people is expected and population numbers will in all probability remain stable.

Water supply is a major problem. All villages surveyed have at least one borehole to supply water for domestic purposes, but these tend to be operating at their limit. Open wells, used for the watering of cattle, are dry or drying up, while the Molopo River course itself is dry. Foodlots and vegetable gardens are not as productive (if at all) as before, while stock numbers have been reduced quite considerably due to the lack of water.

The popular opinion among the communities is that the construction of the Disaneng Dam has contributed to, if not caused, the drying up of the Molopo River course and this has subsequently resulted in a range of problems, namely:

- The drying up of dams, open wells and boreholes;
- A drop in the water table;
- The loss of valuable grazing land around the river.

These have in turn resulted in:

- The loss of livestock;
- The closure of foodlots and vegetable gardens;
- A reduced well-being of the affected communities.

With the construction of the Modimola Dam the overwhelming concern is that the problems presently being experienced will multiply, and unless some sort of an agreement is reached, whereby all can benefit from the construction of the dam, the future of the villages along the Molopo River, in the opinion of the local communities, looks unpromising.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 No major environmental impact on the river reach downstream of Disaneng Dam could be identified in the course of this study.

5.2 Localised impacts of a minor nature should be studied further, viz:

- Groundwater recharge from surface flow in the river reach from Disaneng Dam to Makgobistad.
- Relative importance of riverine vegetation in the fodder balance of stock under extensive grazing conditions in the river reach between the Disaneng Dam and the Setlagoli River confluence.

APPENDIX A

TABLES

Disaneng Dam Runoff.

TABLE 1

	OCT.	NOV.	DEC.	JAN.	FEB.	MRCH.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	TOTALS
1924	0	0,4	5,44	3,01	0,78	19,76	9,08	1,4	0,18	0	0	0	40,05
1925	0	0,14	0,05	0,55	0,18	0	0	0	0	0	0	0	0,92
1926	0,16	0,05	1,27	0,61	0,12	1,67	0,55	0	0	0	0	0	4,43
1927	0,94	0,31	0,92	32,74	12,4	1,71	0,39	0	0	0	0	0	49,41
1928	0,05	9,45	3,15	0,56	0,19	0,14	0,05	0	0	0	0	0	13,59
1929	0	0,27	1,82	1,28	0,55	1,92	0,61	0	0	0	0	0	6,45
1930	0	0	0,17	1,09	0,45	0,04	0,15	0,05	0	0	0	0	1,95
1931	0	0,63	0,51	0,1	0,49	1,22	0,38	0,01	0	0	0	0	3,34
1932	0	0,01	3,28	1,24	0,05	0	0	0	0	0	0	0	4,58
1933	0	4,31	9,31	22,66	7,24	0,29	0,03	0,02	0,01	0	0	0	43,87
1934	0,21	2,33	1,49	0,35	0,49	3,22	1,02	0	0	0	0	0	9,11
1935	0	0,04	0,69	1,8	6,19	7,34	1,82	0,24	0,08	0	0	0	18,2
1936	0	6,38	2,31	9,91	3,54	0,08	0	0	0	0	0	0	22,22
1937	0	0	3,63	1,53	0,25	0,05	0,11	0,04	0	0	0	0	5,61
1938	0,04	0,02	1,22	2,21	5,11	2,65	0,38	0	0	0	0	0	11,63
1939	0	0,35	0,93	0,98	0,36	13,5	4,48	0	0	0	0	0,15	20,75
1940	0,05	0	12,92	5,24	0,46	0,05	0	0	0	0	0	0	18,72
1941	0,02	0,01	0,9	3,33	1,2	3,64	1,19	0	0	0	0	0	10,29
1942	0,7	0,23	13,49	5,29	0,33	1,41	3,55	1,03	0	0	0	0,19	26,22
1943	2,65	1,53	0,58	1,8	32,15	10,53	0	0	1,65	0,55	0	0,03	51,47
1944	0,09	0,35	0,11	0	0,01	25,28	8,42	0	0	0	0	0	34,26
1945	0	0	0	5,85	4,3	6,48	1,9	0	0	0	0	0	18,53
1946	0,05	0,02	0,63	1,12	0,31	6,81	2,27	0	0	0	0	0	11,21
1947	0	0	2,29	5,56	1,63	2,48	1,33	0,17	0	0	0	0	13,46
1948	0	0,32	0,11	2,32	0,77	0,15	0,05	0	0	0	0	0	3,72
1949	0	0	8,69	3,07	0,06	4,16	1,66	0,14	0,02	0	0	0	17,8
1950	0,01	0	1,75	0,87	0,23	0,19	3,58	1,19	0,01	0	0	0	7,83
1951	0,2	0,07	0,06	0,56	2,44	0,87	0,04	0	0	0	0	0	4,24
1952	0,03	0,4	0,36	0,08	1,61	1,08	0,22	0,01	0	0	0	0	3,79
1953	0	0,77	1,25	2,02	0,72	0,86	0,43	0,05	0	0	0	0	6,1
1954	0	0,09	0,4	3,6	10,72	3,39	0,07	0	0	0	0	0	18,27
1955	0,15	0,19	3,48	1,15	13,44	5,08	0,2	0,04	0,01	0	0	0	23,74
1956	0,47	0,26	2,19	0,97	1,53	1,38	0,3	0	0	0	0	0,19	7,29
1957	0,75	0,38	0,44	2,84	1,75	1,04	0,27	0,01	0	0	0	0	7,48
1958	0	0,99	0,83	0,93	0,3	0,02	0,26	0,09	0	0	0	0	3,42
1959	0	0,13	3,39	1,13	0,25	0,15	0,07	0,02	0	0	0	0	5,14
1960	0	0,32	7,85	2,58	1,83	4,69	2,41	0,36	0	0	0	0	20,04
1961	0	1,06	0,36	0,21	1,1	0,51	0,63	0,19	0	0	0	0	4,06
1962	0	2,12	0,89	2,65	0,89	0,01	0,03	0,01	0	0	0	0	6,6
1963	0,02	2,46	0,86	0,45	0,25	0,04	0	0	0	0	0	0	4,08
1964	0,03	0,07	1,47	1,56	0,36	0	0,03	0,01	0	0	0	0	3,53
1965	0	0	0	2,04	10,67	3,33	0	0	0	0	0	0	16,04
1966	0	0,01	0,14	81,23	30,02	3,08	18,11	5,8	0	0	0	0	138,39
1967	0	0,03	0,14	0,56	0,29	5,04	2,28	0,21	0	0	0	0	8,55
1968	0	0,14	0,95	0,39	0,14	0,96	1,34	0,34	0	0	0	0	4,26
1969	0,16	0,05	1,53	1,19	1,52	0,43	0	0	0	0	0	0	4,88
1970	0	0	1,93	10,12	3,21	0,02	0,93	0,31	0	0	0	0	16,52
1971	0	1,33	0,72	39,87	13,41	1,07	0,35	0	0	0	0	0	56,75
1972	0	0,12	0,04	0,73	0,42	0,64	0,41	0,07	0	0	0	0,24	2,67
1973	0,08	1	0,49	7,51	3,31	0,61	1,18	0,36	0	0	0	0	14,54
1974	0	1,62	2,77	15,97	8,39	5,96	3,86	0,75	0	0	0	0	39,32
1975	0	0,23	2,84	48,34	17,64	9,91	3,36	0,09	0	0	0	0	82,41
1976	0,17	0,57	2,98	7,88	2,94	5,68	1,83	0	0	0	0	0,04	22,09
1977	0,02	0,11	2,05	6,71	4,07	2,31	0,61	0,02	0	0	0	0	15,9
1978	0,01	0	0,05	5,68	1,89	0	0,07	0,02	0	0	0,02	0,01	7,75
1979	0,35	0,96	0,54	4,29	3,09	0,58	0	0	0	0	0	0	9,81
1980	0	4,05	2,06	15,97	6,04	0,54	0,09	0	0	0	0	0	28,75
1981	0,03	0,04	0,99	2,04	0,57	0,36	2,41	0,76	0	0	0	0	7,2
1982	1,24	0,44	0,6	0,49	0,1	0,01	0	0	0	0	0	0	2,88
1983	0,12	0,13	0,88	0,28	0	0,11	0,04	0	0	0	0	0	1,56
1984	0,07	0,02	0,02	0,84	0,36	0,04	0	0	0	0	0	0	1,35
1985	0,25	0,08	0,44	0,81	0,45	0,1	0,01	0	0	0	0	0	2,14
1986	0,01	0,22	0,65	1,15	0,5	0,53	0,16	0	0	0	0	0,01	3,23
1987	0,02	0,11	0,63	0,45	6,69	3,44	0,43	0,01	0	0	0	0	11,78
1988	0,25	0,12	0,42	1,06	21,63	7,24	0,16	0,04	0	0	0	0	30,92
1989	0	0,55	1,29	0,4	0,71	0,7	1,27	0,37	0	0	0	0	5,29
1990	0,01	0	0,07	20,4	7,32	1,8	0,54	0	0,02	0,01	0	0,02	30,19
1991	0,01	0	0,02	0,06	0,02	0	0	0	0	0	0	0	0,11

TABLE 1A

MMABATHO BULK WATER SUPPLY.

YEAR	Status Quo. 200ha irrig Disaneng Only	DISANENG 50ha MBWS8.5	MODIMOLA SPILLAGE	MODIMOLA/DIS Present Disaneng	SPILLA Lowere Disaneng
1923					
1924	2.41E+07	1.96E+07	1.14E+07	1.02E+07	1.80E+07
1925					
1926					
1927	3.52E+07	2.13E+07	1.13E+07	1.22E+07	1.99E+07
1928	7.46E+06	2.26E+06			1.66E+06
1929					
1930					
1931					
1932					
1933	2.77E+07	1.71E+07	8.03E+06	4.29E+06	1.49E+07
1934	6.05E+05				
1935	9.82E+06				2.15E+06
1936	1.58E+07	9.21E+06	1.16E+06		4.87E+06
1937					
1938	1.84E+06				7.84E+04
1939	1.27E+07				2.91E+06
1940	1.24E+07	6.29E+06			2.92E+06
1941	1.55E+06				3.72E+04
1942	1.72E+07	5.79E+06			3.97E+06
1943	4.20E+07	3.67E+07	2.52E+07	3.03E+07	3.57E+07
1944	2.77E+07	2.11E+07	1.38E+07	1.74E+07	2.06E+07
1945	1.03E+07	4.15E+06	6.64E+05	1.36E+05	2.39E+06
1946	3.41E+06				5.53E+05
1947	5.06E+06				9.19E+05
1948					
1949	6.64E+06				1.13E+06
1950	-5.6E+04				
1951					
1952					
1953					
1954	6.07E+06				1.05E+06
1955	1.58E+07	3.88E+06			3.70E+06
1956					
1957	-1.7E+05				
1958					
1959					
1960	6.67E+06				1.11E+06
1961					
1962					
1963					
1964					
1965	1.86E+06				1.26E+05
1966	1.29E+08	1.15E+08	9.26E+07	1.01E+08	1.15E+08
1967	1.31E+06				5.50E+04
1968					
1969					
1970	4.57E+06				6.89E+05
1971	4.92E+07	3.45E+07	2.06E+07	2.36E+07	3.28E+07
1972					
1973	2.15E+06				9.37E+04
1974	3.06E+07	1.65E+07	6.64E+06	6.60E+06	1.40E+07
1975	7.45E+07	6.81E+07	5.07E+07	6.61E+07	6.94E+07
1976	1.39E+07	7.24E+06	3.31E+06	3.41E+06	6.48E+06
1977	7.69E+06	1.87E+06			1.59E+06
1978	1.11E+06				1.93E+04
1979	1.70E+06				1.94E+05
1980	2.07E+07	7.93E+06	2.18E+05		5.24E+06
1981					
1982					
1983					
1984					
1985					
1986					
1987					
1988	1.60E+07	6.30E+06			4.43E+06
1989					
1990	2.01E+07	8.45E+06	1.64E+06		6.53E+06
1991					
1992					
1993					
Annua Mean	9.36E+06	6.33E+06	3.49E+06	4.05E+06	5.83E+06

TABLE 3

MOLOPO RIVER DOWNSTREAM OF DISANENG DAM: COMPOSITION OF DEMAND.
(COMPARISON BETWEEN 1993 OF 2013 DEMAND AND 10% GROUNDWATER REPLENISHMENT

					Migratory Dependant Population Estimate(Setplan 1993) + 40% Dependant Population Estimate (Setplan 1993)			Stock Grazing Rate = Stock daily water Consumption = Population Annual Growth Rate =					2,00%	0.05 0%		kl 0%		
Bophuthatswana Demand Centre	Botswana Demand Centre	RSA Demand Centre	RIVER Distance Centre		Bophuthatswana 1993 Primary Water Demand	Botswana Est. Imgation Water Demand	Botswana Est. 1993 Primary Water Demand EVN Estimate	Botswana 1993 Primary Water Demand SETPLAN'93 SURVERY	RSA Imgation Water Demand	All Stock Water Demand	TOTAL DEMAND Setplan'93 Estimate	(EVNDIENSTE) Total 1993DEMAND	Bophuthatswana 2013 Primary Water Demand EVNestimate	Bophuthatswana 2013 Primary Water Demand		RSA Imgation Water Demand	2013 Stock Water Dem	2013 TOTAL DEMAND EVNestimate
			kl/day	ld/day	ld/day		ld/day			ld/day	Mm^3/annum	Mm^3/annum	ld/day	ld/day	SETPLAN'93 SURVEY ld/day		ld/day	Mm^3/ann
DISANENG DAM			0									0						
VILLAGE	MOKATAKO		4		567		170.1	31.99			8	0.22	0.27	843	170.1	32		8	0.37
RAM CONFLUENCE			13								18	0.01	0.01			0		18	0.01
MAKGOBISTAD	PHITSANE		25		160			23.52			24	0.08	0.07	282		24		24	0.11
LOPORUNG	LOPORUNG		38		42			19.53			26	0.03	0.02	65		20		26	0.03
			42								8	0.00	0.00			0		8	0.00
	S10H		40				4				8	0.00	0.00		4	0		8	0.00
LOGAGANE	DIKHUKHUNG		50		27			11.9			8	0.02	0.01	42	0	12		8	0.02
MAKGORI	S20H		59		29		5				18	0.02	0.02	45	8	0		18	0.03
TSHIDILAMOLOMO	S20H		72		36		24				26	0.02	0.03	53	24	0		26	0.04
SETLAGOLI			79		28						14	0.02	0.02	40	0	0		14	0.02
MABULE	S100H		88		60		40	27.93			18	0.04	0.04	57	40	25		18	0.05
BOPHUT/RSA			96								18	0.01	0.01			0		16	0.01
			114								36	0.01	0.01			0		36	0.01
	IRRIGATION	IRRIGATION	130			2466			9397		32	4.34	4.54		2466	0	9397	32	4.34
			161								62	0.02	0.02			0		62	0.02
																0			

TABLE 3

ANNUAL RUNOFF PAST DISANENG DAM SITE.

Million m^3

YEAR	Status Quo. 200ha irrig Disaneng Only	MMABATHO BULK WATER SUPPLY. DISANENG 60ha MBWS6.5	MODIMOLA SPILLAGE	MODIMOLA/DIS Present Disaneng	SPILLAGE Lowered Disaneng
1923					
1924	2.41E+07	1.98E+07	1.14E+07	1.02E+07	1.60E+07
1925					
1926					
1927	3.82E+07	2.13E+07	1.13E+07	1.22E+07	1.99E+07
1928	7.48E+06	2.26E+06			1.88E+06
1929					
1930					
1931					
1932					
1933	2.77E+07	1.71E+07	9.03E+06	4.29E+06	1.49E+07
1934	6.03E+06				2.15E+06
1935	9.82E+06				4.87E+06
1936	1.58E+07	9.21E+06	1.16E+06		
1937					7.84E+04
1938	1.04E+06				2.91E+06
1939	1.27E+07				2.92E+06
1940	1.24E+07	6.29E+06			3.72E+04
1941	1.55E+06				3.97E+06
1942	1.72E+07	5.76E+06			3.57E+07
1943	4.20E+07	3.67E+07	2.52E+07	3.03E+07	2.06E+07
1944	2.77E+07	2.11E+07	1.38E+07	1.74E+07	2.99E+06
1945	1.03E+07	4.16E+06	6.94E+05	1.38E+06	5.53E+05
1946	3.41E+06				9.19E+05
1947	5.03E+06				
1948					1.19E+06
1949	6.94E+06				
1950	-5.6E+04				
1951					
1952					
1953					1.05E+06
1954	6.07E+06				3.70E+06
1955	1.58E+07	3.88E+06			
1956					
1957	-1.7E+05				
1958					
1959					1.11E+06
1960	6.07E+06				
1961					
1962					
1963					
1964					1.26E+05
1965	1.65E+06				1.15E+06
1966	1.29E+06	1.15E+06	8.26E+07	1.01E+06	5.50E+04
1967	1.31E+06				
1968					
1969					6.69E+05
1970	4.57E+06				3.26E+07
1971	4.82E+07	3.45E+07	2.08E+07	2.39E+07	
1972					9.97E+04
1973	2.15E+06				1.40E+07
1974	3.08E+07	1.65E+07	6.64E+06	5.60E+06	6.94E+07
1975	7.46E+07	6.81E+07	5.07E+07	6.81E+07	6.48E+06
1976	1.38E+07	7.24E+06	3.31E+06	3.41E+06	1.59E+06
1977	7.66E+06	1.87E+06			1.93E+04
1978	1.11E+06				1.94E+05
1979	1.70E+06				5.24E+06
1980	2.07E+07	7.93E+06	2.16E+06		
1981					
1982					
1983					
1984					
1985					
1986					
1987					4.43E+06
1988	1.60E+07	6.30E+06			
1989					5.53E+06
1990	2.01E+07	9.45E+06	1.84E+06		
1991					
1992					
1993					
Annus Mean	9.36E+06	6.33E+06	3.49E+06	4.05E+06	5.83E+06

modimdel.wq!

TABLE 5 : LAND USE SUMMARY

	MOKATAKO	PHITSANE	LOPORUNG	DIKHUKUNG	MABULE
PRIMARY SCHOOL	1	1	1	1	1
SECONDARY SCHOOL		1			1
CRECHE	2	4	2	1	1
CLINIC	1	1	1	1	1
CHURCH	3	7	1	5	6
BAR/BEER HALL	1	4	1	1	
SHOP/CAFE/GENERAL DEALER	3	9	2	4	5
POST OFFICE		1			1
POLICE STATION		1			
LOCAL POLICE	1		1		1
SERVICE STATION		1			
BUTCHER			1		4
CO-OPERATIVE					2
AGRI-HOUSE				1	

APPENDIX B

FIGURES

No	DAT.	WYSIGINGS / REVISIONS	GETEKEN DRAWN	GOEDGEKEUR APPROVED

MODIMOLA DAM IMPACT ASSESSMENT:

DISANENG DAM TO BRAY DEMAND CENTRES

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MAFIKENG
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MAFIKENG

VEL NR
SHEET NO

FIG 1.

MOLOPO RIVER DOWNSTREAM OF DISANENG.

SPILLAGE vs NATURAL STATE.

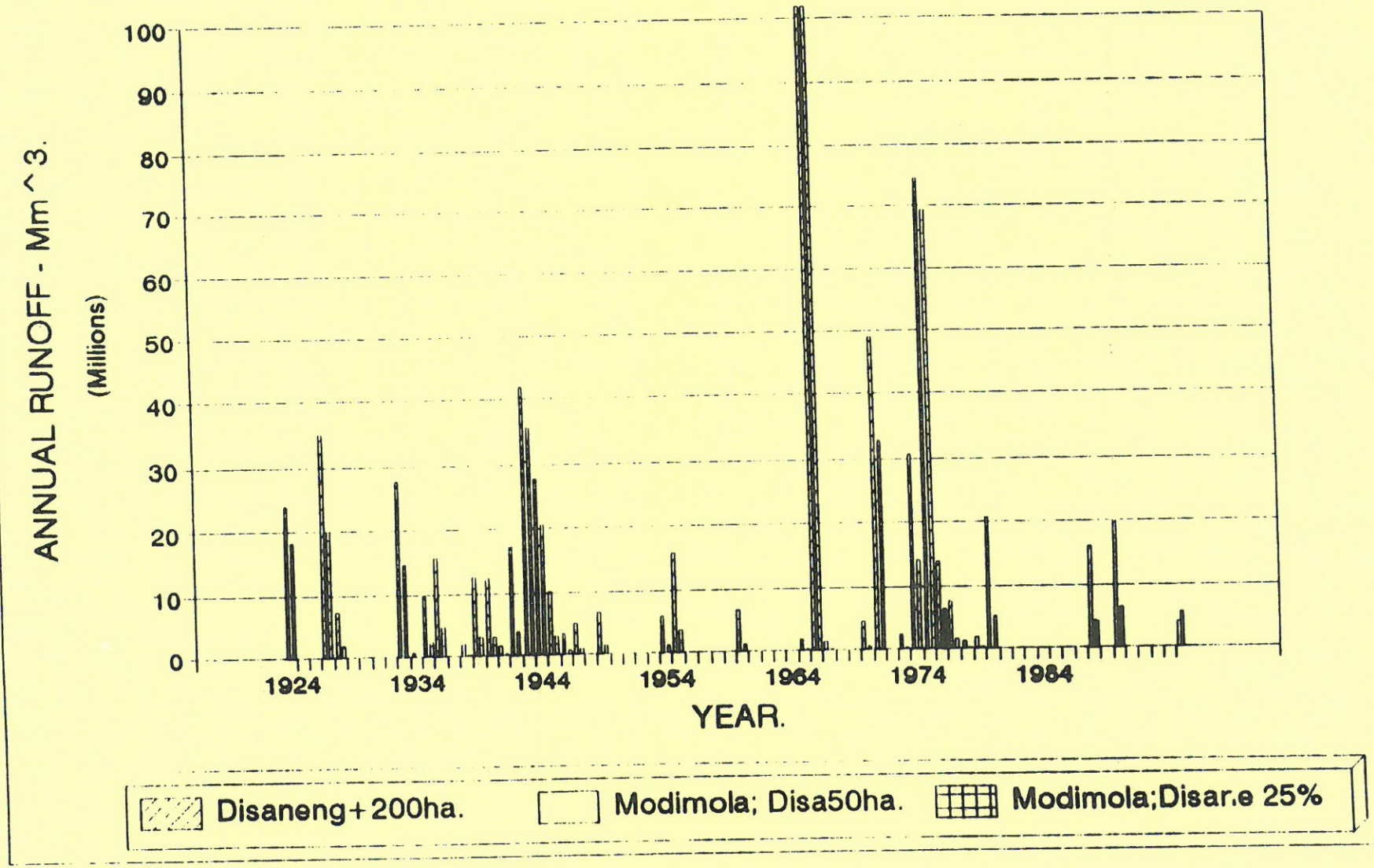

FIGURE 2

MOLOPO RIVER D/S OF DISANENG DAM.

WATER DEMAND.

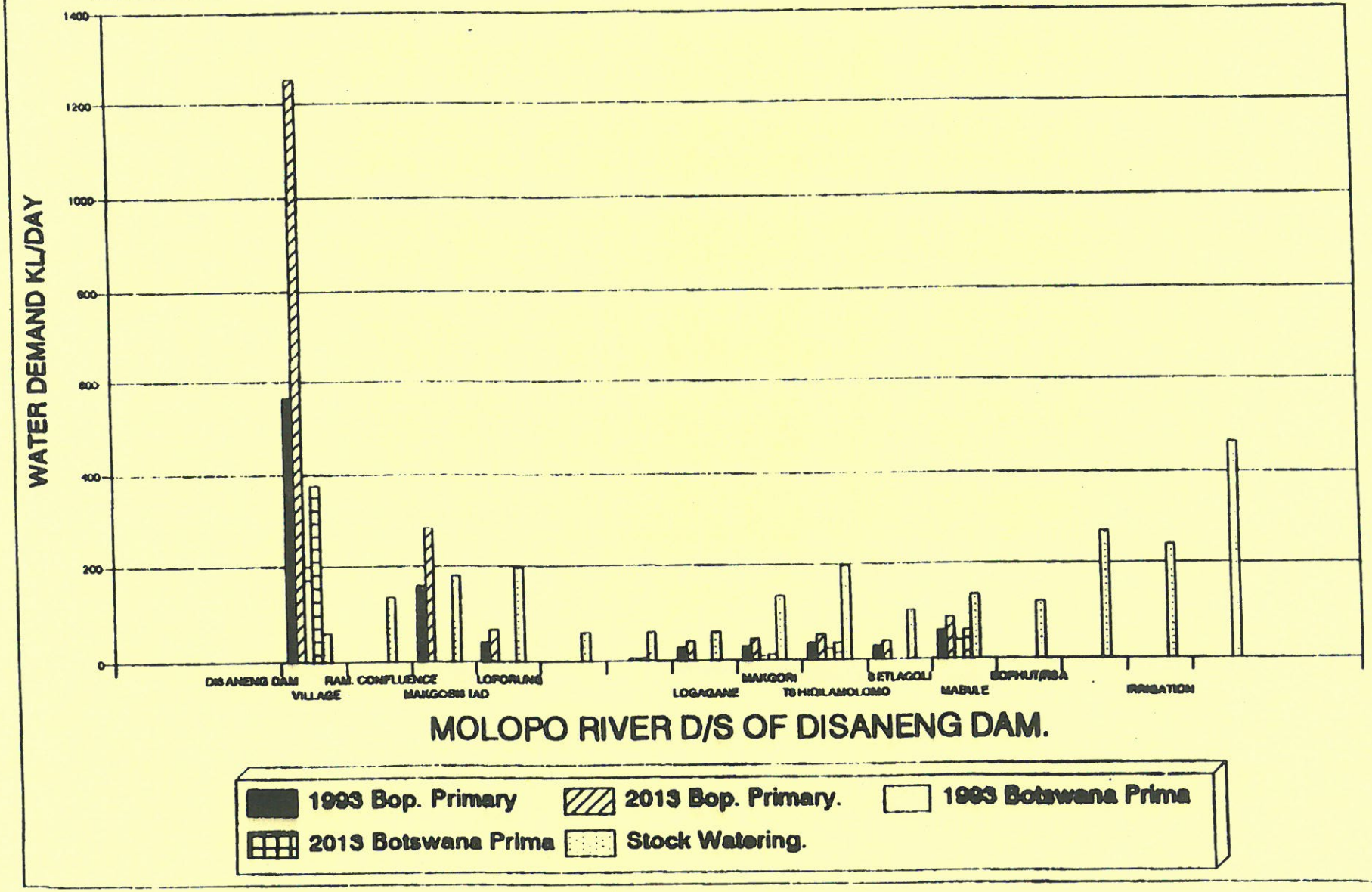

FIGURE 3

MOLOPO RIVER D/S OF DISANENG DAM.

CUMULATIVE WATER DEMAND vs 10%RECHARGE

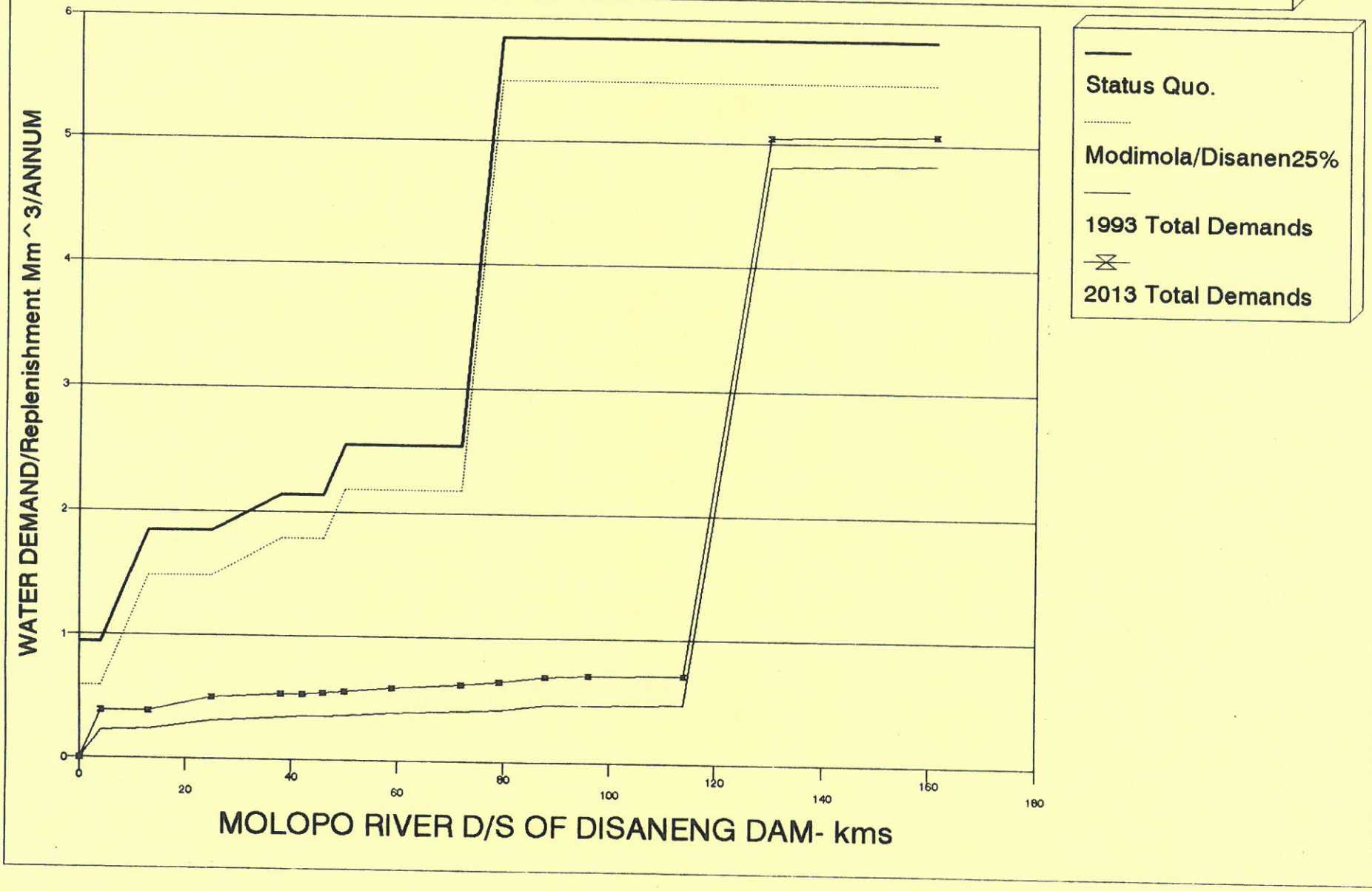

FIGURE 4

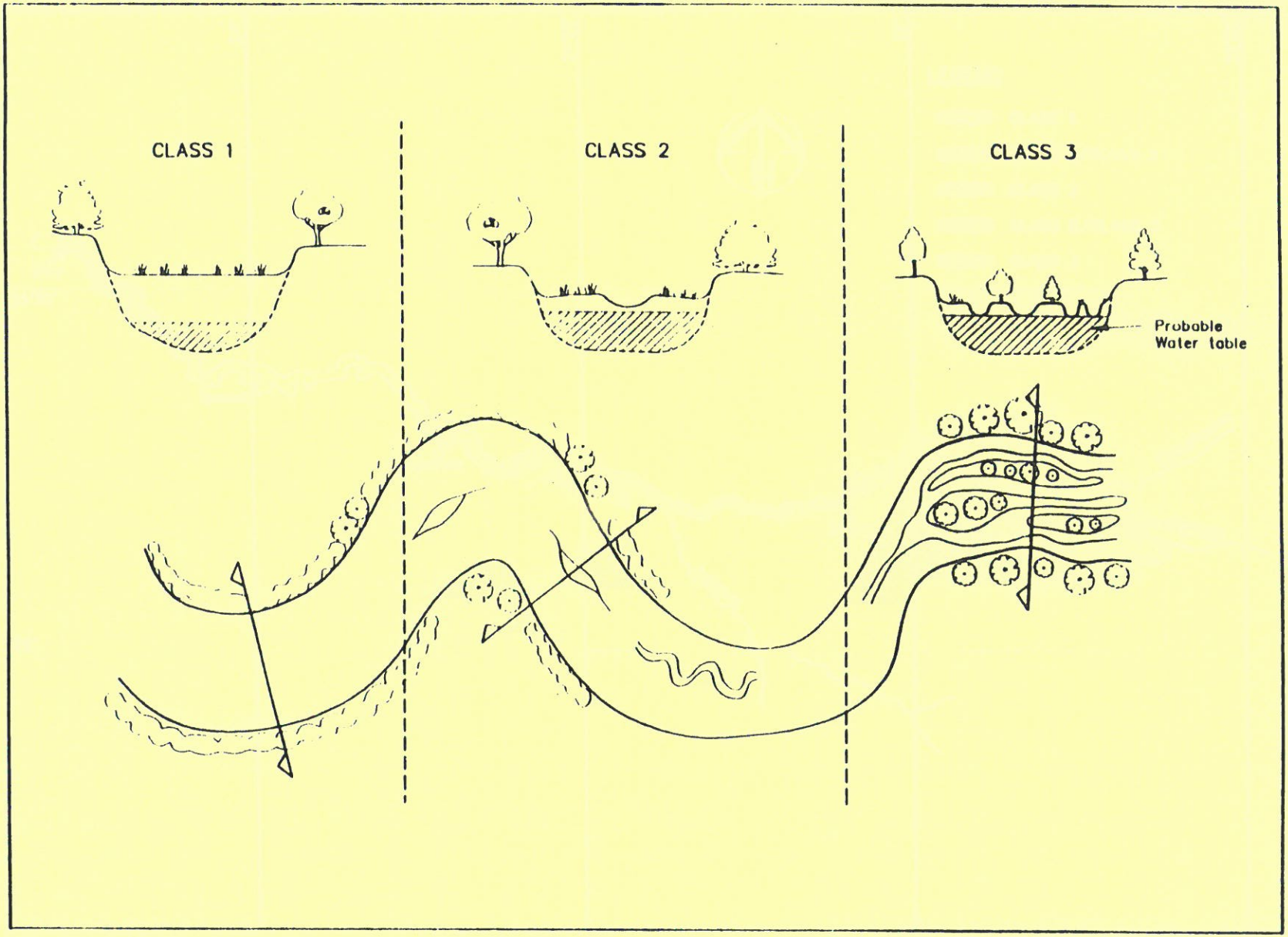

FIGURE 5 Schematic diagram of the three categories of the used to classify the condition of the Molopo River below Disaneng Dam.

FIGURE 5

DISANENG DAM RUNOFF.

FREQUENCY OF EXTREME DROUGHT PERIODS.

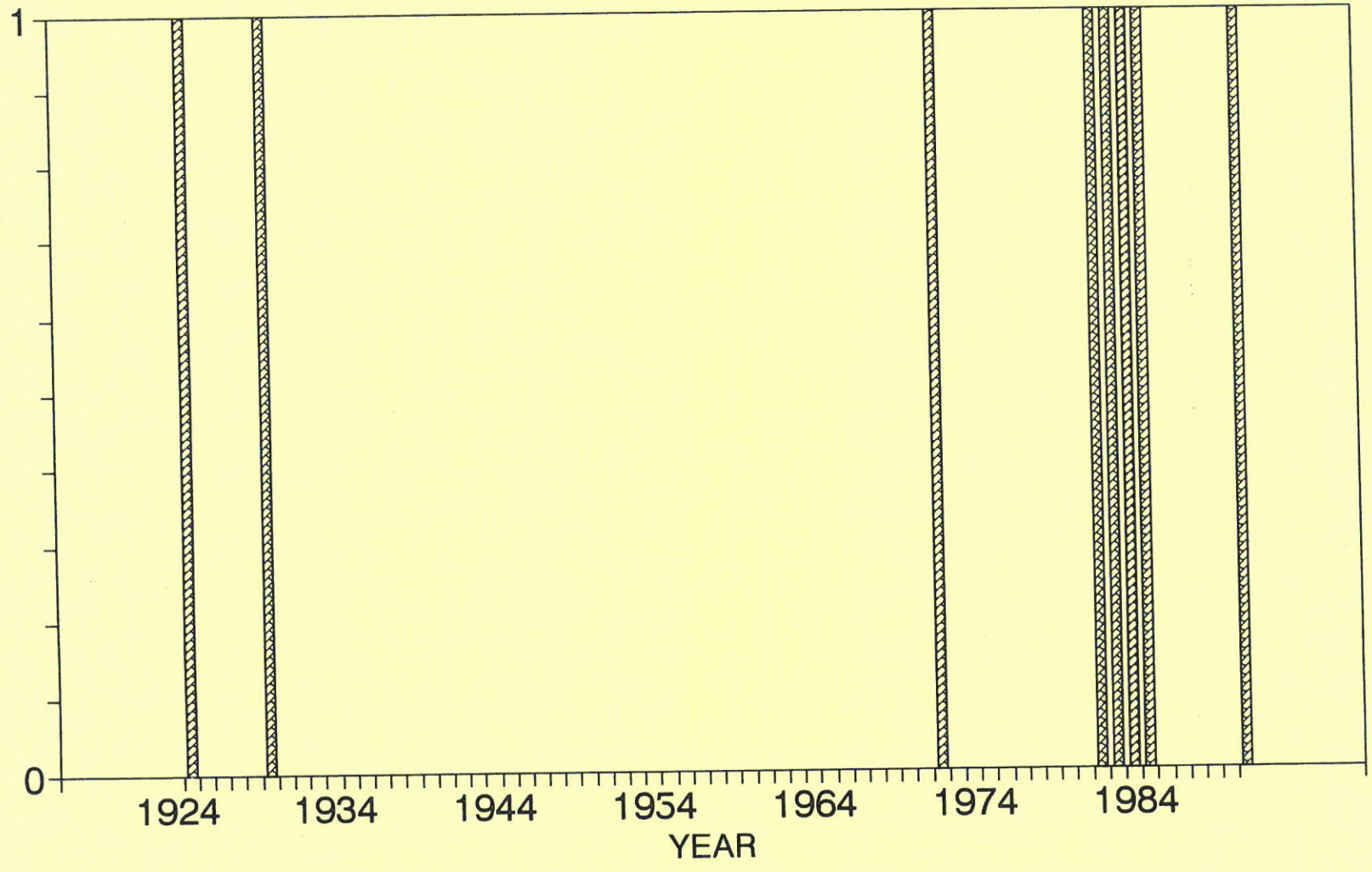

FIGURE 7

EVN PROJECTS MANAGEMENT
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2.2.(456)(2)

PROPOSED MODIMOLA DAM
PRELIMINARY INVESTIGATION INTO THE ENVIRONMENTAL IMPACTS DOWNSTREAM OF THE EXISTING DISANENG DAM

SEPTEMBER 1994

EVN CONSULTING ENGINEERS (RSA) (PTY) LTD
Consulting Civil, Structural, Agricultural & Project Managers
P O Box 373 : 9 Tillard Street : MAFIKENG
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PROJECT NO 9066

Project Engineer: S Southwood (Pr Eng)

PROPOSED MODIMOLA DAM : PRELIMINARY INVESTIGATION INTO THE ENVIRONMENTAL IMPACTS DOWNSTREAM OF THE EXISTING DISANENG DAM

SECTION A - REPORT

SECTION B - ADDENDUM

SECTION A

REPORT

1. INTRODUCTION

1.1 Augmentation of Water Supply to Mmabatho

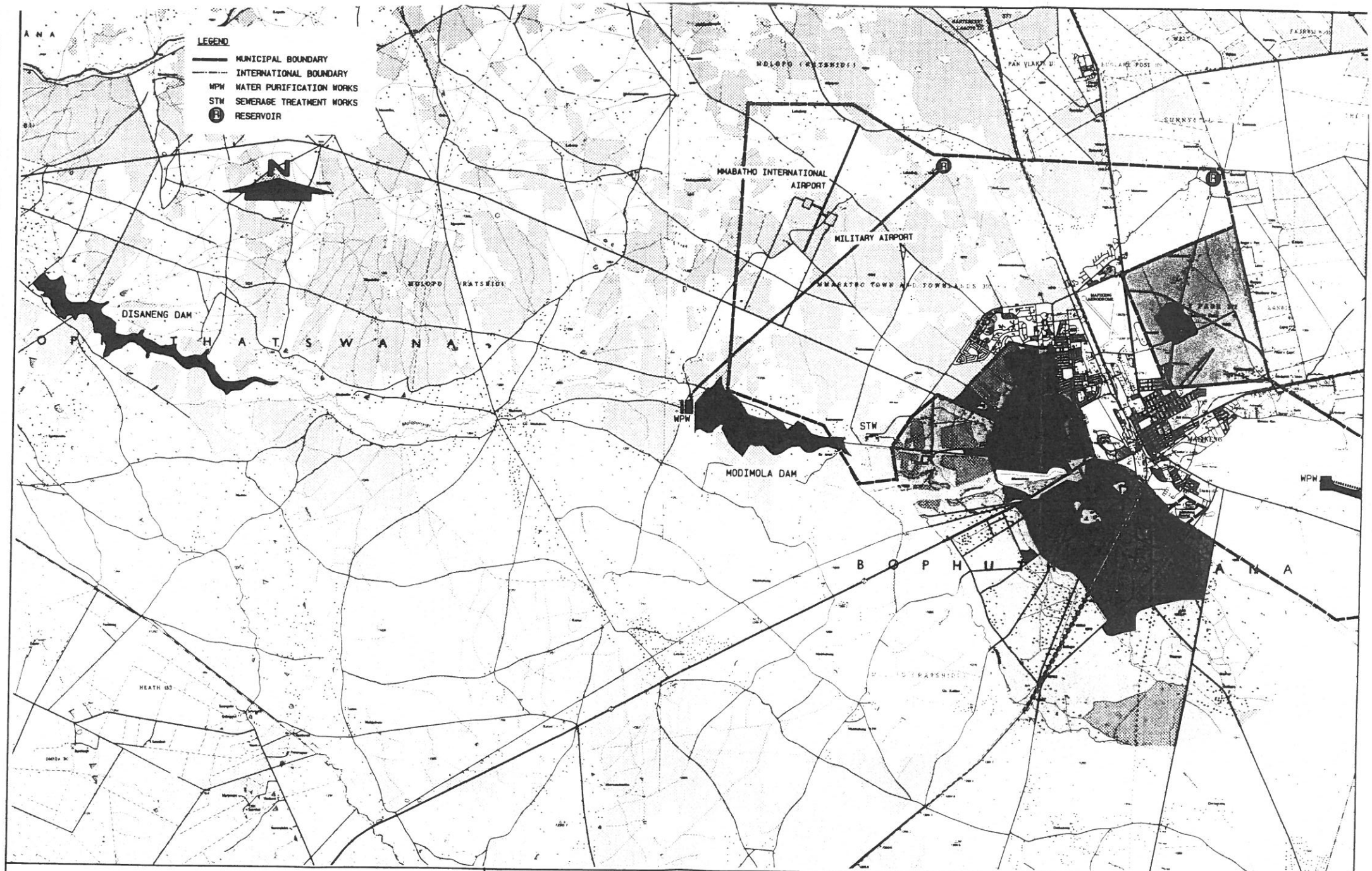
Mmabatho, the capital of the North West Province of RSA, is expanding rapidly and the water demand is expected to exceed the supply from available groundwater resources in the east by 1995. **An urgent need for water supply augmentation exists.**

An intensive investigation into 11 different combinations of water supply options has indicated that the exploitation of the Molopo river resource provides the most appropriate solution in a phased programme of water supply.

The existing Disaneng dam of 17,4Mm^3 capacity has been utilised for the irrigation of some 200 ha over the past decade. The possibility of abstracting water for Mmabatho from this source has indicated that it would be more economical to construct a new dam at Modimola, which is ca. 20kms nearer to Mmabatho and also provides advantages in terms of lower static pumping head. (See locality Map 9066/13). Construction of the Modimola Dam is scheduled to commence in 1994 with impoundment scheduled for the 1995/1996 season.

1.2 Study Extract

The Molopo river is an intermittent international river, rising in the Republic of South Africa (RSA), flowing westward through the Northwest and Northern Cape Provinces and through Mmabatho to the confluence with the Ramathlabama river from where it forms the boundary between RSA and Botswana. The river leaves the Northwest Province after the confluence with a major tributary, the Setlagole, at Mabule, from whence the river centre is the boundary between Botswana and RSA. Although a single record exists of surface flow in the Molopo river up to the vicinity of Noenieput in the previous century *(van Bladeren pers. comm.)*, the practical furthest extent of surface runoff is Watersend, west of Pomfret. This study considers the environmental impact of the proposed abstractions from the Modimola Dam to feasibly extend no further than the Setlagole river confluence. Nevertheless, developments up to the farm Blackheath are included herein for completeness' sake.



MMABATHO BULK WATER SUPPLY

LAYOUT: WESTERN SUPPLY AREA

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MAFIKENG

VEL NR
SHEET NO

9066/13

1.3 Other Environmental Studies

An Environmental Impact Assessment has been conducted for the Modimola Dam. *(CSIR 1993)*. (1) No significant impacts were identified, and certain minor impacts are being resolved in terms of the ameliorative measures proposed. For example:

A water quality simulation of the Molopo System indicates that abstraction at the intended supply rates from the proposed Modimola Dam could result in severe salinity problems of short duration in Disaneng Dam.

Indications are that the lowering of the Disaneng Dam spillway or operation of the dam to minimise evaporation will result in the water in Disaneng Dam being of acceptable salinity levels.

1.4 Purpose of this Study

The present study is intended to identify at a scoping level, the potential environmental impacts on the impacted Molopo river reach and dependant environments downstream of Disaneng Dam.

Study Level

This study is intended to be at the scoping level, that is:

- existing information is evaluated in context with the proposed development;
- potential problem areas are defined, and the potential for remedial action discussed;
- areas requiring further study are emphasized.

The co-operation of the Botswana Department of Water Affairs is gratefully acknowledged.

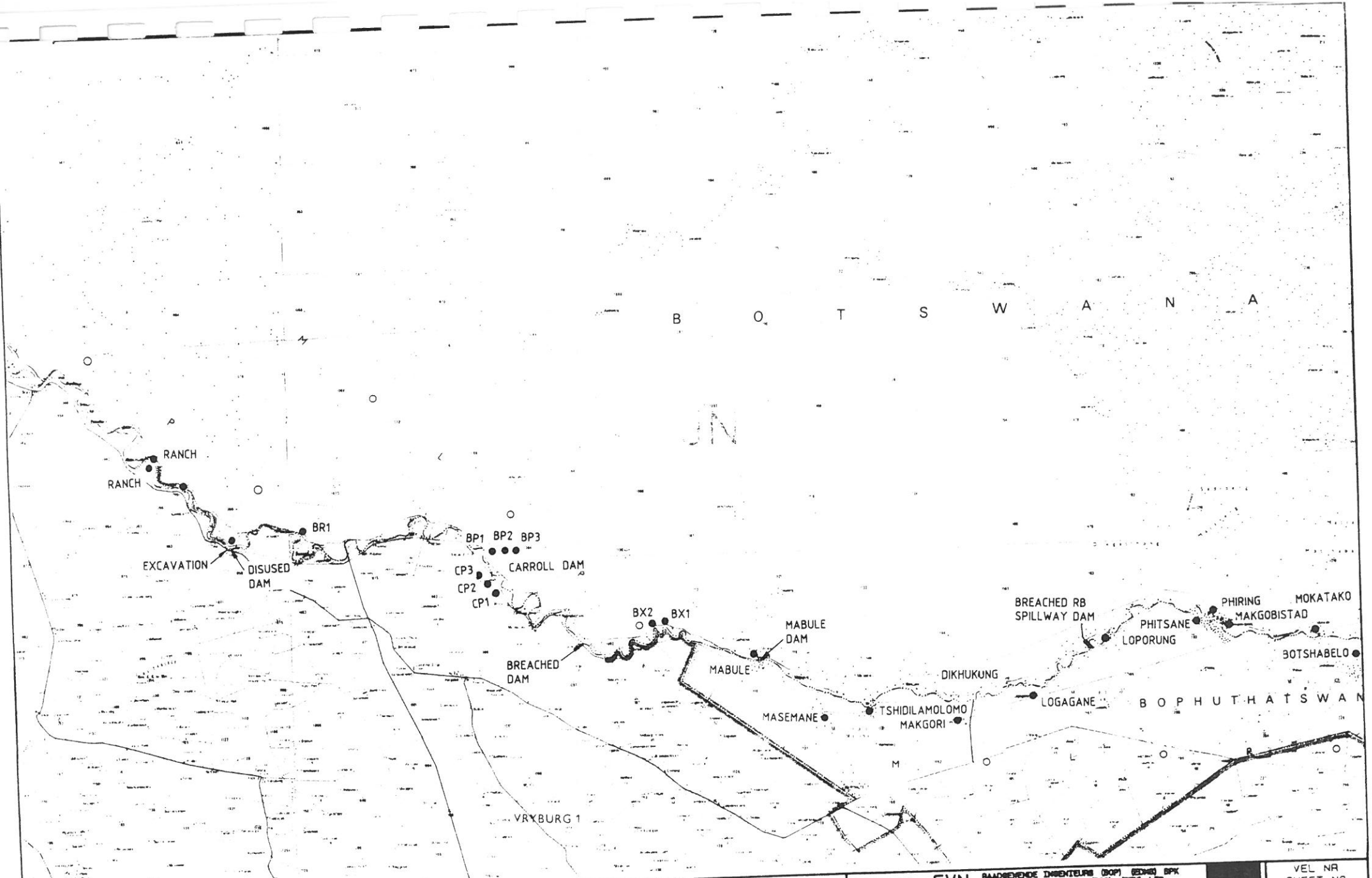
2. DESCRIPTION OF EXISTING DEVELOPMENT

The layout of salient features downstream of Disaneng Dam is indicated on the appended Figure 1.

2.1 North West Province

Settlements

The North West Province area is characterized by expanses of grazing land with



No	DAT.	WYSIGINGS / REVISIONS	GETEKEN DRAWN	GOEDGEKEUR APPROVED

MODIMOLA DAM IMPACT ASSESSMENT:

DISANENG DAM TO BRAY DEMAND CENTRES

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VEL NR
SHEET NO
FIG.1.

village clusters decreasing in size and increasing in internodal distance toward the west.

2.1.1 Land Use

Dryland cropping appears to have been practised in the past, but the consecutive 1980's drought years have apparently resulted in a considerable reduction in arable activities.

2.1.2 Irrigation

Disaneng Dam is utilised for the irrigation of 200 hectares of lands some 5km to the north, and a fishery at the dam. Disaneng Dam has become a popular recreational resort for yachting and a yacht club exists near the dam wall.

2.2 Botswana

Settlements

The Botswana area is characterised by ranching activities, with less settlements than in the North West Province (see para. 4.4). A symbiotic relationship apparently exists between neighbouring villages on either side of the border.

2.2.1 Land Use: Ranching & subsistence pastoral farming activities predominate

2.2.2 Irrigation

Irrigation development by the Commonwealth Development Corporation (CDC) to the north of the farm Blackheath comprises 3 centre pivots totalling 104,5ha. Lucerne is presently being grown under the 19,5ha pivot, while the others are fallow. Generally, 2 crops of maize are cropped annually. Water is pumped from 6 boreholes ranging in yield from 23 *l/s* to 43 *l/s*. *(Pers. Comm. Mike Jacks CDC)*. Borehole depth is allegedly 50 to 80m. Developments for at least 50kms downstream of this point are negligible.

2.3 R.S.A

The RSA farms are typically used for ranching. Considerable irrigation development was noted on the farm Blackheath, north of Vergeleë. Two centre pivots, each of approximately 100 hectares in extent, are in operation and a third is under construction. *(K. Carroll Pers. Comm.)* Water is sourced from six deep boreholes

(> 100m deep) yielding ca. 120 litres/sec and a dam in the Molopo river of capacity purportedly 1 Million m^3. Preferential abstraction from the dam, is practised whenever water levels permit a reduction in pumping energy requirements. *(Pers. Comm. Karel Carroll)*. Downstream development is negligible.

2.4 Estimated Water Demand

The water demand associated with each of the developments is listed in Table 2.

- Bophuthatswana primary water demands were abstracted from *EVN-1993 "Disaneng West Water Supply Scheme"* [3]
- Botswana water demands were estimated from dwelling counts estimated from an aerial reconnaissance of the riverine reach as well as field data reproduced in para. 4.4). A unit water consumption of 400l/household/day was estimated.
- Stock water demands were estimated using a density of 150 Mature Stock Units (MSU) for 1 kilometre on either side of the river. Unit consumption allowance including conveyance and storage losses was taken to be 50 litres/MSU/day.

Irrigation demands were estimated on the basis of 11 000 m^3/annum gross demand per hectare.

3. DESCRIPTION OF PROPOSED DEVELOPMENTS

3.1 Bophuthatswana

The Disaneng Irrigation Scheme will be reduced to 50 hectares in the near future. The proposed Modimola Dam will abstract a target draft of 8,5Mm^3/annum at high risk levels to maximise the conjunctive yield ability of groundwater, treated sewage effluent and surface water.

The growth in water demand of each of the villages referred to in Fig.1 are listed in Table 2 for a design horizon of 20 years.

Primary water demands are expected to increase at a rate of 2% per annum which is essentially due to an increase in affluence since population growth is limited by physical factors.

3.2 Botswana

The Settlements are expected to remain static since the trend toward urbanisation in the productive southeastern district comprising the Gaborone-Lobatsi axis is expected to counteract natural population growth. *(Pers. Comm. Botswana DWA)*.

The CDC irrigation development may increase in future, but this is dependant on the outcome of a resource monitoring programme to be instituted in 1994. *(Pers. Comm. Mike Jacks CDC)*. In view of the alleged dolomitic character of the substrata, and from experience with related dolomites to the south, we are presently of the opinion that present abstraction rates are in excess of recharge rates *(Partridge Pers. Comm.)*. Further development is therefore unlikely, and it is feasible that a reduction in water use will occur in time. We have illustrated a static trend in irrigation demand in Table 2 over time.

3.3 R S A

Further irrigation development is planned, but we are of the opinion that present abstraction rates are already in excess of sustainable yields considering groundwater recharge rates in this semi-arid area (see Par. 3.2 above). A groundwater study covering certain dolomitic aquifers to the south by the RSA Department of Water Affairs: Directorate Geohydrology is in the process of completion, and this may elucidate this position. We have assumed present abstraction rates to remain constant with time. (Table 2, Fig 4).

4. INITIAL IMPACT ASSESSMENT

4.1 Surface Runoff

Only flood runoff is of consequence here, since the Molopo river is seasonal, and direct run-of-river abstraction is therefore irrelevant.

4.1.1 Definition of Scenarios

For the purposes of illustration, three upper catchment development scenarios were defined:

- **Status Quo**

  The spatial distribution of Mean Annual Runoff for the existing river system with Disaneng Dam in place, is indicated in Table 3. This "Status Quo"

scenario differs from the undeveloped catchment state in that present irrigation abstraction for 200ha and evaporative loss in Disaneng Dam has been imposed on the "natural" state. "Natural State" annual runoff may be gauged from Table 1.

- **Modimola Dam with Disaneng Dam at Present Full Supply Capacity**
  This option assumes the construction of Modimola Dam to a Full Supply Capacity of *21,9 Mm^3* without any changes to Disaneng Dam. As already indicated, salinity levels in Disaneng Dam are expected to rise to excessive levels (greater than 2 000 mS/m electrical conductivity for short periods) with this option.

- **Modimola Dam with Disaneng Dam at 25% of Present Full Supply Capacity**
  This option is included in response to the anticipated high salinity levels and can be practically achieved by either lowering part of the present spillway, or else by operating the dam outlets to practically achieve the same result.

4.1.2 Simulation Procedure

The source hydrological data for this report is the HRU 11/81 "Orange River" set of the Surface Water Resources of South Africa. More recent simulations by Dr Pitman (4) on the Molopo River upstream of Disaneng Dam (SSI 1992) include the exceptional dry cycle of the 1980's and this results in a reduction in Mean Annual Runoff of an estimated 15% at Disaneng Dam, as compared with the HRU 11/81 reports.

Reservoir simulation at design draft of 8,5Mm^3/annum was conducted with the simulation time resolution set to 1 month.
Monthly fluctuations in the Mmabatho demand curve were incorporated.
Mean annual rainfall and evaporation data was used.

The Modimola-Disaneng system was simulated as a linked cell model, with both the intervening catchment and Modimola Spillages as inflow to Disaneng Dam.
Effluent inflow was ignored to offset the fact that the present model does not operate on a variable draft rule as would occur in practice to further maximise

system yield. In any event, effluent flow is a legitimate dedicated source of supply to Mmabatho, and cannot be brought into the present water supply equation downstream of Modimola Dam.

While the full simulation was conducted, only the summary of annual values or statistical mean values are included herein.

4.1.3 Discussion of Results

4.1.3.1 At Disaneng Dam

Reference should be made to Table 4.

Status Quo

The present annual spillage distribution is as shown in the second column: "Status Quo" and this indicates a Mean Annual Spillage of 9,36Mm^3, compared to the Mean Annual Runoff at the dam site of 17,4Mm^3. Significant periods of no spillage occur from 1929 to 1932, from 1961 to 1964 and from 1981 to 1987, all inclusive.

Modimola and Disaneng at 100%

The simulated annual spillage distribution is as shown in the fifth column: "Modimola/Dis: Present Disaneng" and this indicates a Mean Annual Spillage of 4,05Mm^3, compared to the Mean Annual Runoff at the dam site of 17,4Mm^3. Protracted periods of no spillage occur from 1934 to 1942, a substantial period from 1946 to 1965 and from 1977 to 1991, all inclusive.

Modimola and Disaneng at 25%

The simulated annual spillage distribution is as shown in the sixth column: "Modimola/Dis: Lowered Disaneng" and this indicates a Mean Annual Spillage of 5,83Mm^3, compared to the Mean Annual Runoff at the dam site of 17,4Mm^3. Significant periods of no spillage occur at roughly the same frequency as the "Status Quo" situation.

In conclusion, it will be seen that the spillage *frequency* of the lowered Disaneng Dam will approximate to that for the present "Status Quo" condition. Annual spillage *volumes* will generally be reduced by approximately one third, but apparently will be sufficient to recharge the riverine aquifers up to the confluence

with the Ramatlhabama river and possibly beyond in all cases, although other recharge mechanisms (e.g. direct infiltration) are thought to be preponderant.

From Figure 4 it will be noted that a first order conservative estimate of 10% aquifer recharge based on the unrealistic assumption that the flood flow in the Molopo River is the only recharge mechanism, results in no significant water deficits upstream of approximately 130 km river distrance, which corresponds to the large irrigation abstractions near the farm Blackheath which in any event - are apparently recharged from a totally different mechanism, viz. rainfall infiltration into dolomitic compartments remote from the Molopo River.

4.1.3.2 Along International Border

The MAR of the Ramatlhabama River at the Molopo confluence is estimated to be $9Mm^3$.

The MAR of the catchment between the Ramathlabama River and the Setlagoli River is estimated to be $7Mm^3$.

The MAR of the Setlagoli River is estimated to be $33Mm^3$. (HRU 11/81)

The tabulation of cumulative downstream MAR with distance will be found in Table 3. The relative reduction in mean flow volumes is expected to be as follows:

Immediately downstream of Ramathlabama River Confluence	: 20%
Immediately upstream of Setlagoli River Confluence	: 14%
Immediately after Setlagoli River Confluence	: 6%

The effect of a hypothetical 10% groundwater recharge is indicated in Figures 3 and 4.

4.1.4 Conclusions

4.1.4.1 The 13km river reach between the Disaneng Dam and the Ramathlabama River confluence will experience the largest reduction in Developed MAR i.e. 38%. No Surface Water Resource development potential exists in this vicinity, and the impact of this 38% reduction is therefore negligible. Although groundwater resources are the primary source of water at present, plans are under way to supply these villages from Disaneng Dam in future.

4.1.4.2 The reduction in mean annual flow volume of between 20% and 14% prior

to the junction with the Setlagoli River and only 6% thereafter is similarly inconsequential from the point of view of surface water resource development, since water supply is essentially from groundwater development reliant on other recharge mechanisms e.g. rainfall infiltration and lateral seepage along buried river channels - See Para. 4.2 and Addendum.

4.1.4.3 The effect of the proposed Modimola Dam on groundwater augmentation may be significant locally up to - say - Makgobistad, but insignificant beyond this point. These villages are in any event proximate to the Disaneng Dam and can be economically served directly from this dam if groundwater resources are adversely affected.

4.2 Possible Effects on Groundwater Resources in the Western Part of the Molopo District

4.2.1 Description of Area

The area in question extends from the Modimola Dam site to the confluence of the Setlagole River, a distance of some 80km. Over this distance the Molopo River occupies a shallow valley, which is cut into granite rocks of the Basement Complex, overlain by a thin veneer of Kalahari Group sediments, as far as the vicinity of Makgobistad; it then crosses outcropping banded ironstones and schists of the Kraaipan Formation, after which it is underlain by Kalahari Group sediments. The thickness of the Kalahari Group increases progressively downstream, until it reaches approximately 100m at the western end of the Molopo District. Throughout this area the Kalahari sediments overlie granites and occasional narrow belts of Kraaipan rocks. Deep, sub-Kalahari palaeo-valleys are associated with Pre-Kalahari courses of the Mheele and Setlagole rivers. These buried valleys offer preferential pathways for subsurface groundwater migration. Groundwater quality throughout the western part of the Molopo District is generally good, with some areas along the lower Molopo River having TDS concentrations of less than 500mg/l; elsewhere values are between 500 and 1000 mg/l. A few boreholes show the effects of biological contamination, usually as a result of poor borehole construction.

4.2.2 Groundwater Development

Throughout the western part of the Molopo District boreholes or shallow wells in the alluvium of the river channels provide the sole source of water for domestic consumption and cattle watering. Boreholes are generally low-yielding, north of the river upstream of Makgobistad yields average 0,5 - 1,5 litre per second over a daily pumping period of 12 hours. To the south of the river over the same stretch the geohydrological potential is very much lower; in fact, average yields are less than 0,1 litre per second and about 80% of boreholes sited using the best scientific methods are dry. We have previously drawn attention to this area, which contains several large villages, as one where there is urgent need for the provision of primary water from surface sources. To the west of Makgobistad average borehole yields are of the order of 0,5 l/s over a 12 hour period. The water commonly occurs at or immediately below the contact between Kalahari Group sediments and the underlying bedrock. Boreholes are deep (usually more than 100m), and the deep phreatic level makes the use of handpumps problematical. Windpumps or small motor pumps are the preferred types of equipment. No use is made of groundwater for irrigation in view of the low yields. The only area in which irrigation is, in fact, taking place is on the farm Blackheath, located in South Africa some 25km downstream of the Bophuthatswana border and in the adjacent area of Botswana, where a total of some 300 ha has been developed for irrigation by centre-pivot in close proximity to the river channel. The Botswana development is under the control of the Commonwealth Development Corporation. Groundwater is reportedly being abstracted from 13 boreholes with a combined yield of some 130 litres per second; these boreholes tap an aquifer within a belt of rocks of the Ghaapplato Dolomite Formation, which crosses the channel of the Molopo River in this area. These dolomitic rocks contain high-yielding aquifers in the Morokweng and Mothibistad areas to the south, but because of limited recharge, these require careful management to ensure that the resources are not overexploited. It is not known whether the requisite studies have been carried out in the case of the Blackheath aquifer, but the extent of present or intended exploitation is such that delineation of the aquifer and quantification of the water balance should certainly be undertaken. Such a study should obviously include the contribution to recharge from river flow.

4.2.3 Groundwater Recharge

Recharge of the groundwater aquifers present in the western part of the Molopo District is from three possible sources: vertical infiltration of rainwater, slow horizontal seepage along buried valleys, and recharge in proximity to surface channels from episodic river flow. The relative contribution to regional groundwater reserves from each of these sources is unknown, but research has shown that about 1 - 2% of rainfall (i.e. some 4 - 8 mm) infiltrates from surface to replenish local aquifers. The effects of recharge from occasional flow down channel of the Molopo river would probably be restricted to a zone extending to about 1km on either side of this channel. The average annual natural discharge of the Molopo River west of the Modimola dam site is of the order of 24 million m^3; at its confluence with the Molopo, some 80 km to the west, the Setlagole River contributes some 33 million m^3 annually, on average. The extent of recharge from this source depends on the downstream reach of each flow event and the frequency of events; no quantative estimates are available, *but the contribution to the overall regional water balance is probably very small. Along the valley of the Molopo River it may, however, be highly significant*. Since many of the villages in the western Molopo District and in Botswana are located in proximity to the river, the possible effects of variations in river recharge on rural water supply in this area cannot be ignored. Recharge from lateral seepage originates from areas of higher rainfall and, in some instances, from high-yielding dolomitic aquifers. *Migration rates are slow, averaging about one metre per year*, and contributions to the overall budget are likely to be small and localized.

4.2.4 Initial Impact Assessment

It is these meagre sources of replenishment which sustain the groundwater resources of the area, and, if demand is not to exceed supply, sound management practices must be applied. Reduction of recharge via any one of the mechanisms listed above is likely to have an adverse effect on the groundwater balance, either locally or regionally. Loss of recharge as a result of upstream impoundment of flow along the Molopo River is almost certain to have an adverse effect on the yields of boreholes *in proximity to the river channel*, although this may be slow to become apparent. Another possible adverse consequence is the migration, into the zone of exploitation and reduced recharge, of poorer quality groundwater.

4.2.5 Possible Mitigatory Measures

The adverse effects of reduction of the natural flow regine of the Molopo River between the Modimola dam site and the confluence of the Setlagole river *could be mitigated* by controlled discharge from the existing Disaneng Dam, located a few kilometers below the Modimola site. We understand that, if the Modimola Dam is constructed, water from the Disaneng Dam will have very limited uses and may be available for this purpose. However, the relative advantages of this form of recharge, in comparison with the provision of surface water of assured amount and quality to the western part of the district through the construction of a pipeline alongside the river, needs to be investigated. Such a pipeline would traverse easy terrain and could supply water under gravity to a major part of the population of the western Molopo District as well as to adjacent areas of Botswana. In this comparison the high cost of drilling new boreholes through the Kalahari sediments, and the not inconsiderable ongoing cost of exploiting small and finite borehole yields from great depth, need to be considered.

The economic viability of such an alternative should be investigated.

4.3 Ecological Impacts

4.3.1 Introduction

Drinking water for Mmabatho is currently supplied from dolomitic groundwater compartments to the east of the city. Predictions are that the increase in demand will exceed the existing annual supply by 1995. The Bophuthatswana Department of Water Affairs is presently investigating possible options to ensure that an adequate supply of drinking water will be available in the future. The options currently under investigation would all impact on the structure and functioning of the Molopo River, especially the reach of river downstream of Disaneng Dam. This report describes a scoping study of the potential impacts on the aquatic environment and grazing potential of the riverine and river bed vegetation.

4.3.2 Methodology

For the impact identification phase (scoping), information on the potential impacts of altered flow scenarios on the Molopo River below Disaneng Dam was gathered using three methods:

- An aerial reconnaissance of the Molopo River was undertaken on 13

September 1993. The survey covered the stretch of river between Disaneng Dam and the small town of Bray, about 260 km further downstream. Characteristics of the river were identified and noted on a topographical map. A video recording was also made of some of the important features of the river and was later studied in greater detail at the CSIR's offices.

- A search was carried out on the Waterlit national water research literature database for reports or scientific papers which referred to the Molopo River below Disaneng Dam. However, only references which could be found on the database referred to the Molopo River upstream of Mafikeng/Mmabatho.
- A number of publications and reports on the ecological flow requirements of rivers in the Kruger National Park (where most research on ecological flow requirements is currently focused) were consulted.

4.3.3 Description of the Molopo River below Disaneng Dam

A description of the water resources of the Molopo River catchment below Disaneng Dam is given in Section 4.1.

The Molopo River was classified into three categories using information gathered during the aerial reconnaissance of the river. The characteristics of the three categories are illustrated in **Figure 5**:

Class 1 These river reaches can be described as a wide, flat-bottomed sandy channel which is characteristic of many of the rivers of the region (Allanson *et al.*, 1990). The river bed appears to be vegetated with grass which may be an indication of a deep subsurface water table (or recent rains/surface runoff which is unlikely at the end of winter). Few signs of overgrazing were observed although different grazing densities could be inferred from the difference in veld colour on either side of the border fence running down the centre of the river. Class 1 was regarded as indicative of a relatively unimpacted river.

Class 2 The river bed is vegetated with grass but signs of degradation of the

river channel were observed. Pools were observed in the river bed, most were dried up and signs of overgrazing were observed in the area around these pools. These pools may be the result of dykes or other geological formations forcing the ground water closer to the surface. A single incised meandering river channel was observed in the upper reaches of the Mabula and Loporung dams. Class 2 was regarded as a river reach showing signs of degradation.

Class 3 The river bed (or macro channel) is characterized by multiple channels and vegetated gravel, sand and rock outcrops. The vegetated outcrops act as areas where sediment accumulate. Some signs of veld degradation, mainly bush encroachment and overgrazing were observed. These generally occurred in the reaches close to Disaneng Dam and the Setlagole confluence where floods or spates probably occur during the summer months.

The Molopo River below Disaneng Dam was classified as follows (**Figure 6**):

Disaneng Dam to confluence of the Ramatlabama River	Class 3
Ramatlabama confluence to Makgohistad	Class 3
Makgohistad to Loporung Dam	Class 3/Class 2
Loporung Dam to Logagane	Class 2
Logagane to Setlagole confluence	Class 3
Setlagole confluence to Mabule	Class 3
Mabule to RSA/Bophuthatswana border	Class 3/Class 2
RSA border to Molopo River border post	Class 1
Molopo River border post to farm Tennant	Class 1/Class 2
Farm Tennant to Bray	Class 1

These observations seem to indicate that the "condition" of the river improves in a downstream direction. The river reaches downstream of Disaneng Dam and downstream of the Setlagole confluence generally show the characteristics described in the Class 3 classification. This may be the result of short duration high flows in these reaches during summer months and over utilization of the river

vegetation.

4.3.4 Potential Environmental Impacts on the Molopo River Below Disaneng Dam

The combined storage of Modimola and Disaneng dams will reduce the frequency of floods down the Molopo River (see section 4.1 on surface runoff and Table 4). According to projections by EVN, the frequency at which spills would occur from Disaneng Dam will be reduced. Long periods, sometimes as long as 8 years, may go by without water spilling from Disaneng Dam. The impact of these reduced flows will probably be restricted to the Molopo River between Disaneng Dam and the Ramathlabama river and to a lesser extent to the confluence with the Setlagole River. The environmental impacts identified in this section refer mostly to this river reach.

It is believed that the construction of Modimola Dam will probably have a major impact on the riverine vegetation but a minor impact on the aquatic fauna.

Riverine vegetation - The multiple channel configuration and vegetated outcrops are probably the result of bush encroachment on the river below Disaneng Dam & the Setlagole confluence. The biotic component found in these areas are generally hardy (drought tolerant) vegetation which can utilize underground sources of water between spates. The projected reduction in the spills from Disaneng Dam will probably reduce the groundwater recharge of the river banks. It is expected that this could have a major negative impact on the riverine vegetation.

The reduction in flows from Disaneng Dam may reduce the recharge to the groundwater aquifer. The water demand of the riverine vegetation will also deplete the groundwater aquifer further. The reduction in spills will also reduce the moisture content of the river banks and in turn, reduce the vegetation cover. Such a reduction in vegetation cover may lead to increased erosion rates and general degradation of the river.

Aquatic Fauna - The aquatic fauna of rivers like the Molopo River is not strictly riverine fauna but consists mostly of hardy ephemeral opportunists. When surface

flow takes place, flying invertebrate insects such as mayflies and dragonflies utilize the opportunity to colonize streams and pools. The semi-permanent pools and dams in the river help to maintain some aquatic organisms although the species diversity is expected to be very limited. The aquatic fauna is generally adapted to the intermittent nature of flow in the river and has a variety of mechanisms to survive periods of drought (Allanson *et al.*, 1990). It is predicted that the salinity in Disaneng Dam would increase substantially due to evaporation and spills can be expected to have higher salinities than those currently observed. The organisms would probably be euryhaline, i.e. also adapted to wide fluctuations in water quality. The projected reduction in flow in the Molopo River below Disaneng Dam would probably have a minor impact on the aquatic fauna because they are opportunists.

In terms of larger species, the characteristics of the Molopo River are not conducive to maintaining a healthy fish population and large species diversity. Hardy fish like barbel can probably be found in the dams and pools which form in the river. These species are generally adapted to cope with wide fluctuations in flow and water quality so it is not expected that the status quo would change much.

4.3.5 Impact on Grazing Potential Below Disaneng Dam

In an area like that along the Molopo River, the riverine vegetation and riparian zone offers a resource of nutrients which are generally not available from the surrounding area. It also provides a source of nutrition to animals at a different time of the year which helps these animals to survive dry periods.

From the aerial survey the riparian zone appeared to be narrow and restricted to the banks of the river. The river bed in the Class 1 & 2 reaches appeared to be well vegetated. The areas of the river which are classified as Class 1 & 2, are about 2250 ha (about 150 km by 150m). This area is small compared to the size of some of the farms in the area. In fact, the riverine vegetation contributes no more than 5% of the surface area of farms, to which stock has access.

It should be noted that the border fence between the RSA and Botswana runs along the centre of the river giving farmers on both sides access to the river bed. The border fence between Bophuthatswana and Botswana is on the Bophuthatswana

river bank giving only Botswana farmers access to the river bed.

With the limited information available, it is difficult to determine the importance of vegetation on the river banks and in the river bed as a resource for feeding cattle and game. However, the projected reduction in spills and flows from Disaneng Dam will *probably have a negative impact on the riverine and river bed vegetation, comprising approximately 5% of the total* grazing resource in the reach between Disaneng Dam and the Setlagole River.

4.3.6 Subjects that Need Further Investigation

It is recommended that the following subjects be investigated further:

1. Where appropriate, the aerial observation should be confirmed with ground-truth data.
2. The riverine vegetation as resource for grazing should be investigated in further detail to establish the importance thereof in the regional fodder flow for stock.
3. The possibility of releasing water from Disaneng Dam to maintain the ecological health of the river should be evaluated while recognising the gravity of the water scarcity in the district.

4.3.7 Conclusions

With regard to the river reach between Disaneng Dam and the Setlagole River:
The projected reduction in flows downstream of Disaneng Dam will probably have:

- a major negative impact on the riverine and river bed vegetation, (comprising ca5% of the grazing area riparian to the river)
- a minor negative impact on the aquatic fauna.

It is recommended that the present status, extent and significance to local ecosystems and human communities supported by the riverine and river bed vegetation, be investigated in greater detail.

4.3.8 References

Allanson, B.R., Hart, R.C., O'Keefe, J.H. and Robarts, R.D. (1990). Inland Waters of Southern Africa: An Ecological Perspective. Monographiae Biologicae, Vol 64.

Kluwer Academic Publishers, Dordrecht. 458 pp.

4.4 SURVEY OF BOTSWANA COMMUNITIES DOWNSTREAM OF DISANENG DAM

Introduction

Settlement Planning Services were instructed by EVN Consulting Engineers to investigate, by way of a "pilot" survey in liaison with the Botswana Department of Water Affairs, the dependence on the Molopo River of the local communities downstream of Disaneng Dam. The purpose of the survey was to determine the physical status of the villages, to identify existing water infrastructure and its condition and to ascertain the attitudes and opinions of the local communities with regard to water supply.

This report is based on interviews and "windscreen" surveys conducted in the villages on the Botswana side of the Molopo River between Mokatako and Mabule (see Fig. 1). The interviews, intended to obtain information on water usage and problems associated with water, were held with the Tribal Authority and members of the local communities.

The report begins with summaries outlining the findings, problems and concerns recorded in the respective villages, viz Mokatako, Phitshane, Loporung, Dikhukhung and Mabule. It concludes by highlighting the main findings of the survey, as well as the principal concerns of the communities with regard to water supply and usage.

The following is a summary, per village, of the main findings, comments and grievances recorded in the field. Population data is abstracted from the 1991 Census. Migrant dependance is estimated from spot surveys done on a seasonal basis.

Population: Stable - 914
Including Seasonal Migrants - 1223

4.4.1 Mokatako

a) Location and Physical Status

- The sparsely settled village of Mokatako is situated on the eastern edge of

the "study area", near the confluence of the Ramatlabama and Molopo Rivers.

b) Current Status of Water Supply

- The village has 1 borehole which supplies the community with water, via 6 standpipes, for domestic purposes. The borehole is not coping with the present demand as it tends to dry up during dry periods.

- To alleviate the water shortage problem, the Botswana Department of Water Affairs is constructing a water supply pipeline from Phitshane (in the west) to the village, and will install an extra 4 standpipes within the village. The pipeline, which is approximately 0,5km from the village, is almost complete.

- The water consumption per household in the village is estimated to be approximately 200l per day (approximately 25l per person).

- Due to the drying up of the Molopo River course following the completion of Disaneng Dam and the resultant drop in the water table, open wells along the river, previously used to the watering of cattle, have dried up. Cattle now need to be taken to cattle-pens to be watered and fed.

c) Opinions and Attitudes of Community

- The village has suffered a shortage of water since the construction of the Disaneng Dam, with the Molopo River last having any "trickle" of water in December 1992.

- Future water demands are expected to increase due to the return of disillusioned people, who left the villages in search of work, from the cities. The return of these people to the villages is presumably due to reasons rather than economic reasons.

- A community, which is dependent on the limited overflow from the Disaneng Dam, is understandably very concerned as to what will happen once the Modimola Dam is constructed.

4.4.2 Phitshane

Population: Stable - 672

Including Seasonal Migration - 940

a) Location and Physical Status

- The village of Phitshane is situated approximately 12 km west of Mokatako and is the second largest village visited after Mabule. The settlement pattern while dispersed, is more concentrated than Mokatako.

b) Current Status of Water Supply

- The village has 4 operating boreholes, only 1 of which has a sustained yield and is therefore the main source of supply for the village. It is also intended that this particular borehole will supply the water for the new pipeline (mentioned in 2.1), feeding the village of Mokatako.

- There are 2 header tanks and 25 standpipes within the village.

- The water consumption per household in the village is estimated to be approximately 200l per day (approximately 25l per person).

- The river bed is used for grazing purposes in the rainy months. The cattle are forced to leave the area in search of water in the dry months.

- There are two communal gardens in the village. These are not productive as there is not enough water for both domestic and gardening purposes.

- All open wells, previously used for the watering of cattle, have dried up. As a result cattle are either taken to a syndicate borehole further away from the river, or to a private borehole where the water has to be payed for.

c) Opinions and Attitudes of Community

- The community believes that the construction of the Disaneng Dam has caused the drastic shortage of water in the village.

- The community sees the Molopo River as a "Common Dish" from which both the Botswana and Bophuthatswana people should benefit, but the local concern is that with the proposed construction of the Modimola Dam, this will probably never be the case.

- Future water demands are also expected to increase due to people returning from the cities, (for the same reasons as mentioned in 2.1).

4.4.3 Loporung

Population: Stable - 558
Including Seasonal Migration - 781

a) Location and Physical Status

- Loporung is situated approximately 15 km west of Phitshane. This is one of the smaller villages surveyed and also has a dispersed settlement pattern.

b) Current Status of Water Supply

- The village has 1 borehole supplying water for domestic purposes via 5 standpipes (see photograph B). There is also a small existing dam, but its water level is very low at the moment as it depends on the limited overflow from the Disaneng Dam.

- Water consumption per household is estimated at approximately 200l per day (approximately 25l per person).

- Open wells (see photograph A), which are used for the watering of cattle, are dry or drying up, with only the wells next to the dam still yielding any water. With a result, large amounts of stock have been lost due to the lower carrying capacity ofthe land.

- The river bed is used for grazing purposes, especially in the early raining season, as the cattle get fatter a lot faster than usual.

- There is a vegetable garden at the Primary School as well as a co-operative garden, within the village, but not much irrigation is taking place due to water shortages.

c) Opinions and Attitudes of Community

- According to the community water availability has decreased drastically since the construction of Disaneng Dam. It is therefore a concern of the community that if Modimola Dam is constructed not only their village, but all villages along the river, will be subject to further water shortages.

- In the opinion of the community, if no water is released from Disaneng Dam to replenish their dam, future development will be extremely difficult and the well-being and livelihood of the community will be threatened.

4.4.4 Dikhukhung

Population: Stable - 340
Including Seasonal Migration - 476

a) Location and Physical Status

- The village of Dikhukhung, which is the smallest of the villages visited, is approximately 11 km west of Loporung.

b) Current Status of Water Supply

- There is 1 main borehole supplying water to 7 standpipes within the village.

- Open wells, used for the watering of cattle, are being dug ever deeper and still very little water is being found. This has also proved to be very dangerous, as the wells tend to collapse and lives have been lost in their excavation.

- There are very few private boreholes nearby and the community needs permission and money to obtain water from them. This, together with the fact that the open wells are drying up, has resulted in a great reduction in the quantity of cattle kept by the community.

- Like the previous villages the river bed is used for grazing purposes during early rains.

- The village used to have 3 small plots, each approximately 1 Ha in extent, for gardening purposes, but these have been discontinued as there is not enough water.

c) Opinions and Attitudes of Community

- It is the opinion of the community that since the construction of the Disaneng Dam water has become scarcer and scarcer, with open wells and the main course of the river drying up.

- The community believes that if the Modimola Dam is constructed the water problems and shortages, presently being experienced, will multiply.

4.4.5 Mabule

Population: Stable - 798

Including Seasonal Migration - 1492

a) Location and Physical Status

- This is the largest of the villages visited and is situated on the western border of the "study area", downstream of the confluence of the Setlagola and Molopo Rivers. While dispersed the settlement is focused on a village centre which is the seat of the tribal authority.

b) Current Status of Water Supply

- The village has 1 borehole which supplies water for domestic purposes, as well as having 2 syndicate boreholes further inland for the watering of cattle. There are 15 public standpipes as well as private yard connections at the teachers housing, clinic and tribal office.

- There is a large dam, constructed in 1959, which at capacity can supply water for approximately 5 years (see photographs C & D). No water has been fed into the dam from the Molopo River for many years, the main water volume coming from the Setlagola River.

- There are no permanent open wells, but in the dry season, due to the 2 syndicate boreholes drying up, wells are dug in the river bed near the dam, to water the cattle.

- Cattle use the river bed for grazing purposes all year round.

- There are 4 vegetable gardens in the village each with its own pump, headertank and sprinkler system.

c) Opinions and Attitudes of the Community

- It is the opinion of the community that the construction of the Disaneng Dam has caused the Molopo River to stop flowing, resulting in the village having to rely on local rains and the Setlagola River to replenish the dams water supply. The failure of such rains to fall will therefore result in the dam eventually drying up.

4.4.6 Conclusion

All the villages surveyed have a traditional subsistence farming base which supports a fairly stable rural population. With no commercial or industrial economic base very few people are attracted to the villages. The main increases in population is therefore due to people returning from the cities - more for traditional rather than economic reasons - and natural population growth. No large influx of people is expected and population numbers will in all probability remain stable.

Water supply is a major problem. All villages surveyed have at least one borehole to supply water for domestic purposes, but these tend to be operating at their limit. Open wells, used for the watering of cattle, are dry or drying up, while the Molopo River course itself is dry. Foodlots and vegetable gardens are not as productive (if at all) as before, while stock numbers have been reduced quite considerably due to the lack of water.

The popular opinion among the communities is that the construction of the Disaneng Dam has contributed to, if not caused, the drying up of the Molopo River course and this has subsequently resulted in a range of problems, namely:

- The drying up of dams, open wells and boreholes;
- A drop in the water table;
- The loss of valuable grazing land around the river.

These have in turn resulted in:

- The loss of livestock;
- The closure of foodlots and vegetable gardens;
- A reduced well-being of the affected communities.

With the construction of the Modimola Dam the overwhelming concern is that the problems presently being experienced will multiply, and unless some sort of an agreement is reached, whereby all can benefit from the construction of the dam, the future of the villages along the Molopo River, in the opinion of the local communities, looks unpromising.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 No major environmental impact on the river reach downstream of Disaneng Dam could be identified in the course of this study.

5.2 Localised impacts of a minor nature should be studied further, viz:

- Groundwater recharge from surface flow in the river reach from Disaneng Dam to Makgobistad.
- The feasibility of extending the planned "Disaneng West Water Supply Scheme", to include Botswana communities.
- Relative importance of riverine vegetation in the fodder balance of stock under extensive grazing conditions in the river reach between the Disaneng Dam and the Setlagoli River confluence.

6. LIST OF REFERENCES CONSULTED

(1) (EVN Consulting Eng.) Modimola Dam Design Report - December 1993

(2) CSIR - Environmental Services (1993) - Initial Environmental Impact Assessment of the proposed Modimola Dam, Mmabatho, Bophuthatswana.

(3) EVN Consulting Engineers - 1993 - Disaneng West Water Supply Scheme - Feasibility Report.

APPENDIX A

TABLES

Disaneng Dam Runoff.

TABLE 1

	OCT.	NOV.	DEC.	JAN.	FEB.	MRCH.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	TOTALS
1924	0	0.4	5.44	3.01	0.78	19.76	9.08	1.4	0.18	0	0	0	40.05
1925	0	0.14	0.05	0.55	0.18	0	0	0	0	0	0	0	0.92
1926	0.16	0.05	1.27	0.61	0.12	1.67	0.55	0	0	0	0	0	4.43
1927	0.94	0.31	0.92	32.74	12.4	1.71	0.39	0	0	0	0	0	49.41
1928	0.05	9.45	3.15	0.56	0.19	0.14	0.05	0	0	0	0	0	13.59
1929	0	0.27	1.82	1.28	0.55	1.92	0.61	0	0	0	0	0	6.45
1930	0	0	0.17	1.09	0.45	0.04	0.15	0.05	0	0	0	0	1.95
1931	0	0.63	0.51	0.1	0.49	1.22	0.38	0.01	0	0	0	0	3.34
1932	0	0.01	3.28	1.24	0.05	0	0	0	0	0	0	0	4.58
1933	0	4.31	9.31	22.66	7.24	0.29	0.03	0.02	0.01	0	0	0	43.87
1934	0.21	2.33	1.49	0.35	0.49	3.22	1.02	0	0	0	0	0	9.11
1935	0	0.04	0.69	1.8	6.19	7.34	1.82	0.24	0.08	0	0	0	18.2
1936	0	6.38	2.31	9.91	3.54	0.08	0	0	0	0	0	0	22.22
1937	0	0	3.63	1.53	0.25	0.05	0.11	0.04	0	0	0	0	5.61
1938	0.04	0.02	1.22	2.21	5.11	2.65	0.38	0	0	0	0	0	11.63
1939	0	0.35	0.93	0.98	0.36	13.5	4.48	0	0	0	0	0.15	20.75
1940	0.05	0	12.92	5.24	0.46	0.05	0	0	0	0	0	0	18.72
1941	0.02	0.01	0.9	3.33	1.2	3.64	1.19	0	0	0	0	0	10.29
1942	0.7	0.23	13.49	5.29	0.33	1.41	3.55	1.03	0	0	0	0.19	26.22
1943	2.65	1.53	0.58	1.8	32.15	10.53	0	0	1.65	0.55	0	0.03	51.47
1944	0.09	0.35	0.11	0	0.01	25.28	8.42	0	0	0	0	0	34.26
1945	0	0	0	5.85	4.3	6.48	1.9	0	0	0	0	0	18.53
1946	0.05	0.02	0.63	1.12	0.31	6.81	2.27	0	0	0	0	0	11.21
1947	0	0	2.29	5.56	1.63	2.48	1.33	0.17	0	0	0	0	13.46
1948	0	0.32	0.11	2.32	0.77	0.15	0.05	0	0	0	0	0	3.72
1949	0	0	8.69	3.07	0.06	4.16	1.66	0.14	0.02	0	0	0	17.8
1950	0.01	0	1.75	0.87	0.23	0.19	3.58	1.19	0.01	0	0	0	7.83
1951	0.2	0.07	0.06	0.56	2.44	0.87	0.04	0	0	0	0	0	4.24
1952	0.03	0.4	0.36	0.08	1.61	1.08	0.22	0.01	0	0	0	0	3.79
1953	0	0.77	1.25	2.02	0.72	0.86	0.43	0.05	0	0	0	0	6.1
1954	0	0.09	0.4	3.6	10.72	3.39	0.07	0	0	0	0	0	18.27
1955	0.15	0.19	3.48	1.15	13.44	5.08	0.2	0.04	0.01	0	0	0	23.74
1956	0.47	0.26	2.19	0.97	1.53	1.38	0.3	0	0	0	0	0.19	7.29
1957	0.75	0.38	0.44	2.84	1.75	1.04	0.27	0.01	0	0	0	0	7.48
1958	0	0.99	0.83	0.93	0.3	0.02	0.26	0.09	0	0	0	0	3.42
1959	0	0.13	3.39	1.13	0.25	0.15	0.07	0.02	0	0	0	0	5.14
1960	0	0.32	7.85	2.58	1.83	4.69	2.41	0.36	0	0	0	0	20.04
1961	0	1.06	0.36	0.21	1.1	0.51	0.63	0.19	0	0	0	0	4.06
1962	0	2.12	0.89	2.65	0.89	0.01	0.03	0.01	0	0	0	0	6.6
1963	0.02	2.46	0.86	0.45	0.25	0.04	0	0	0	0	0	0	4.08
1964	0.03	0.07	1.47	1.56	0.36	0	0.03	0.01	0	0	0	0	3.53
1965	0	0	0	2.04	10.67	3.33	0	0	0	0	0	0	16.04
1966	0	0.01	0.14	81.23	30.02	3.08	18.11	5.8	0	0	0	0	138.39
1967	0	0.03	0.14	0.56	0.29	5.04	2.28	0.21	0	0	0	0	8.55
1968	0	0.14	0.95	0.39	0.14	0.96	1.34	0.34	0	0	0	0	4.26
1969	0.16	0.05	1.53	1.19	1.52	0.43	0	0	0	0	0	0	4.88
1970	0	0	1.93	10.12	3.21	0.02	0.93	0.31	0	0	0	0	16.52
1971	0	1.33	0.72	39.87	13.41	1.07	0.35	0	0	0	0	0	56.75
1972	0	0.12	0.04	0.73	0.42	0.64	0.41	0.07	0	0	0	0.24	2.67
1973	0.08	1	0.49	7.51	3.31	0.61	1.18	0.36	0	0	0	0	14.54
1974	0	1.62	2.77	15.97	8.39	5.96	3.86	0.75	0	0	0	0	39.32
1975	0	0.23	2.84	48.34	17.64	9.91	3.36	0.09	0	0	0	0	82.41
1976	0.17	0.57	2.98	7.88	2.94	5.68	1.83	0	0	0	0	0.04	22.09
1977	0.02	0.11	2.05	6.71	4.07	2.31	0.61	0.02	0	0	0	0	15.9
1978	0.01	0	0.05	5.68	1.89	0	0.07	0.02	0	0	0.02	0.01	7.75
1979	0.35	0.96	0.54	4.29	3.09	0.58	0	0	0	0	0	0	9.81
1980	0	4.05	2.06	15.97	6.04	0.54	0.09	0	0	0	0	0	28.75
1981	0.03	0.04	0.99	2.04	0.57	0.36	2.41	0.76	0	0	0	0	7.2
1982	1.24	0.44	0.6	0.49	0.1	0.01	0	0	0	0	0	0	2.88
1983	0.12	0.13	0.88	0.28	0	0.11	0.04	0	0	0	0	0	1.56
1984	0.07	0.02	0.02	0.84	0.36	0.04	0	0	0	0	0	0	1.35
1985	0.25	0.08	0.44	0.81	0.45	0.1	0.01	0	0	0	0	0	2.14
1986	0.01	0.22	0.65	1.15	0.5	0.53	0.16	0	0	0	0	0.01	3.23
1987	0.02	0.11	0.63	0.45	6.69	3.44	0.43	0.01	0	0	0	0	11.78
1988	0.25	0.12	0.42	1.06	21.63	7.24	0.16	0.04	0	0	0	0	30.92
1989	0	0.55	1.29	0.4	0.71	0.7	1.27	0.37	0	0	0	0	5.29
1990	0.01	0	0.07	20.4	7.32	1.8	0.54	0	0.02	0.01	0	0.02	30.19
1991	0.01	0	0.02	0.06	0.02	0	0	0	0	0	0	0	0.11

TABLE 2

MOLOPO RIVER DOWNSTREAM OF DISANENG DAM: COMPOSITION OF WATER DEMAND.

BOPHUTATSWANA DEMAND CENTRE	BOTSWANA DEMAND CENTRE	RSA DEMAND CENTRE	RIVER DISTANC kms.	Bophutatswana 1993 Primary Water Demand kl/day	Botswana Est. 1993 Primary Water Deman kl/day	Botswana Actual. 1993 Primary Water Demand kl/day	RSA Irrigation	Stock Water Demand kl/day	1993 TOTAL Mm^3/an	Bophutatswana 2013 Primary Water Demand kl/day	Botswana 2013 Primary Water Demand kl/day (EVN AERIAL estimate)	RSA IRRIGATION DEMAND kl/day	2013 Stock Water Demand kl/day	2013 TOTAL Mm^3/an
DISANENG DAM			0						0					
VILLAGE	MOKATAKO		4	567	170	32		60	0.30	1252	375.6		60	0.62
RAM. CONFLUENCE			13					135	0.05				135	0.05
MAKGOBISTAD	PHITSANE		25	160		24		180	0.13	282			180	0.17
LOPORUNG	LOPORUNG		38	42		20		195	0.09	65			195	0.09
			42					60	0.02				60	0.02
	S10H		46		4			60	0.02		6		60	0.02
LOGAGANE	DIKHUKHUNG		50	27		12		60	0.04	42	0		60	0.04
MAKGORI	S20H		59	29	8			135	0.06	45	12		135	0.07
TSHIDILAMOLOMO	S60H		72	36	24			195	0.09	53	36		195	0.10
SETLAGOLI			79	28				105	0.05	40	0		105	0.05
MABULE	S100H		88	60	40	28		135	0.10	87	60		135	0.10
BOPHUT/RSA			96					120	0.04				120	0.04
			114					270	0.10				270	0.10
	IRRIGATION	IRRIGATION	130		2466		9397	240	4.42		2466	9397	240	4.42
			161					465	0.17				465	0.17

TABLE 2.1.3.3: HYDROGEOLOGICAL POTENTIAL - MOLOPO DISTRICT

Hydrogeological Unit	Litho-stratigraphic Unit	Overall Groundwater Potential	Static Level (m)	Range of Yields (l/s)	Range of Depths (m)	Quality Rating (TDS ppm)	Possible Deleterious Constituents	Suggested Utilization
HU2	Granodiorites (Basement Complex)	Moderate to High	< 25	1,5-5,0	40-60	Good < 500	None	Extended rural Small urban Small irrigation
HU3	Granodiorites (Basement Complex) Amygdaloidal Lavas (Ventersdorp Supergroup)	Moderate	< 25	0,5-1,5	40-60	Good < 500	None	Extended rural Small urban Small irrigation
HU4	Granodiorites (Basement Complex) Amygdaloidal Lavas (Ventersdorp Supergroup)	Poor	< 25	< 0,5	40-60	Good < 500	None	Extended rural Small urban Small irrigation
HU5	Granodiorites (Basement Comlex) Dolomites (Griqualand West Sequence) and Amygdaloidal Lavas (Ventersdorp Supergroup)	Very poor	< 20	< 0,1	40-60	Moderate 450-1 400	Nitrates (settlements)	Small rural Stock-watering Not irrigation

NB!

2.1.4 Groundwater Potential

The hydrogeological potential of each district is shown on Map No. M103, of the accompanying map series. It also indicates which villages have insufficient groundwater available.

Messrs. Partridge, Maud and Associates recommended an average borehole density of 4 per square kilometer and the average of the likely range of sustainable yields for each hydrogeological unit should be used as representative of boreholes in that unit. The average of the likely range of the 12 hour sustainable yields for each hydrogeological unit is as follows:

HU1 5,00 l/s
HU2 3,25 l/s
HU3 1,00 l/s
HU4 0,30 l/s
HU5 0,00 l/s

The 12 hour pumping rate recommended allows for the recharge of the different litho-stratigraphic units.

In estimating the available groundwater supply an 8 hour pumping period per day was assumed. Provision for supplying the SDD is made by allowing 8 hours of pumping to meet the GAADD whilst the sustainable yield is based on 12 hours pumping per day.

TABLE 3

MOLOPO RIVER DOWNSTREAM OF DISANENG DAM: COMPARISON BETWEEN DEMAND & 10% REPLENISHMENT.

				WATER DEMAND		MEAN ANNUALRUNOFF. FOR VARIOUS DEVELOPMENT SCENARIOS						
BOPHUTATSWANA DEMAND CENTRE	BOTSWANA DEMAND CENTRE	RSA DEMAND CENTRE	RIVER DISTANCE kms.	1993 CUMULATIVE TOTAL Mm^3/annu	2013 CUMULATIVE TOTAL Mm^3/annu	STATUS QUO. RUNOFF Mm^3/annum	DISANENG ONLY, ESTIMATED STATUS QUO RUNOFF Mm^3/annum	RECHARGE 10% Mm^3/annum	MODIMOLA DAM+ DISANENG@ 100% RUNOFF Mm^3/an	RECHARG 10%	MODIMOLA DAM+ DISANENG@ 25% RUNOFF Mm^3/annum	RECHARGE 10%
DISANENG DAM			0	0	0	9.36	9.36	0.94	4.05	0.41	5.83	0.58
VILLAGE	MOKATAKO		4	0.30	0.62		9.36	0.94		0.41		0.58
RAM. CONFLUENCE			13	0.35	0.67	9	18.36	1.84	9	1.31	9	1.48
MAKGOBISTAD	PHITSANE		25	0.48	0.83		18.36	1.84		1.31		1.48
LOPORUNG	LOPORUNG		38	0.58	0.93	3	21.36	2.14	3	1.61	3	1.78
			42	0.60	0.95		21.36	2.14		1.61		1.78
	S10H		46	0.62	0.97		21.36	2.14		1.61		1.78
LOGAGANE	DIKHUKHUNG		50	0.66	1.01	4	25.36	2.54	4	2.01	4	2.18
MAKGORI	S20H		59	0.72	1.08		25.36	2.54		2.01		2.18
TSHIDILAMOLOMO	S60H		72	0.82	1.19		25.36	2.54		2.01		2.18
SETLAGOLI			79	0.86	1.24	33	58.36	5.84	33	5.31	33	5.48
MABULE	S100H		88	0.96	1.34		58.36	5.84		5.31		5.48
BOPHUT/RSA			96	1.00	1.39		58.36	5.84		5.31		5.48
			114	1.10	1.48		58.36	5.84		5.31		5.48
IRRIGATION	IRRIGATION	IRRIGATION	130	5.52	5.90		58.36	5.84		5.31		5.48
			161	5.69	6.07		58.36	5.84		5.31		5.48

TABLE 4

ANNUAL RUNOFF PAST DISANENG DAM SITE.

for different Development Options

Million m^3

		MMABATHO BULK WATER SUPPLY.			
YEAR	Status Quo. 200halrrig Disaneng Only	DISANENG 50haMBWS8.5	MODIMOLA SPILLAGE	MODIMOLA/DI Present Disaneng	SPILLAGE Lowered Disaneng
1923					
1924	2.41E+07	1.96E+07	1.14E+07	1.02E+07	1.80E+07
1925	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1926	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1927	3.52E+07	2.13E+07	1.13E+07	1.22E+07	1.99E+07
1928	7.46E+06	2.28E+06	0.00E+00	0.00E+00	1.66E+06
1929	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1930	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1931	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1932	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1933	2.77E+07	1.71E+07	8.03E+06	4.29E+06	1.49E+07
1934	6.05E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1935	9.82E+06	0.00E+00	0.00E+00	0.00E+00	2.15E+06
1936	1.58E+07	9.21E+06	1.16E+06	0.00E+00	4.87E+06
1937	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1938	1.84E+06	0.00E+00	0.00E+00	0.00E+00	7.84E+04
1939	1.27E+07	0.00E+00	0.00E+00	0.00E+00	2.91E+06
1940	1.24E+07	6.29E+06	0.00E+00	0.00E+00	2.92E+06
1941	1.55E+06	0.00E+00	0.00E+00	0.00E+00	3.72E+04
1942	1.72E+07	5.79E+06	0.00E+00	0.00E+00	3.97E+06
1943	4.20E+07	3.67E+07	2.52E+07	3.03E+07	3.57E+07
1944	2.77E+07	2.11E+07	1.38E+07	1.74E+07	2.06E+07
1945	1.03E+07	4.15E+06	6.64E+05	1.36E+05	2.99E+06
1946	3.41E+06	0.00E+00	0.00E+00	0.00E+00	5.53E+05
1947	5.06E+06	0.00E+00	0.00E+00	0.00E+00	9.19E+05
1948	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1949	6.64E+06	0.00E+00	0.00E+00	0.00E+00	1.19E+06
1950	-5.6E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1951	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1952	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1953	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1954	6.07E+06	0.00E+00	0.00E+00	0.00E+00	1.05E+06
1955	1.58E+07	3.88E+06	0.00E+00	0.00E+00	3.70E+06
1956	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1957	-1.7E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1958	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1959	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1960	6.67E+06	0.00E+00	0.00E+00	0.00E+00	1.11E+06
1961	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1962	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1963	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1964	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1965	1.85E+06	0.00E+00	0.00E+00	0.00E+00	1.26E+05
1966	1.29E+08	1.15E+08	8.26E+07	1.01E+08	1.15E+08
1967	1.31E+06	0.00E+00	0.00E+00	0.00E+00	5.50E+04
1968	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1969	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1970	4.57E+06	0.00E+00	0.00E+00	0.00E+00	6.89E+05
1971	4.92E+07	3.45E+07	2.06E+07	2.36E+07	3.28E+07
1972	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1973	2.15E+06	0.00E+00	0.00E+00	0.00E+00	9.97E+04
1974	3.06E+07	1.65E+07	6.64E+06	6.60E+06	1.40E+07
1975	7.45E+07	6.81E+07	5.07E+07	6.61E+07	6.94E+07
1976	1.39E+07	7.24E+06	3.31E+06	3.41E+06	6.48E+06
1977	7.69E+06	1.87E+06	0.00E+00	0.00E+00	1.59E+06
1978	1.11E+06	0.00E+00	0.00E+00	0.00E+00	1.93E+04
1979	1.70E+06	0.00E+00	0.00E+00	0.00E+00	1.94E+05
1980	2.07E+07	7.93E+06	2.18E+05	0.00E+00	5.24E+06
1981	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1982	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1983	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1984	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1985	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1986	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1987	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1988	1.60E+07	6.30E+06	0.00E+00	0.00E+00	4.43E+06
1989	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1990	2.01E+07	8.45E+06	1.84E+06	0.00E+00	6.53E+06
1991	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1992	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1993	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Annua Mean	9.36E+06	6.33E+06	3.49E+06	4.05E+06	5.83E+06

TABLE 5 : LAND USE SUMMARY

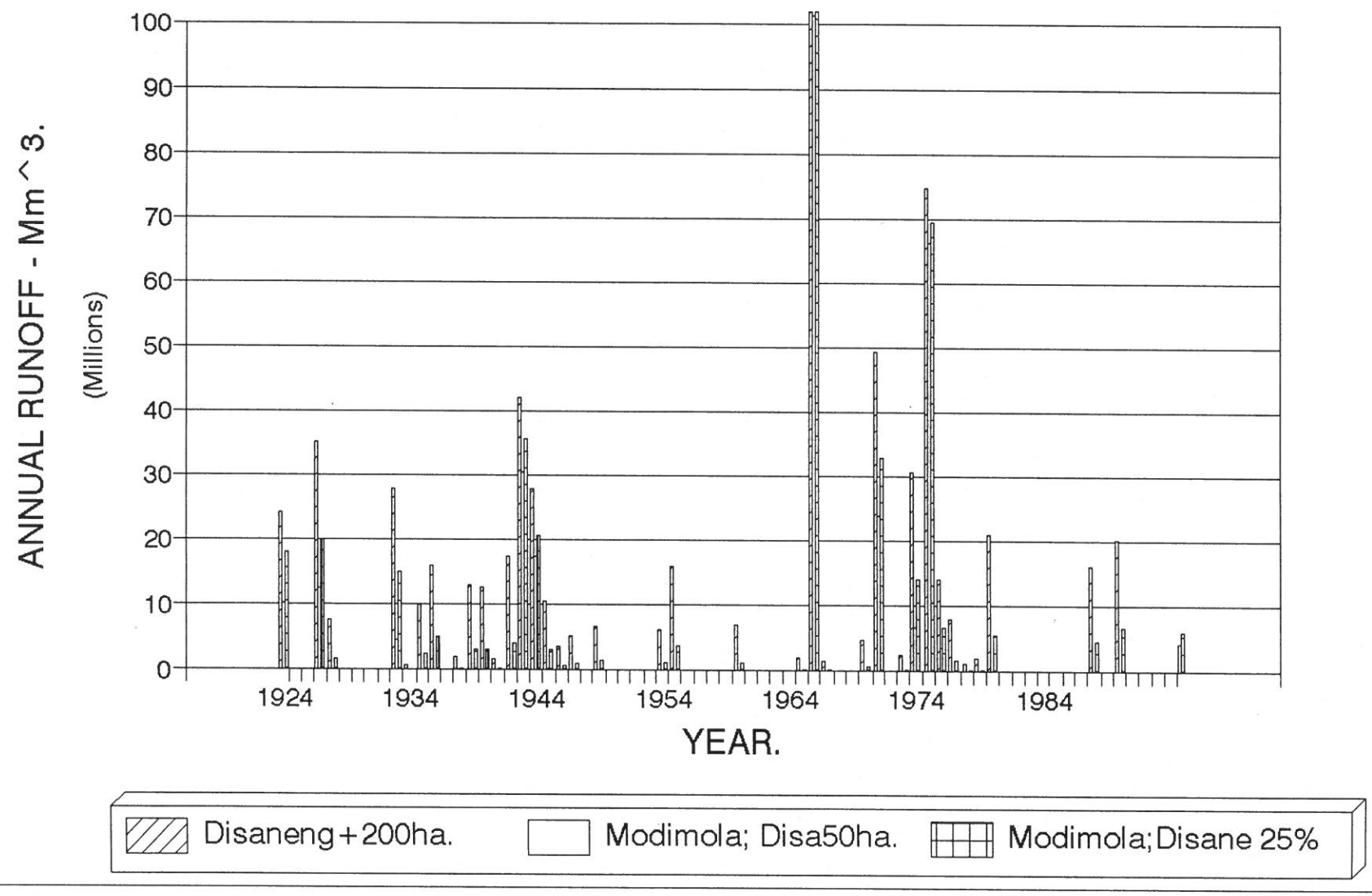
	MOKATAKO	PHITSANE	LOPORUNG	DIKHUKUNG	MABULE
PRIMARY SCHOOL	1	1	1	1	1
SECONDARY SCHOOL		1			1
CRECHE	2	4	2	1	1
CLINIC	1	1	1	1	1
CHURCH	3	7	1	5	6
BAR/BEER HALL	1	4	1	1	
SHOP/CAFE/GENERAL DEALER	3	9	2	4	5
POST OFFICE		1			1
POLICE STATION		1			
LOCAL POLICE	1		1		1
SERVICE STATION		1			
BUTCHER			1		4
CO-OPERATIVE					2
AGRI-HOUSE				1	

APPENDIX B

FIGURES

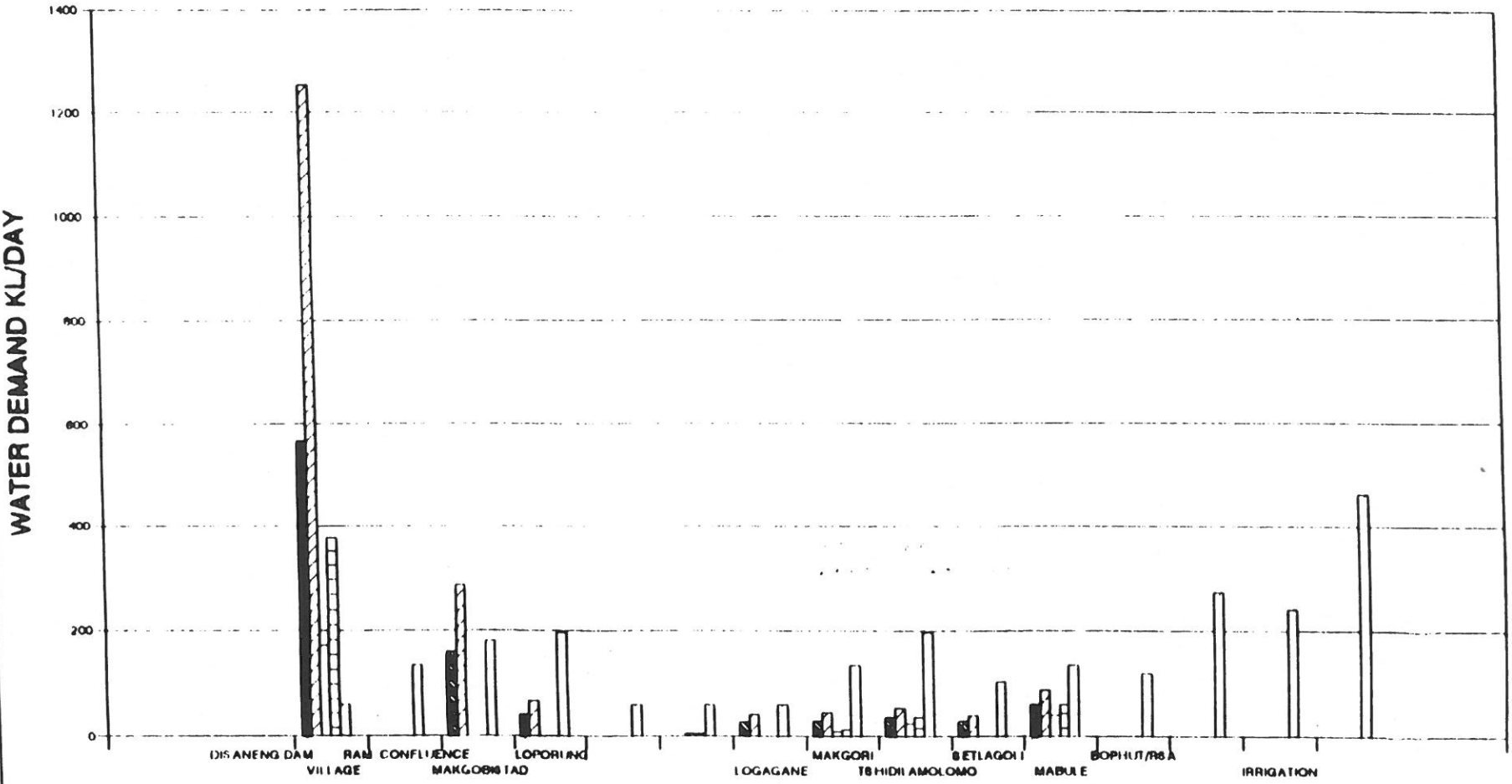
MOLOPO RIVER DOWNSTREAM OF DISANENG.

SPILLAGE vs NATURAL STATE.



MOLOPO RIVER D/S OF DISANENG DAM.

WATER DEMAND.



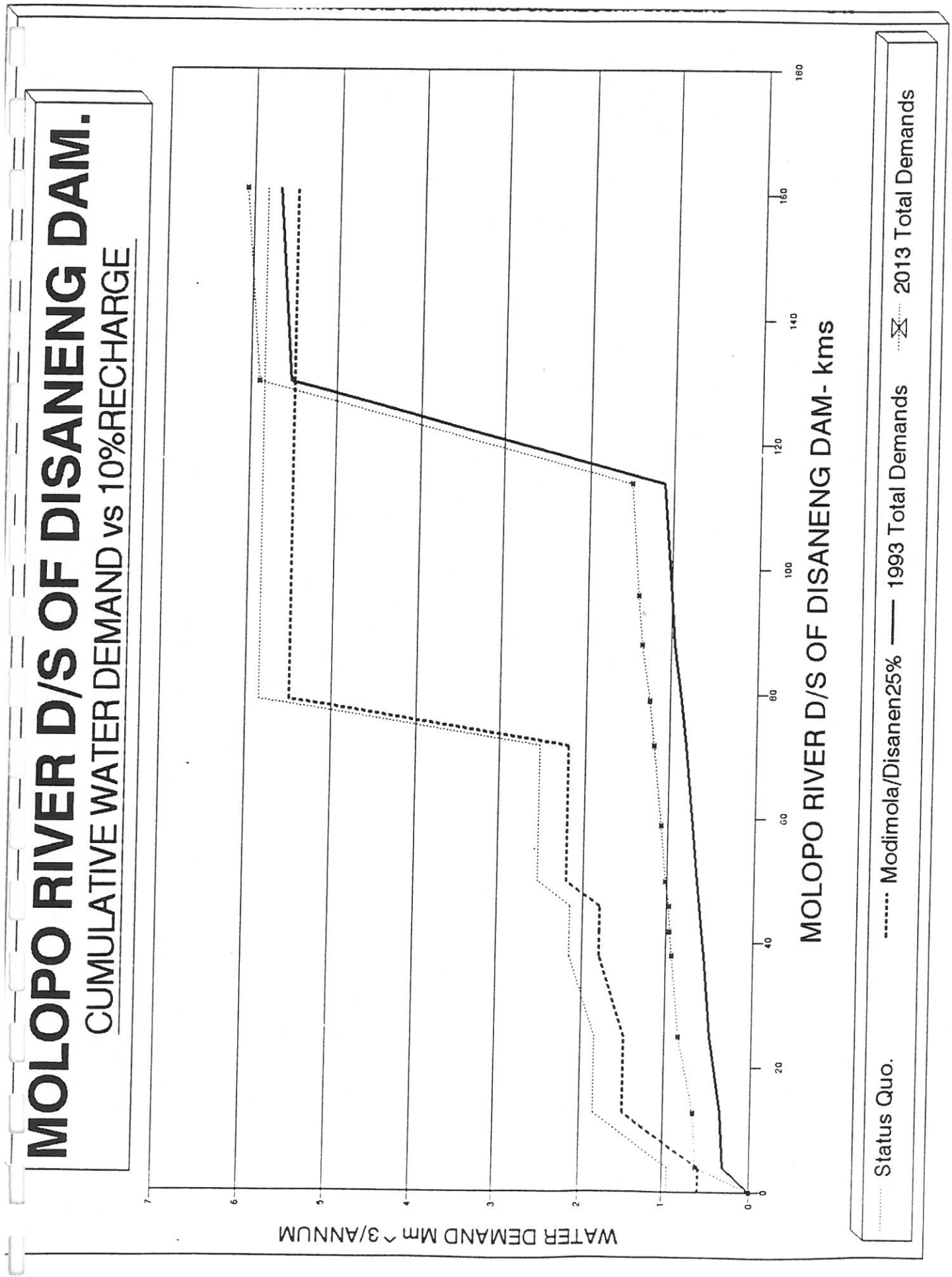
MOLOPO RIVER D/S OF DISANENG DAM.

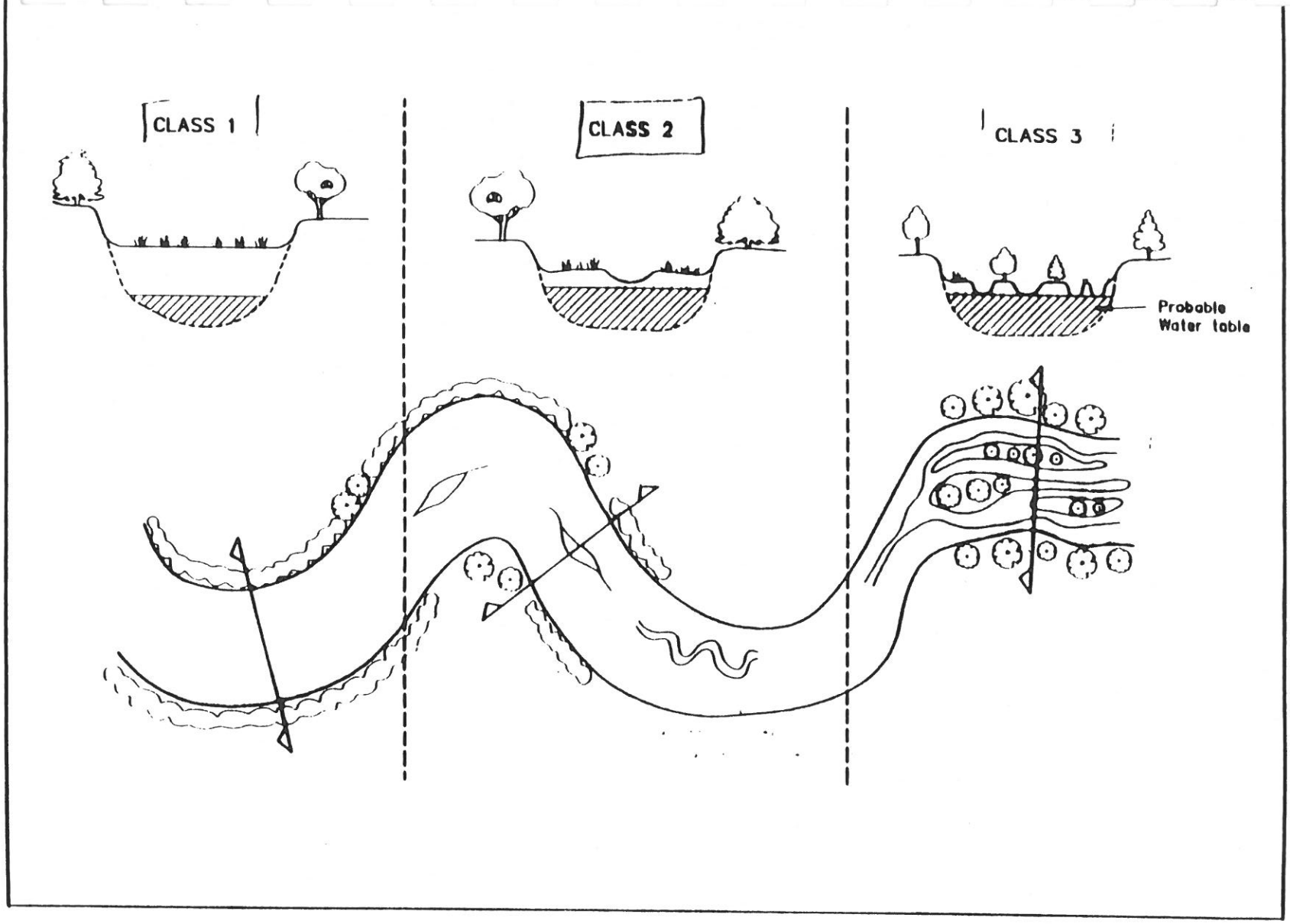
1993 Bop. Primary
2013 Bop. Primary.
1993 Botswana Prima
2013 Botswana Prima
Stock Watering.

FIGURE

N.B. EXTREME HYPOTHESIS FOR ILLUSTRATION ONLY!

a) Groundwater recharge exclusively from Molopo river influent flow.
b) 10% of mean annual flood flow is available for recharge.





URE 5 Schematic diagram of the three categories of the used to classify the condition of the Molopo River below Disaneng Dam.

FIGURE 5

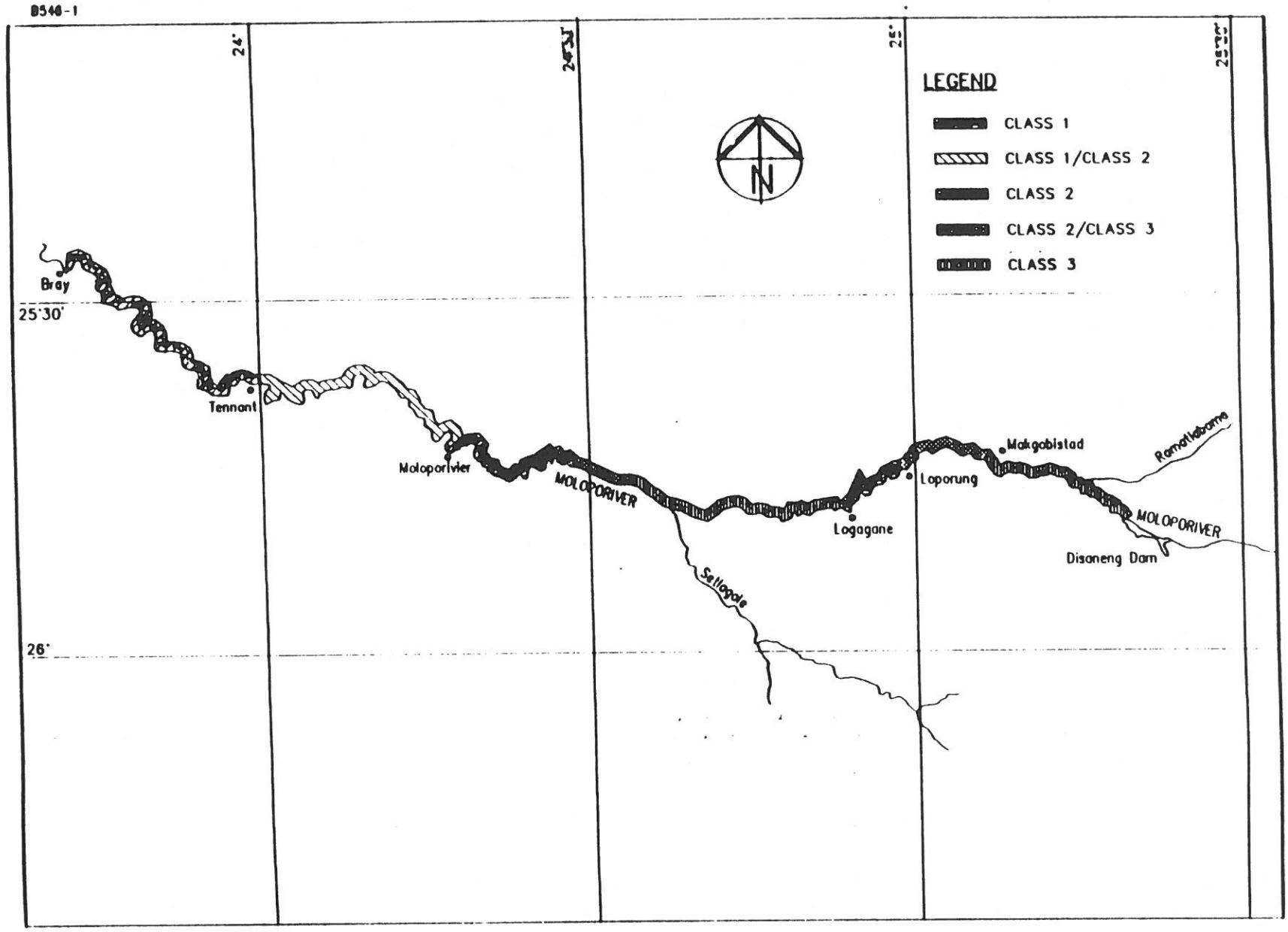
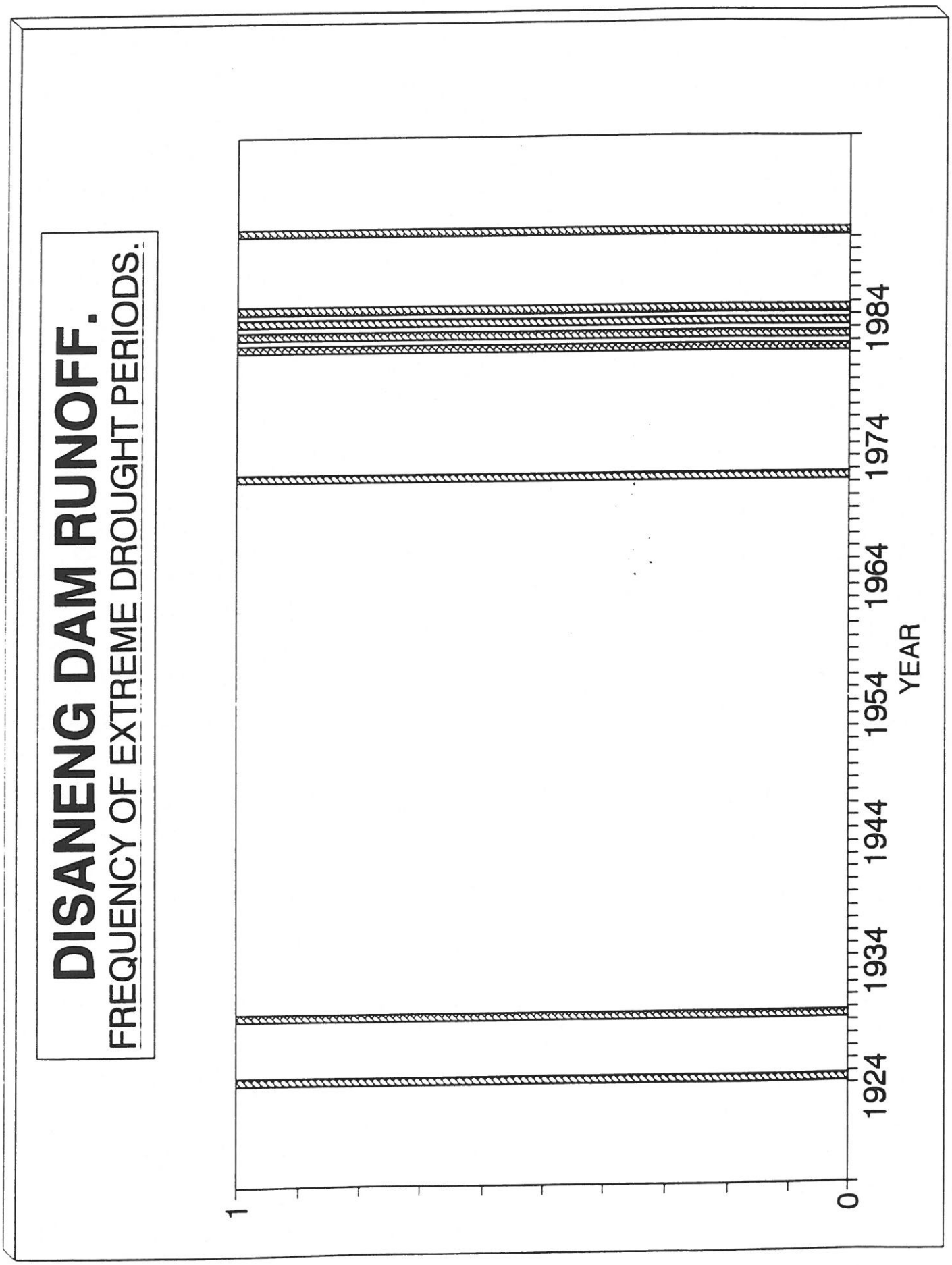


FIGURE 6 **Map of the Molopo River from Disaneng Dam to Bray showing the classification of the river based on the aerial survey of the river.**

FIGURE 6

FIGURE 7


DISANENG DAM RUNOFF.
FREQUENCY OF EXTREME DROUGHT PERIODS.
1
0
1924
1934
1944
1954
1964
1974
1984
YEAR

SECTION B

ADDENDUM

PROPOSED MODIMOLA DAM

ENVIRONMENTAL IMPACT ASSESSMENT DOWNSTREAM OF DISANENG DAM

REPORT SEQUENCE AND STRUCTURE

1. **DRAFT REPORT : SEPTEMBER 1993**

   DATABASE:

   Existing information, augmented by aerial reconnaissance survey of floodplain condition and settlement locality and settlements size as well as location and extent of irrigation development.

2. **REPORT : MAY 1994**

   DATABASE:

   As for September 1993 report, but supplemented by Section 4.4 SETPLAN Survey of Botswana Communities Downstream of Disaneng Dam.

3. **ADDENDUM : MAY 1994**

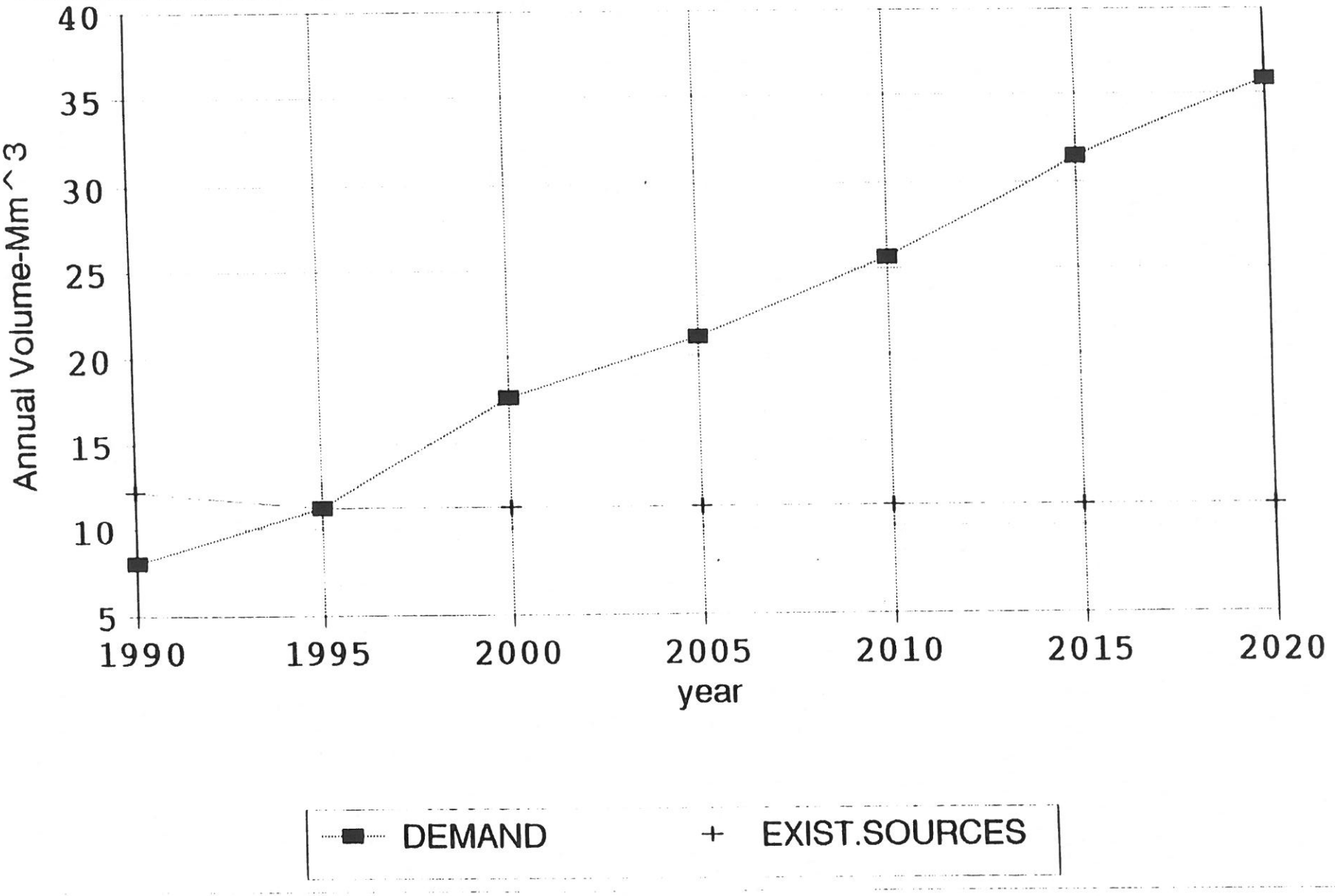
   Manuscript version of presentation to the Botswana - RSA JPTC Working Group in Gaborone. Illustrations of possible groundwater recharge mechanisms included. Concern of Botswana communities over reduced groundwater supplies after completion of Disaneng Dam indicated as an unfortunate coincidence with the severe 1980's drought.

4. **ADDENDUM : AUGUST 1994**

   Typed version of May 1994 Addendum, with all drawings and sketches improved.

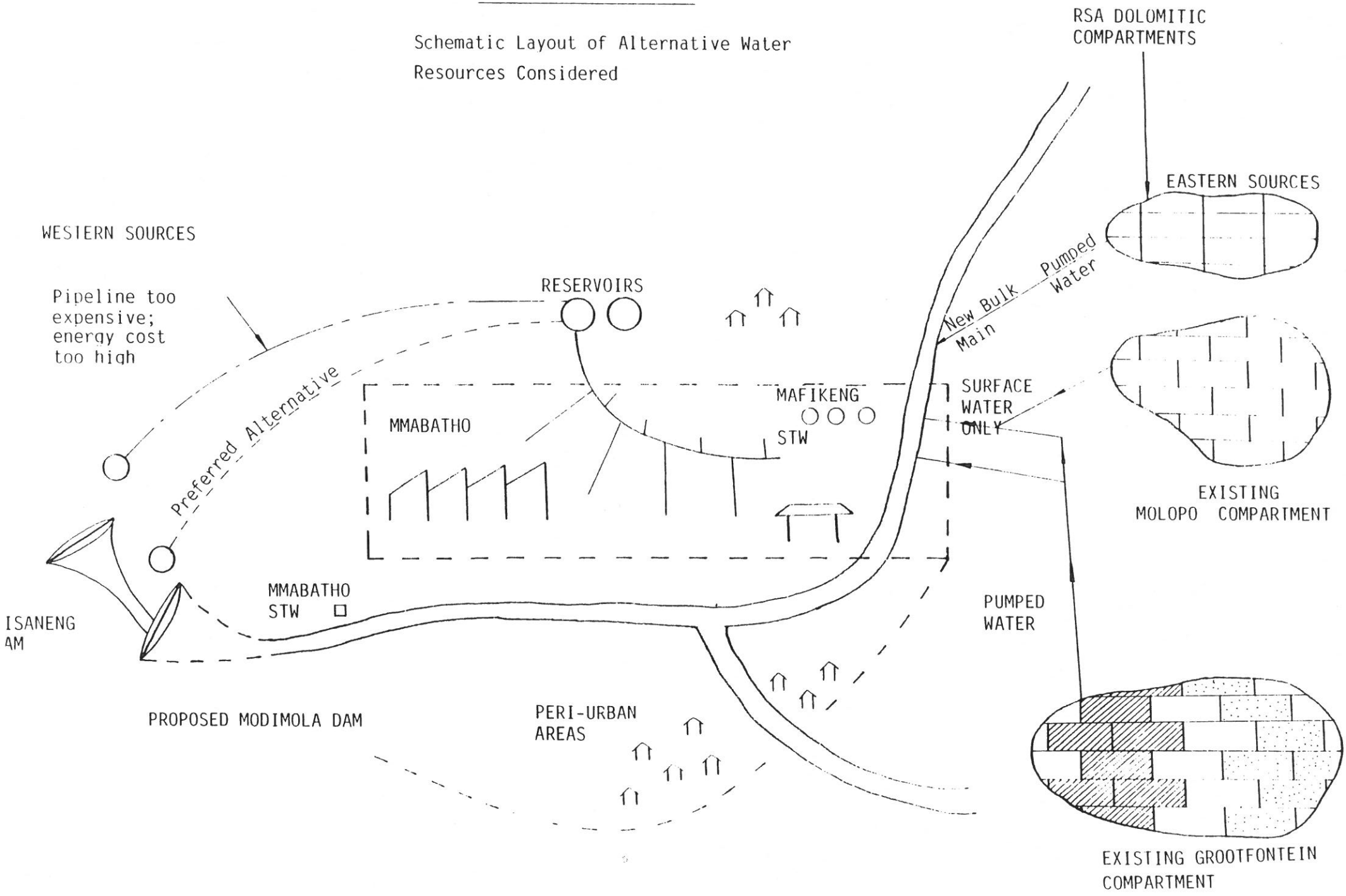
GREATER MMABATHO BULK WATER SUPPLY

PROJECTED DEMAND vsEXISTING SUPPLY

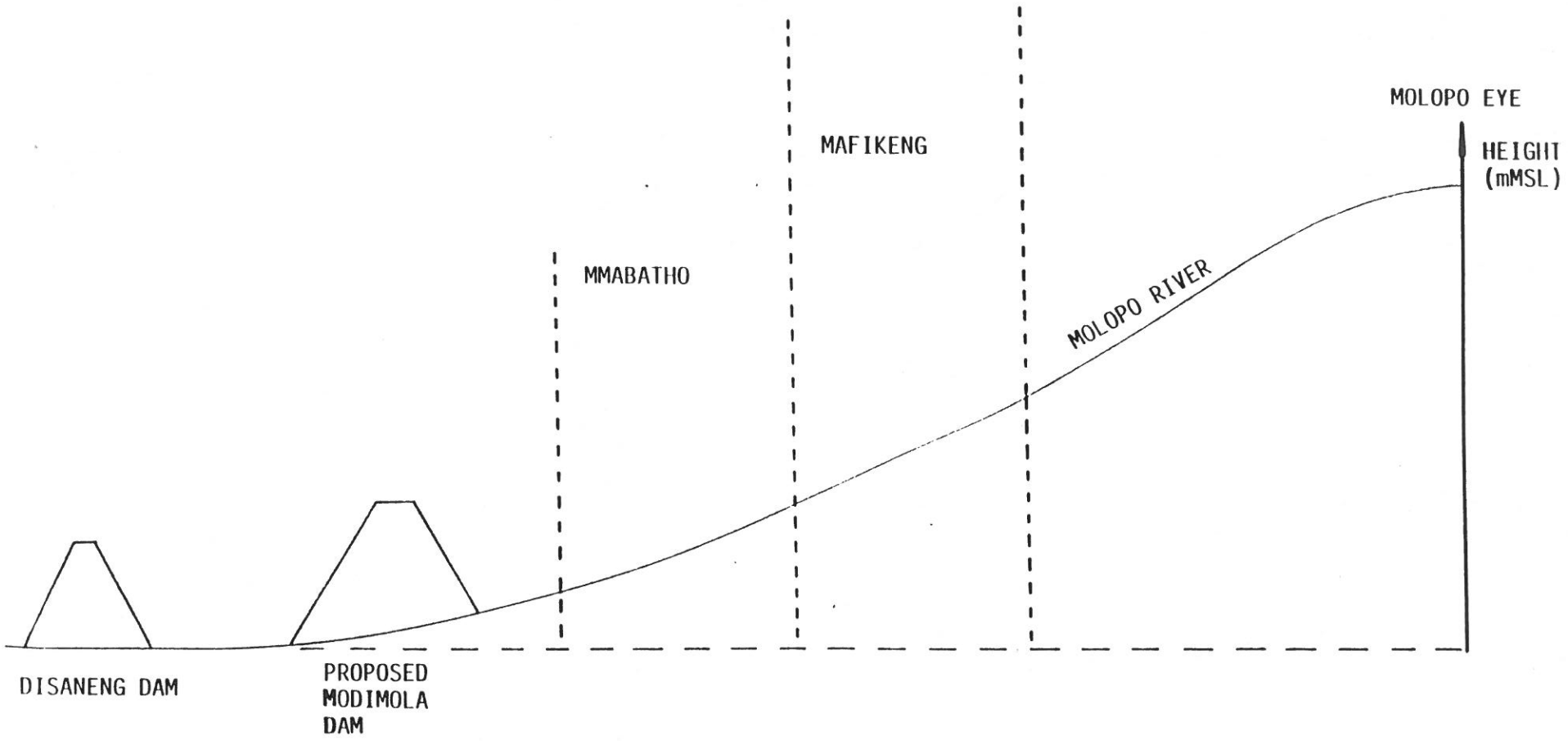


PROPOSED MODIMOLA DAM

Schematic Layout of Alternative Water Resources Considered



MMABATHO BULK WATER SUPPLY



PROPOSED MODIMOLA DAM

ENVIRONMENTAL IMPACT ASSESMENT

REGION 1

TO DISANENG DAM

CSIR REPORT
OCT 1993

REGION 2

DOWNSTREAM OF DISANENG DAM

EVN FIRST REPORT (SEP 1993)
EVN AMENDED REPORT (MAY 1994)
EVN ADDENDUM (JUNE 1994)

NB: EVN MAY 1994 : p 26 PARA 5.1 & 5.2
No Major Environmental Impact!
Localise impacts may require further study (para 5.2)

9066 PRES2/IGVS

MODIMOLA DAM

INITIAL IMPACT ASSESMENT

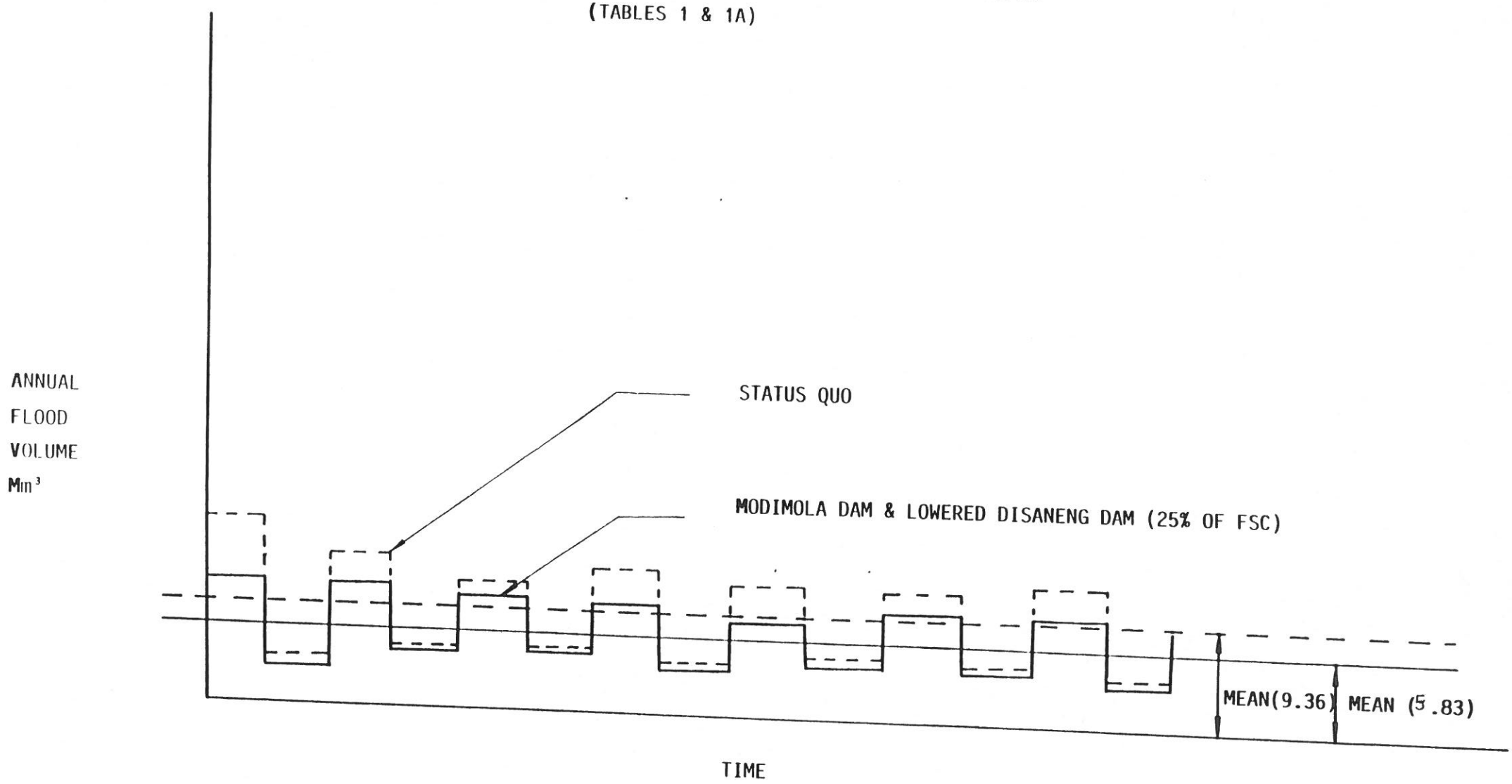
NEGATIVE	POSITIVE
HOUSES INUNDATED: RELOCATION	ASSURED WATER SUPPLY: MMABATHO
SALINITY IN DISANENG DAM WILL INCREASE	MOST ECONOMICAL AUGMENTATION OPTION
MAY AFFECT ENVIRONMENT DOWNSTREAM OF DISANENG DAM	CAN RE-USE TREATED DILUTED SEWAGE EFFLUENT ECONOMICALLY

REGION:	ISSUE	PROPOSED AMELIORATIVE MEASURE
1)	DISANENG DAM INCREASE IN SALINITY	MAINTAIN DISANENG DAM AT LOW LEVELS
2)	DWELLINGS AND INFRASTRUCTURE FLOODED	RELOCATE INHABITANTS REINSTATE RESIDENCES (COMMUNITY CO-OPERATION)

REGION 2

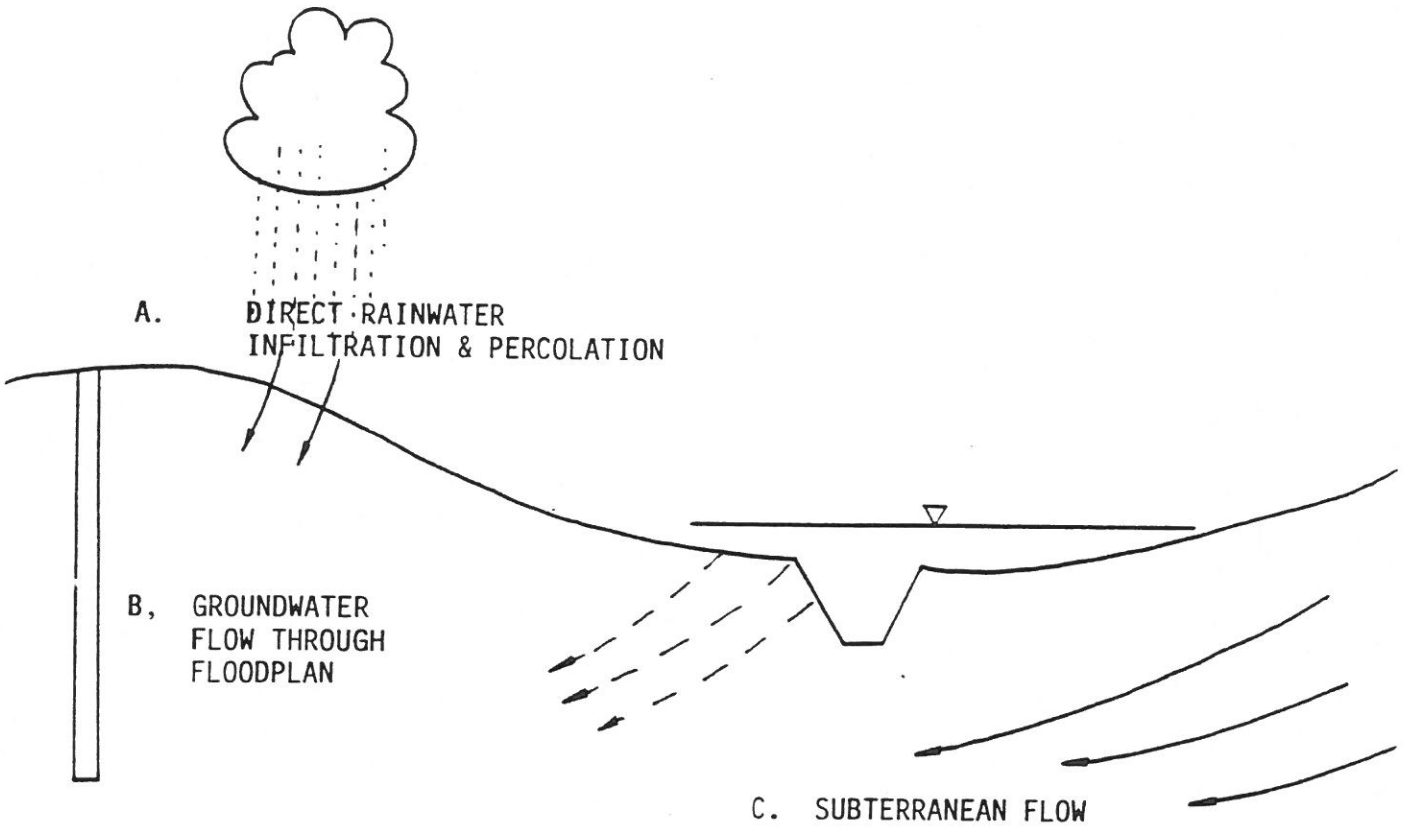
ISSUE	Proposed Ameliorative Measure
REDUCED SURFACE RUNOFF DOWNSTREAM	None, since storage sites are still significantly smaller than the surface runoff still entering these basins. Beneficial use of water favours the relatively deep upstream sites at Modimola & Disaneng Dams.
POTENTIALLY REDUCING LOCALISED GROUNDWATER REPLENISHMENT	(i) Further study to : (a) Refine a conceptual groundwater recharge model (b) Estimate the effect which reduced flood runoff may locally have on groundwater recharge If necessary, consider amending the Molopo River System operating rules to minimise any potential impact which can be predicted - with certainty - to arise from the construction of the Modimola Dam.
POTENTIALLY AFFECTING GRAZING IN MOLOPO RIVER FLOODPLAIN	(i) Further study to: (a) Determine relative importance of riverine vegetation to stock (b) Assess the potential impact of reduced flood runoff on fodder flow for stock (c) Recommend ameliorative measures: e.g. Operate Disaneng Dam in a manner to minimise impact.

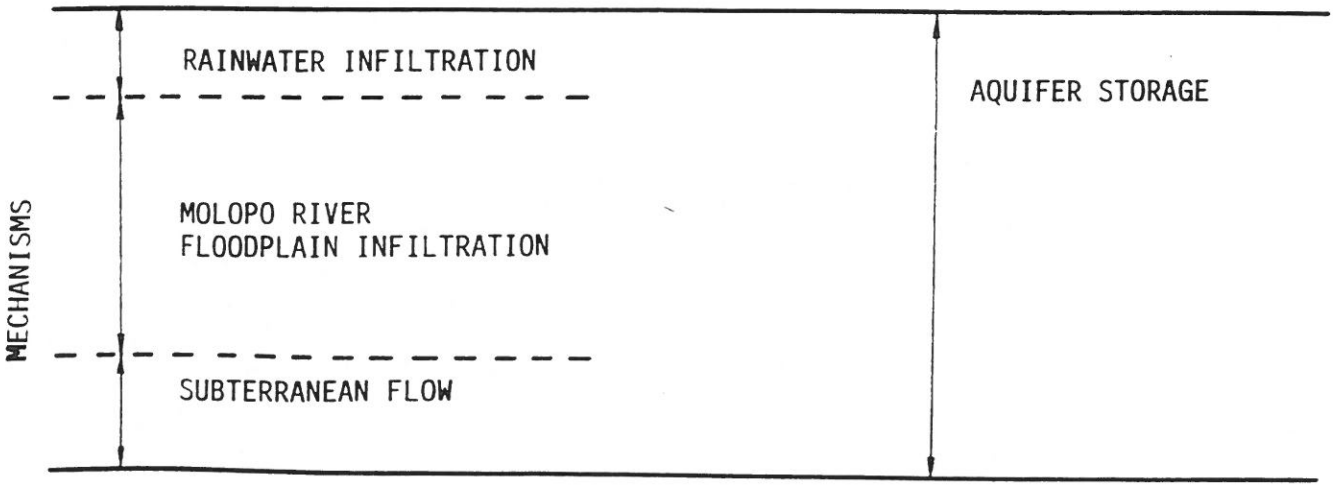
FLOOD SURFACE RUNOFF MODEL FOR
MODIMOLA - DISANENG - MOLOPO RIVER REACH
(TABLES 1 & 1A)



CONCEPTUAL

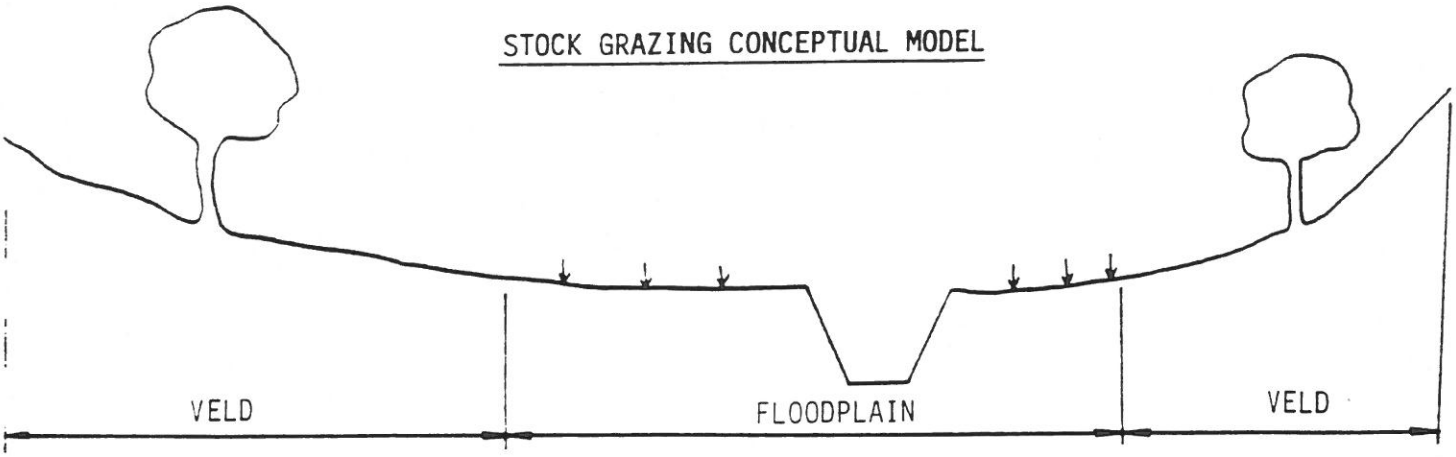
GROUNDWATER RECHARGE MODEL



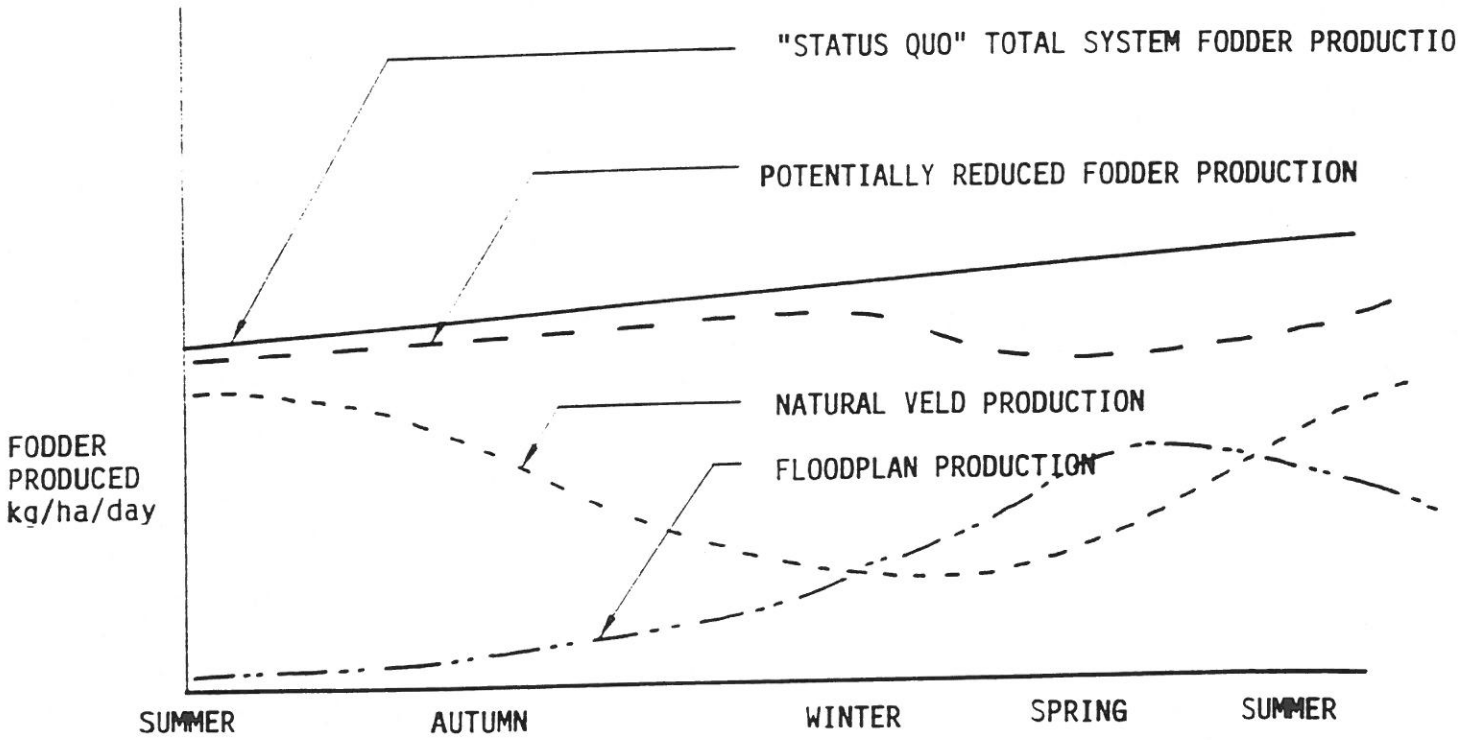


* RELATIVE MAGNITUDE OF INDIVIDUAL RECHARGE MECHANISMS TO BE DETERMINED BY FURTHER STUDY AS RECOMMENDED IN REPORT.

STOCK GRAZING CONCEPTUAL MODEL



SEASONAL PALATABLE FODDER FLOW



SHOULD BOTSWANA CONSIDER THIS POTENTIAL IMPACT TO BE A CAUSE FOR CONCERN, FURTHER STUDY SHOULD BE AIMED AT DETERMINING:

a) The relative importance of Floodplain Productivity in the total fodder flow.
b) The effect, if any, of Modimola Dam on reducing total fodder production.
c) Recommending ameliorative measures.

ATTITUDINAL FACTORS

Messrs SETPLAN frequently encountered the attitude in Botswana villages that the Disaneng Dam was to blame for the water shortages experienced in villages proximate to the Molopo River.

The perception therefore exists that the building of any further dam such as the Modimola Dam wiwll inevitably result in a worsening of the water supply situation.

EVN could find no grounds for the reported attitude, but we consider that the perception that exists should be negated by recalling the true facts to the local inhabitants:

a) The 1980's drought was the worst in living memory : some commentators have put the probability of occurrence of such an extreme event at once in 200 years.

The building of the Modimola Dam will not - of itself - have any significant impact on the water supply situation.

Although very improbable, a drought of disastrous proportions may still occur during this century, but the occurrence of such an extreme event should not be linked to the Modimola Dam construction.