Report P W 120/00/0390

RSA-KWAZULU PERMANENT WATER COMMISSION

MHLATUZE CATCHMENT STEERING COMMITTEE

MHLATUZE RIVER BASIN STUDY

RECONNAISSANCE STUDY OF THE WATER RESOURCES OF AND THE WATER REQUIREMENTS FROM THE MHLATUZE RIVER CATCHMENT

VOLUME 1 OF 2

MAIN REPORT

APRIL 1990

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MHLATUZE RIVER BASIN STUDY

RECONNAISSANCE STUDY OF THE WATER RESOURCES OF AND THE WATER REQUIREMENTS FROM THE MHLATUZE RIVER CATCHMENT

EXECUTIVE SUMMARY

The Government's decision in 1965 to develop a deep water harbour at Richards Bay and a rail link to the interior created a basis for large scale development in the region. With the commissioning of the harbour in 1976 the first stage of the project was completed and the foundation was laid for further development.

In 1973 a White Paper entitled "Mhlatuze Government Water Scheme, Goedertrouw Dam" (WP.Q-'73) announced Government's decision to construct a large dam on the Mhlatuze river to secure an adequate water supply to the Richards Bay area. A supplementary report in 1979 (WP.O-'79) secured the additional funds required to complete the dam and the scheme was in operation in the early eighties.

White Paper Q-'73 indicated that Goedertrouw Dam should be capable of supplying projected water demands up to about 1995. To date some of the major irrigation developments that were anticipated in 1973 have not materialised and, as a result, there is general acceptance in the area that there is adequate water for years to come.

Recently announced plans to go ahead with the development of large areas under irrigation, together with anticipated expansion by the major industrial water user in Richards Bay, have necessitated a reassessment of the water supply system.

This report presents a reconnaissance level assessment of available water resources in the Mhlatuze Basin System together with an assessment of current and projected water demands. The degree to which available water

resources can meet current and future demands has been assessed by means of a systems analysis.

The study shows that, although irrigation development has been slower than anticipated in 1973, growth in industrial water demand was more rapid than expected, and as a result the system will fail to meet demands if new irrigation schemes are developed. In fact, if demands grow as expected at present, the system will require augmentation from as early as 1993. The study goes on to show that should none of the major new demands materialise, and if demand in the area grows uniformly in concert with growth in other centres in South Africa, the system would still require augmentation before the turn of the century.

If an augmentation scheme is to be implemented to meet anticipated demands between the years 2000 and 2020, it would have to be a major augmentation scheme capable of delivering on average at least 175 million cubic metres of water per annum.

The report concludes by recommending that three further studies commence as soon as possible. Two would be short term studies aimed at interim management of the system until augmentation can be provided. The third is a study of possible augmentation schemes.

RECONNAISSANCE STUDY OF THE WATER RESOURCES OF AND THE WATER REQUIREMENTS FROM THE MHLATUZE RIVER CATCHMENT

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RECONNAISSANCE STUDY OF THE WATER RESOURCES OF AND THE WATER REQUIREMENTS FROM THE MHLATUZE RIVER CATCHMENT

1. TERMS OF REFERENCE

The Department of Water Affairs (DWA) commissioned Watermeyer Legge Piesold & Uhlmann (WLPU) to evaluate the water resources of the Mhlatuze basin in relation to short term water demands and to identify areas calling for further studies.

The reconnaissance study was to include the following:

- appraisal of the hydrology of the Mhlatuze river, its tributaries and the coastal lakes.
- assessment of the underground water resources, especially along the coastal plain.
- determination of the existing water demands and water rights and projection of demands to 1995 and 2020.
- determination, by system analysis, of the degree to which the water resources can meet present and future demands and with what reliability, and an indication of the confidence limits of the reliability assessment.
- identification of long term development options.
- indication of areas for further study, with proposals for such investigation.

2. INTRODUCTION

2.1 Background

Richards Bay and the surrounding areas are experiencing rapid economic growth and consequently water demands are rising steeply. The Mhlatuze Water Board (MWB) is responsible for the control and bulk distribution of treated water and for disposal of used water within its area of supply while the Department of Water Affairs (DWA) is responsible for the development of the sources of raw water supply and for the administration of the pollution control sections of the Water Act. The Nkwaleni, Heatonville and Mfule Irrigation Boards are responsible for the control of organised irrigation in the areas lying in RSA and the Department of Agriculture and Forestry for the KwaZulu areas.

In the middle to lower reaches of the Mhlatuze river irrigation use is presently subject to works permits from the Minister of Water Affairs as this part of the river basin lies within a Government Water Control Area. The intention is to schedule these areas in terms of section 63 of the Water Act in the near future. Certain rights to use of water from the Mhlatuze river and from Lake Cubhu have been entrenched in Water Court Orders. Beyond the confines of the Government Water Control Area and the area of supply of the MWB, use of water from the public streams for irrigation, which would be the major use affecting the water resources, must accord with the riparian principles of equitable sharing laid down in the Water Act.

The sources of water are the Mhlatuze river and its main tributaries, the Mfule, Mhlatuzana and Nseleni, and the coastal lakes, Mzingazi and Cubhu. Flow from the Mhlatuze upstream of the main tributaries is regulated by means of the Goedertrouw dam which is the main component of the Mhlatuze Government Water Scheme.

The White Paper Q-'73 associated with the Mhlatuze Government Water Scheme (Republic of South Africa, 1973) sets out the history of development of the supply area and the water demands as at 1973, with projections for the quinquennia 1975 through 2000. The White Paper indicated that a shortfall in supply would be unlikely to occur before the period 1995-2000.

In an internal report (Department of Water Affairs, 1985) prepared by engineers Geldenhuys and Perkins of the DWA Planning Directorate, the findings were that the projected irrigation developments in the Nkwaleni-Heatonville area and in KwaZulu would probably not materialise in full for some considerable time and that potential afforestation would also be slow to affect the river flow. Accordingly, it was suggested that the system could readily meet its commitments till the year 2000. Nevertheless, the data on which the analysis was based were considered by the authors to be inadequate and their recommendation was that additional river flow, lake behaviour and demand data be sought so that the analysis could be repeated when sufficient information had been assembled.

Although the additional information accumulated since 1985 is not substantial, an urgent further investigation has been prompted largely by announcements of impending major expansions by Mondi, Richards Bay Minerals and other principal water users. Recent press reports have it that up to R3 billion is to be invested in the area within the next three years.

At an interview in Pretoria on 26 July 1989, arranged by the Chief Engineer : Project Planning, DWA, WLPU was invited to submit a proposal indicating how the further investigation could be conducted, the personnel who would be involved, how long it would take and, for budgeting purposes, what would be the likely cost. A proposal was submitted in mid-August and a second proposal envisaging a wider scope in September 1989. After protracted discussions regarding the extent and depth of the required investigation, DWA requested WLPU in late October to proceed with a preliminary basin study of limited scope. A steering committee was appointed and the first meeting was held in Pretoria on 7 November 1989.

2.2 General Description of the Basin

2.2.1. Physiography

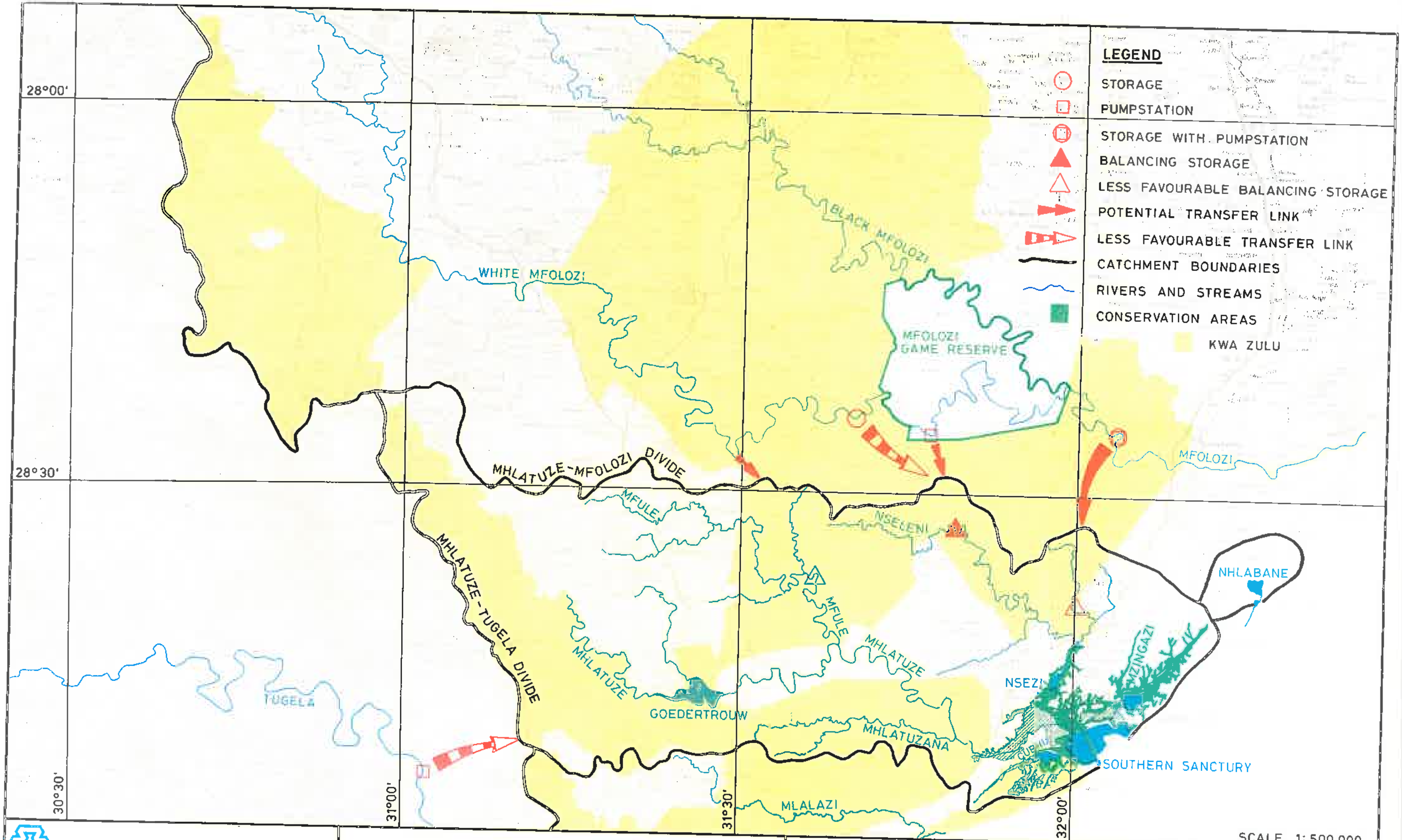
Plate I at scale 1:500 000, shows the study basin in relation to its neighbouring catchments, Tugela and Mfolozi. As may be noted, most of the Mhlatuze catchment lies between latitudes 28°30′ and 28°50′S and longitudes 31° and 32°E. The river system transverses three distinct zones of Natal, viz. Middleveld, Lowveld and Coastal Belt.

Rising in the highlands west of Babanango, elevation 1600 m MSL, the Mhlatuze flows south-eastwards through rolling grassland and extensively cultivated terrain of the Middleveld before entering rugged broken country through which it winds its way, paralleling the Tugela system, till it reaches the headwaters of the Goedertrouw dam, having dropped 1400 m to the Lowveld in a direct distance of about 60 km.

The directional trend becomes almost due east and the gradient flattens to about 1:300 as the river flows the remaining 60 km across a wide alluvial plain to Richards Bay.

A major northbank tributary is the Mfule which rises in the undulating grasslands north of Melmoth. The Mfule, too, flows through rough broken terrain before joining the Mhlatuze, at elevation 75 m MSL a direct distance of about 20 km downstream of Goedertrouw dam.

A second major tributary is the Nseleni which drains into Lake Nsezi, the overflow from which forms extensive wetlands through which the Mhlatuze flows to the partitioned Sanctuary area of Richards Bay. The northern boundaries of both the Mfule and the Nseleni catchment butt on the southern boundary of the White Mfolozi catchment.



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POTENTIAL AUGMENTATION LINKS

PLATE 1

The sandy plain behind the coastal dunes is drained by two streams which flow into the Mhlatuze system - the Mdibi feeds Lake Mzingazi from the north and the Tatatweni receives the outflow from Lake Cubhu in the south.

There are several other smaller permanent lakes in the high rainfall coastal area. Lakes Nsezi, Mzingazi and Cubhu have all three been increased in size by means of artificial embankments and crude spillways.

2.2.2 Climate

The study area lies in the sub-humid summer rainfall region of South Africa and within the influence of the tropical cyclones. Except for the sandy coastal belt and perhaps the Middleveld source area, the catchment lies within the zone assigned by Kovacs the highest runoff factor, viz K=5,6 (Department of Water Affairs, 1989).

Annual rainfall is highest in the coastal belt (MAP in the range 1200-1400 mm) and declines inland to the 700-800 mm range in the Lowveld and Middleveld, rising to the 900-1200 mm range only in the southeast-facing mountains of the source area.

There are distinct rain shadows in the northern and especially north-western slopes of the mountain ranges.

Rainfall is dealt with in detail in the Chapter 4, Hydrology.

Examination of temperature statistics for Melmoth, Empangeni and Richards Bay, being reasonably representative of the three physiographical zones of the study area, indicate fairly similar ranges for the Coastal Belt and Lowveld in both average daily minimum to maximum temperature and relative humidity, viz. 16°C to 27°C and 82-83% respectively. Melmoth, as may be expected, is somewhat more temperate, viz. 13°C to 25°C and 77% respectively.

2.2.3 Soils and Vegetation

The predominant soil types are lithosols with arenosols in the coastal belt and montmorillonitic clays in the middle reaches - mainly in the irrigation areas.

Vegetation is primarily Ngongoniveld, coastal forest and Zululand thornveld, with lowveld tropical bushveld in the middle reaches of the Mhlatuze and Mfule catchments and highveld sourveld in the upper Mhlatuze.

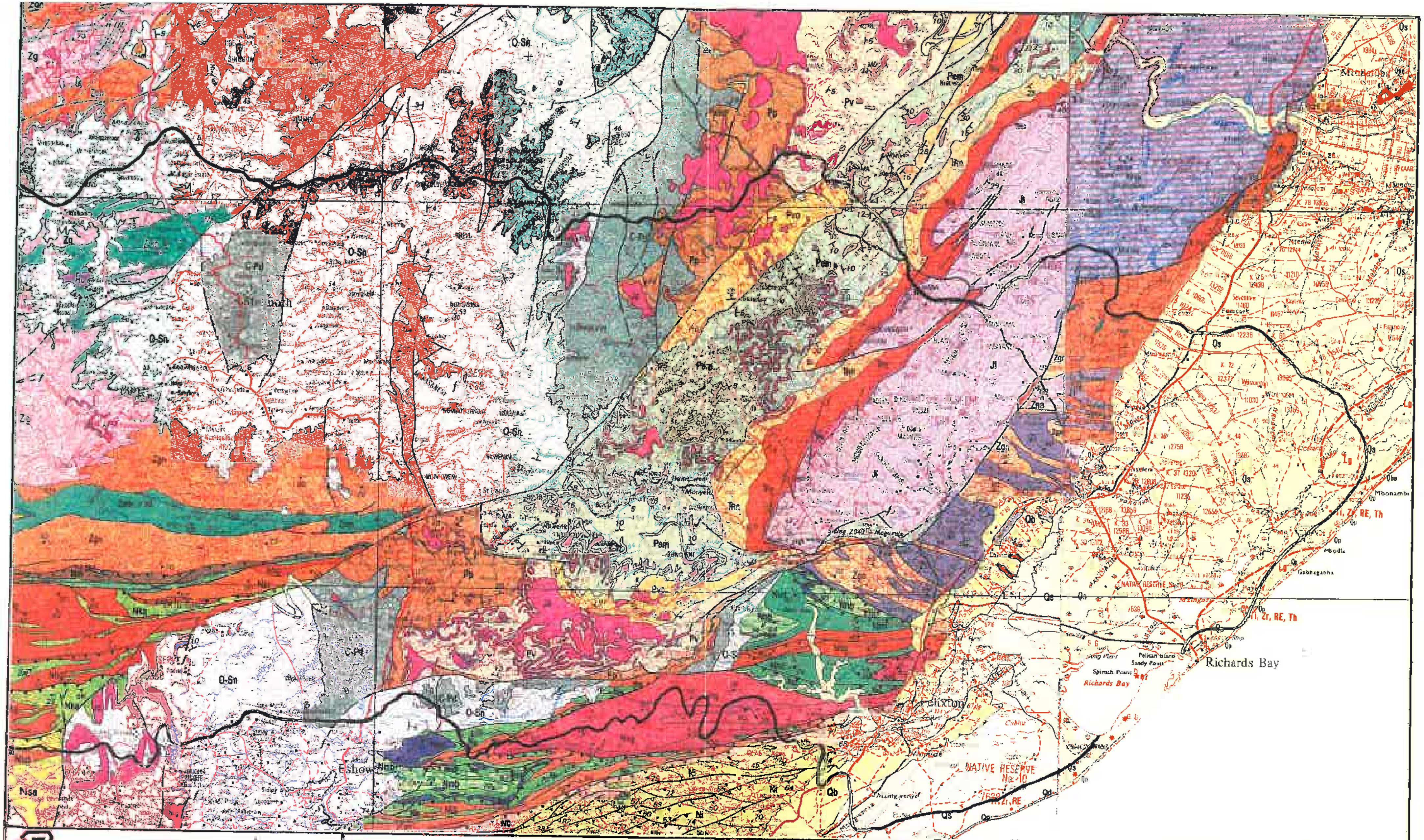
Much of the catchment around Melmoth and of the Coastal Belt has been planted to exotic forest and large areas of the higher rainfall areas of the lowveld are given over to dryland sugarcane. The predominant crop in most of the irrigated areas is sugarcane.

2.2.4 Geology

Plate 2 is a two part detailed geological map of the area embracing the Mhlatuze catchment. Rocks of the Karoo sequence underlie much of the Middleveld and upper catchment of the Mhlatuze - primarily Pietermaritzburg shales and Dwyka Tillite, locally intruded by sills of dolerite.

The Natal Group, the Natal Metamorphic Province and the Pongola Sequence comprise hard rock formations of conglomerate, sandstone, shale, grit, granitic gneiss, quartzitic schist, amphibolite, serpentine, gabbro and basalt.

The same group of sequences extends into the Lowveld, the greater portion of the region being occupied by the Karoo Sequence. The sequence here comprises a thick succession of Dwyka Tillite, Ecca and Emakwezini shales, coal and sandstone, Ntabene and Nyoka mudstones and sandstones and Letaba basalt. Abundant dolerite dykes and sills intrude the Ecca and Emakwezini formations.



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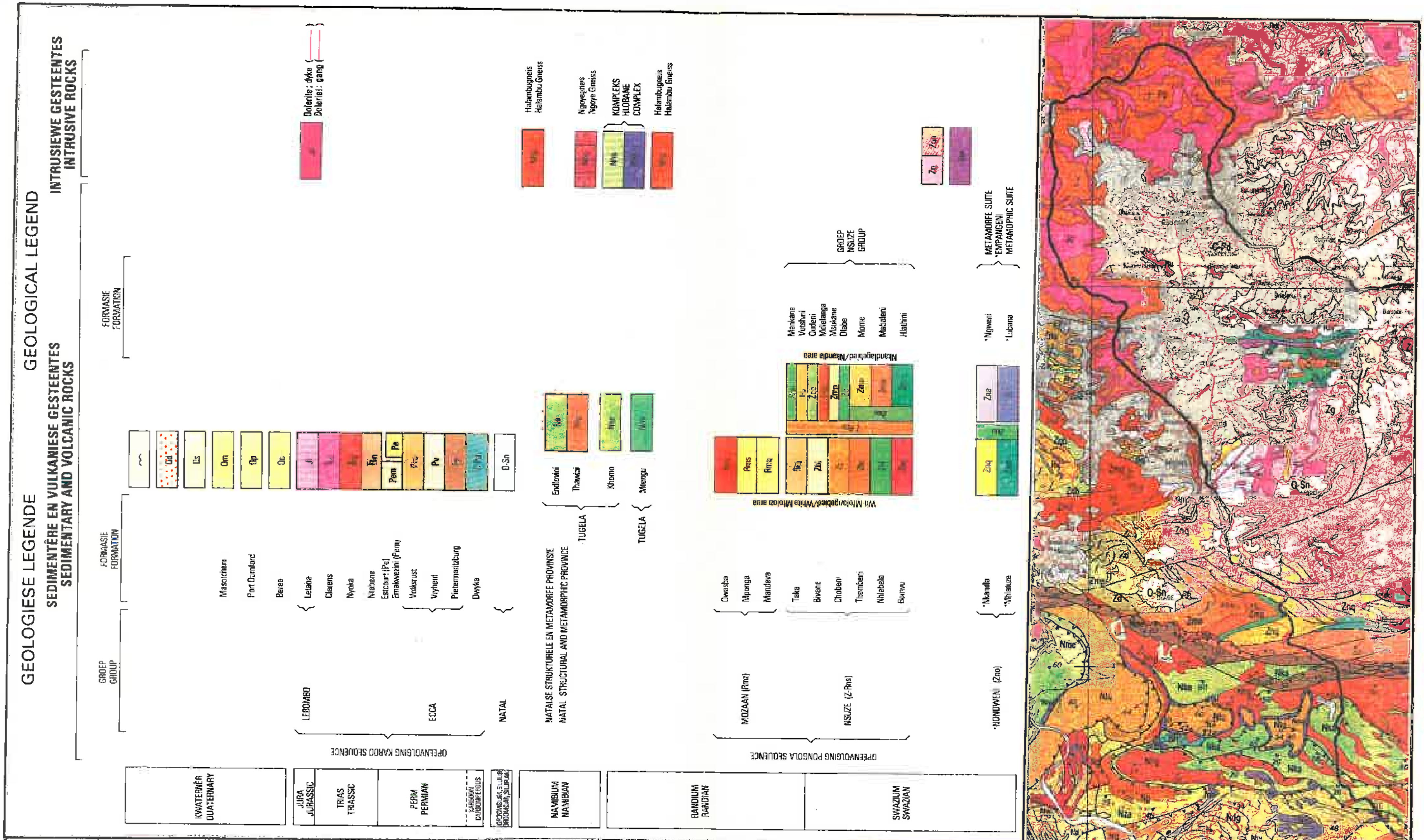
MHLATUZE RIVER CATCHMENT STUDY

GEOLOGICAL MAP - PART 1 OF 2

PLATE 2



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GEOLOGICAL MAP - PART 2 OF 2

PLATE 2

WLPU CONSULTING ENGINEERS

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Alluvial gravels and sands appear in the lower reaches of the Mhlatuze. The Coastal Belt, in which the lakes Nsezi, Mzingazi and Cubhu occur, comprises quaternary alluvial and aeolian red to grey fine-grained clayey sand.

Most of the hard rock formations are extensively folded and faulted. Close to the coast the strike is predominantly north-south while further inland the direction is east-west. The depth of weathering varies considerably and is a function of the morphological history of the area. The abundant dolerite dykes and sills are largely responsible for local displacements of the Karoo sediments.

3. WATER DEMANDS

3.1 Agricultural water demand

Irrigation development in the Mhlatuze river basin lies mainly downstream of Goedertrouw dam. Much of the irrigable area downstream of the dam was proclaimed a Government Water Control Area in June 1977 (Republic of South Africa, 1977). At present, control is exercised in the South African part of the basin by three irrigation boards and in the KwaZulu part by the KwaZulu Department of Agriculture and Forestry.

Each irrigation board has a scheduled irrigation area and a water quota determined by the Department of Water Affairs. The product of scheduled area and quota prescribes the maximum intended water usage by each irrigation board. The quota was determined to suit the estimated requirements of sugar cane. As the water required for irrigation may be less than the quota in certain areas, or the crop irrigated may require less water than sugar cane (eg. citrus), the actual area under irrigation may be larger than the scheduled area, but the total volume of water used should not exceed the product of quota and scheduled area. Scheduled areas and water quotas have been revised since publication of the initial White Paper Q-'73. The figures presented in this report are current figures obtained from a field survey and confirmed by the Department of Agriculture at Cedara.

A short report on the field survey of water abstraction points along the Mhlatuze river and its major tributaries appears in Appendix A.

Table 3.1 is a summary of current (1989) irrigation water demands as well as projected demands for 1995 and 2020. The table allows for 20% distribution losses and for a reduced draft of 40% of the full draft for 25% of the time. This reduced draft for 25% of the time is similar to that allowed in the initial White Paper Q-'73. The following notes apply to the figures given in Table 3.1:-

Table 3.1 Agricultural Water Demands

Description	Scheduled Area (ha)	Water Quota $m^3/h/a$	Area in 1989 (ha)	Usage in 1989 $10^6 m^3/a$	Area in 1995 (ha)	Demand in 1995 $10^6 m^3/a$	Area in 2020 (ha)	Demand in 2020 $10^6 m^3/a$	Water Source
Irrigated Cane:									
South Africa:									
Nkwaleni	5726	12600	5068*	63.857	5068	63.857	5568	70.157	Mhlatuze
Mfule	914	11800	450@	5.310	450	5.310	450	5.310	+ Mfule
Heatonville	5170	11800	1100!	12.980	5170	61.006	5170	61.006	Mhlatuze
Sub-totals	11810		6618	82.147	10688	130.173	11188	136.473	
KwaZulu:									
Macekane	2000	11000	0+	0.000	750	8.250	830	9.130	Mhlatuze
Kwadlama		11000	0+	0.000	220	2.420	220	2.420	Mhlatuze
Madlebe		11000	0+	0.000	450	4.950	500	5.500	Mhlatuze
Bijela		11000	0+	0.000	450	4.950	450	4.950	Mhlatuze
Sub-totals	2000		0	0.000	1870	20.570	2000	22.000	
Irrigated Cane Totals			6618	82.147	2558	150.743	3188	158.473	
Irrigated Other Crops									
Citrus		10000	1090	10.900	1090	10.900	1090	10.900	Mhlatuze
Other		10000	1166	11.660	1166	11.660	1166	11.660	+ Mfule
Irrigated Other Crops Totals:			2256	22.560	2256	22.560	2256	22.560	
Riparian Demand				0.000		9.000		9.000	
Stock Watering Demands				1.700 $		1.700		1.700	Mhlatuze
Sub Totals	13810	454627	8874	106.407	14814	184.003	5444	191.733	
Distribution Losses	20%			21.281		36.801		38.347	
Full Water Demand				127.688		220.803		230.079	
Reduced Water Demand	40%			51.075		88.321		92.032	
Average Water Demand				108.535		187.683		195.567	

Notes:

* 1615ha Irrigated from the Nkwaleni Canal, the balance is irrigated by pumping from the Mhlatuze river.
@ 414ha Scheduled from Mhlatuze river, the rest to be irrigated from the Mfule river.
! 1100ha is the area currently irrigated. Figure obtained from Department of Agriculture at Cedara.
* @ ! All figures confirmed with the Department of Agriculture at Cedara. Natal. 28/11/89.
\+ Areas obtained from the Director of Agricultural Engineering. Ulundi.27/11/1989
$ Figures from KwaZulu Catchments Development Potential Study. Mhlatuze river. Nov. 1989. EVN.
\- Water quotas confirmed with DWA Regional Director for Natal. 28/11/89.

3.1.1 Nkwaleni Irrigation Board

The board administers a scheduled area of 5726 ha with a water quota of 12 600 m^3/ha/a. About 1615 ha is irrigated from the unlined Nkwaleni canal which brings water from Goedertrouw dam. The remaining area is irrigated by pumping directly from the Mhlatuze river.

The area is fully developed with some 5068 ha under cane and 658 ha under other crops (mostly citrus). Further growth is currently restricted by excessive pumping costs. A proposed replacement of the canal by a pipeline would recover some head from Goedertrouw dam and thus make irrigation of a further 1000 ha possible. About half of this area should have soils suitable for irrigation.

It is difficult to estimate losses from the unlined canal but observations made by the farmers put the losses as high as 20% to 25% between the dam and the first irrigator. Water lost from the canal seeps back into the Mhlatuze river and is used by downstream irrigators. Although this water is not lost from the system it should be allowed for as an abstraction from Goedertrouw dam in the system analysis.

Table 3.1 indicates irrigated areas in 1989 and 1995 to be the same, but allows for an additional 500 ha of irrigated cane by 2020, on the assumption that the canal will in due course be replaced by a pipeline.

3.1.2 Mfule Irrigation Board

The board administers a scheduled area of 914 ha with a water quota of 11 800 m^3/ha/a. The schedule comprises 414 ha from the Mhlatuze river and 500 ha from the Mfule river. The area is served by an unlined canal. Water is pumped into the canal from the Mhlatuze river and, when water is available, diverted into the canal from a weir on the Mfule river, i.e.

flow in the canal can be in either direction. Because of this arrangement it is not possible to distinguish what area is being irrigated from which source. The board is currently irrigating some 500 ha of which some 450 ha is irrigated with water pumped from the Mhlatuze river and 50 ha with water from the Mfule. To extend the area would require storage in the Mfule.

The area scheduled from the Mhlatuze river is fully developed, with some 450 ha under cane and 50 ha under other crops. Without storage on the Mfule river, further irrigation development in this area appears unlikely. Table 3.1 indicates no growth and estimates of irrigated areas for 1989, 1995 and 2020 show no change.

3.1.3 Heatonville Irrigation Board

The board administers a scheduled area of 5170 ha with a water quota of 11 800 m^3/ha/a. At present only 1100 ha of riparian land is under irrigation. Design of the irrigation system for the rest of the area is in hand. With the Tongaat-Hulett sugar mill providing the impetus, the remaining 4059 ha on the schedule is expected to be fully developed before 1995. Indications are that the irrigation scheme could be operational in 1992. Excessive pumping costs severely limit further expansion.

Water in the Mhlatuze basin is becoming scarce, and as a result it is unlikely that the Department of Water Affairs would consider extending scheduled irrigation areas. As development in excess of the schedule in Nkwaleni appears simpler than similar development in Heatonville, no growth is anticipated for Heatonville after 1995. Accordingly Table 3.1 indicates no change in irrigated area for 1995 and 2020.

3.1.4 KwaZulu

In terms of the White Paper WP Q-'73 provision has been made to supply supplementary water for the irrigation of 2000 ha at a quota of 11 000 m^3/ha/a. None of this is at present irrigated but plans are in hand to develop a total of 1870 ha in four schemes, namely: Macekane, Kwadlama, Madlebe and Bijela. The Department of Agriculture and Forestry does not contemplate any further development before 1995.

There is some 4000 ha of irrigable land in KwaZulu within the Mhlatuze river basin. The 2000 ha in excess of the schedule lies closer to the higher rainfall coastal region than the roughly 2000 ha currently under development, with the result that the incremental yield attributable to irrigation diminishes towards the coast and development becomes less attractive. At present there are no definite plans for development of the additional areas.

Tongaat-Hulett have studied the feasibility of extending irrigation to the east of Heatonville with a dam on the Ukulu river. The study concluded that 1000-1430 ha could be irrigated on properties riparian to the Ukulu river owned by Scotts Properties Limited, part of the Tongaat-Hulett Sugar Ltd group.

This area is outside the Government Water Control Area and therefore in terms of the Water Act of 1956 a permit would be required for the building of storage capacity in excess of 250 000 m^3 or diversion of more than 110ℓ/s on any one property.

It is unlikely that DWA would sanction the development as competition for industrial water supply is already strong. Tongaat-Huletts' proposed development would adversely affect the yield at Lake Nsezi as the MAR at the proposed dam is about a quarter of that at the lake. In the circumstances, this proposed development has not been included in Table 3.1.

The 1870 ha currently being developed in KwaZulu, together with the 4059 ha being developed at Heatonville, represents a 76% increase which, if the ratio of dryland cane to irrigated cane remains unchanged, would imply that sufficient cane will be produced to accommodate the roughly 50% increase in supply required to bring the Tongaat-Hulett mill up to full production capacity. Accordingly, the projected irrigated area in KwaZulu planted to cane in the year 2020 is put at 2000 ha (i.e. the scheduled area), thus indicating very little growth between 1995 and 2020. The figure may require review at some time in the future.

3.1.5 Other crop irrigation

Table 3.1 also lists other crop irrigation demands. The crops suggested are : mainly citrus, pastures and bananas and constitute roughly 30% of the current pattern. Citrus is the main crop in this category and demands considerably less water than cane. Water usage in Table 3.1 was based on a quota of 10 000m^3/ha/a.

With current expansion of the irrigated cane area the percentage under the heading "other crops" will quickly drop to about 17%, at which level these will not significantly affect monthly water demand figures.

3.1.6 Stockwatering demand

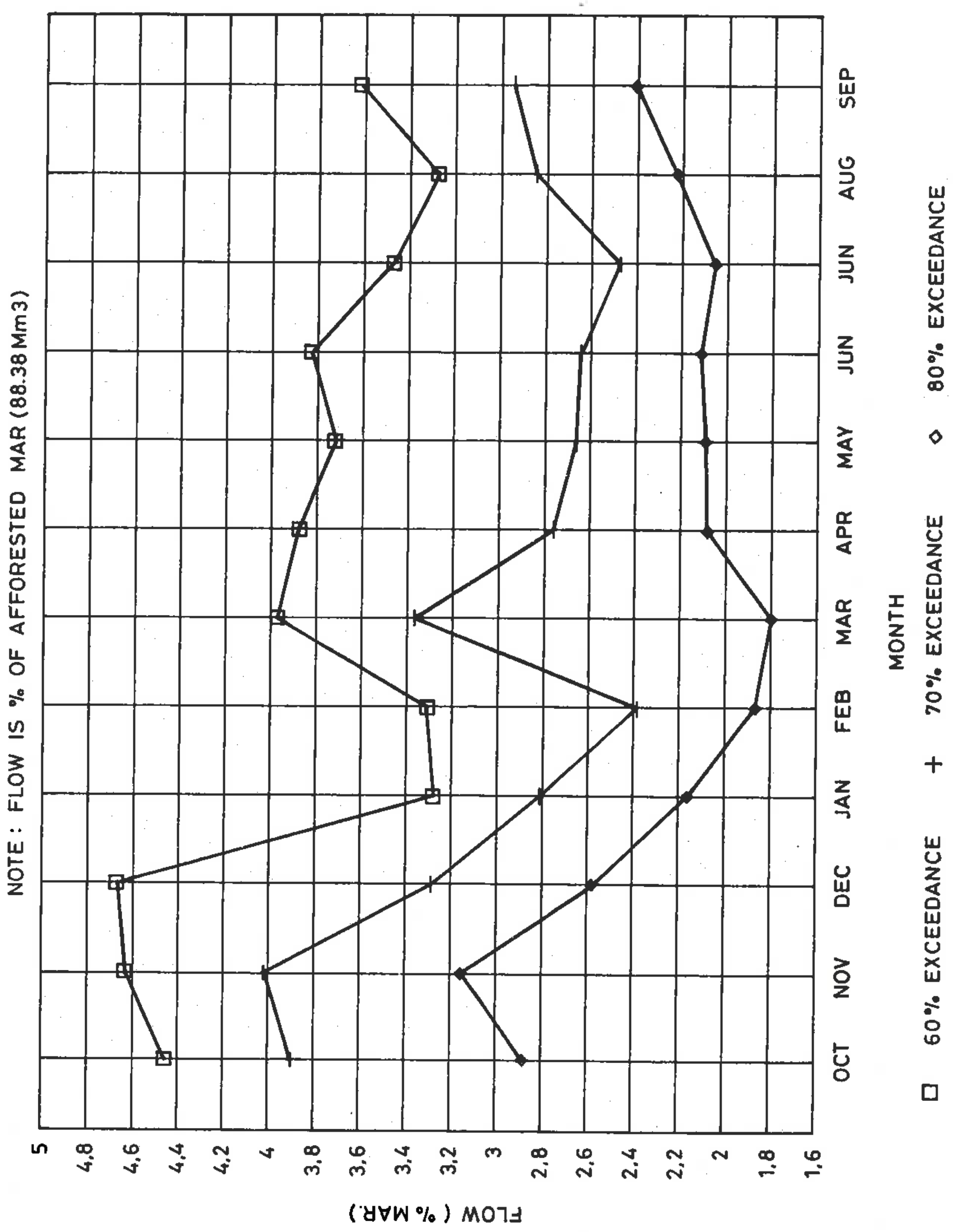
The current stock water demand in the parts of KwaZulu that fall within the Mhlatuze river basin was extracted from the KwaZulu Catchments Development Potential Study (Eksteen, v d Walt & Nissen, 1989). No allowance has been made for growth as the carrying capacity of the veld is already exceeded. Figures are listed in Table 3.1.

3.1.7 Riparian Water Users

The Mfule and Nseleni catchments, as well as the Mhlatuze catchment upstream of Goedertrouw dam, fall outside the Government Water Control Area. Riparian farmers are entitled to fair shares of the normal flow of these rivers and to as much of the surplus water as they can beneficially use for irrigation of riparian land, subject to constraints on maximum abstraction rates and magnitude of permissible storage determined in the Water Act. It seems that few farmers are exercising their rights in the upper parts of the Mhlatuze and Mfule catchments, probably because of the steepness of the terrain and dearth of suitable soils. In fact the potential for irrigation development in both the Mfule and upper Mhlatuze catchments is so poor that water demand for irrigation in these areas can be neglected.

A feasibility study commissioned by Tongaat-Hulett some time ago, identified 1400 ha of irrigable land in the valley of the Ukulu, a lower tributary of the Nseleni. To irrigate the entire area would require storage well in excess of 250 000 m^3, which is the limit that may be constructed without a permit. The likelihood that DWA would recommend the issue of such a permit appears remote and only part of the area is therefore ever likely to be developed. In addition to this block of land, there are other scattered irrigable areas in the Nseleni basin. A conservative estimate of land likely ever to be irrigated from run-of-river is 1000 ha.

Figure 3.1 is a flow duration curve constructed from the simulated runoff record for the Nseleni river over the period 1921 to 1985. An approximate estimate of normal flow is taken to be the flow exceeded 70% of the time during the irrigation season. From Figure 3.1 an estimate of the normal flow would be about 2,7 per cent per month which is equivalent to $28{,}6x10^6m^3/a$.



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MHLATUZE RIVER CATCHMENT STUDY
NSELENI RIVER
FLOW DURATION CURVE

FIG. 3,1

If 1000 ha is developed with an irrigation quota of 10 000 m^3/ha/a and an allowance of 10% is made for return flow, the maximum usage would be 9 $x10^6m^3/a$, which is substantially less than the 28,6 $x10^6m^3/a$ currently available as normal flow. An allowance of 9 $x10^6m^3/a$ has accordingly been made for riparian users in the Nseleni catchment.

3.1.8 Forestry

Although forests are not irrigated, their water demand can be measured in terms of a reduction in runoff, and as such are included in the assessment of agricultural water demands.

The Mhlatuze is zoned as a category III catchment which allows new afforestation (after 1972) to extend until the new afforestation uses 10% of the mean annual runoff of the catchment. As a result of afforestation prior to 1972 the allowable new afforestation permit area exceeds the estimated biological forestry potential. See list of Afforestation Permits issued to 1989 (Department of Environmental Affairs, 1989a).

Currently afforested areas were extracted from a report Commercial Timber and Roundwood Processing in South Africa 1987/88 (Department of Environment Affairs, 1988). Forests in the magisterial districts of Babanango and Mtonjaneni fall inside the study catchment area. From the 1:250 000 map it is estimated that 50% of the afforested areas in the magisterial districts of Mtunzini and lower Umfolozi fall inside the study catchment. Table 3.2 lists afforestation in the study catchment and presents projected areas for 1995 and 2020.

Prediction of growth in afforestation is difficult. Mondi paper mill would require an additional 40 000 ha of forest to feed the planned doubling of their mill by about 1995. However, some of the feedstock for the new plant may come from a proposed bagasse pulping plant at Felixton mill, and some may be imported from areas outside the study catchment (e.g. Mtunzini or lower Umfolozi).

A limit to possible expansion is provided by the biological forestry potential (i.e. the limits imposed by climatological, pedological and suchlike features) which for the study catchment is about 90 300 ha. See Strategic Forestry Development Plan for South Africa, p196 (Department of Environment Affairs, 1989b).

The area of afforestation in Zululand increased at a rate of some 10% in 1987/88. If the growth rate is maintained as a result of demand for wood (eg. by Mondi), the 90 300 ha biological forestry potential of the catchment could be fully exploited by 1995. However, if expansion plans at Mondi are delayed, or if feedstock is derived from another source such as a bagasse pulping plant, the growth rate may be closer to the national average which is about 2%. At this rate the afforested area in the study catchment by 1995 will be about 66 600 ha. Table 3.2 presents projected areas in 1995 and 2020 for scenarios of both slow and fast development.

3.2 Industrial water demand

There are a number of major industrial water consumers within the study area, mostly around Richards Bay. This section deals with major industrial water users only; minor industries are included in the chapter on domestic water demand.

Current water usage can be established fairly accurately but to assess future demands is more difficult. In most cases an increase in demand is related to expansion of a plant or factory. The decision to expand is usually an economic one, and is affected by factors such as demand, political climate, sanctions, market prices and exchange rates. These factors change continuously and affect planning markedly. Most planning is strategic, and it is often not in the interests of the company involved to allow open publication of their plans. This is true of a number of companies within the study area.

Table 3.3 summarises current (1989) water usage and estimated demands in 1995 and 2020. As planning seldom extends more than 5 or 10 years ahead, the table allows for a percentage long term currently unidentified growth between 1995 and 2020. Percentages of 2%, 3%, 4% and 5% are allowed for different growth scenarios. As disposal of industrial effluent is an important factor in the water balance, effluent flows are also recorded in the table.

The following notes apply to the figures presented in Table 3.3.

3.2.1 Richards Bay Minerals

At present Richards Bay Minerals (RBM) operate to the north of the study catchment, their main water source being Lake Nhlabane which is outside the Mhlatuze river catchment. They are currently drawing some 50 000 m^3/d from Lake Nhlabane which is more than the estimated firm yield of the lake. As backup source, RBM holds a 20 000 m^3/d allocation from Lake Mzingazi. As Lake Mzingazi is also overcommitted this allocation was granted on condition the Mhlatuze Water Board would supply make-up water from elsewhere should the water level in Lake Mzingazi fall below the prescribed limit. To permit this condition to be met, RBM paid for the construction of a transfer pipeline from Lake Nsezi to Lake Mzingazi.

The make-up water is supplied by the Mhlatuze Water Board (MWB) from their treatment works at Lake Nsezi. This is not a satisfactory arrangement as it commits 20 000 m^3/d of the Board's treatment capacity to operate at a nominal charge. The Board would prefer to supply raw water directly to RBM and sell the 20 000 m^3/d of treated water to other users.

Table 3.3 Industrial Water Demand

Description	Water Right $10^6 m^3/a$	Usage in 1989 $10^6 m^3/a$	Demand in 1995 $10^6 m^3/a$	Demand in 2020 $10^6 m^3/a$	Current Effluent $10^6 m^3/a$	Effluent in 1995 $10^6 m^3/a$	Effluent in 2020 $10^6 m^3/a$	Water Source
South Africa:								
Mhlatuze Water Board	55.045	0.000	0.000	0.000	0.000	0.000	0.000	Nsezi, Mhlatuze
Richards Bay Minerals		6.393 +	25.571 +	25.571 +	0.000	0.000	0.000	Nsezi(MWB)
Alusaf	2.325	1.553	2.325 *	2.325 *	1.644	1.644	1.644	Mzingazi
Mondi Paper Mill		33.608 *	54.795 *	54.795 *	34.338	54.795	54.795	Nsezi(MWB)
Mondi Board Mill	2.502 @	1.763 *	2.115 *	2.115 *				Mhlatuze
Indian Ocean Fertilizers		5.480 #	7.671 *	7.671 *	7.306	7.306	7.306	Mzingazi(Richards Bay)
Tongaat-Hulett Sugar Mill	1.791 !	1.461	1.791	1.791	1.461	1.791	1.791	Mhlatuze
Possible future development:								
Chemical industry		0.000	6.210	11.690	0.000	2.937	5.516	Mhlatuze(MWB)
Ethanol plant		0.000	1.461	1.461	0.000	1.680	1.680	Mhlatuze(MWB)
Bagasse pulping plant		0.000	16.804	16.804	0.000	5.041	5.041	Mhlatuze(MWB)
Mineral mining		0.000	3.653	3.653	0.000	2.557	2.557	Mhlatuze(MWB)
Sub-Totals:	61.663	50.256	122.397	127.876	44.749	77.752	80.331	
KwaZulu:								
KwaZulu Handcraft Centre	0.001	0.001	0.001	0.001	0.001	0.001	0.001	Mhlatuze
Sub-Totals:	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
Sub Totals	61.664	50.257	122.398	127.877	44.750	77.753	80.332	
Slow long term growth	2.0%			200.807			127.561	
Total for slow growth				206.286			130.140	
Fast long term growth	4.0%			326.292			207.276	
Total for fast growth				331.772			209.855	

Notes:

+ Estimate obtained from user and excludes water used from outside Mhlatuze Basin.
* Estimates obtained directly from users.
# Water supplied by the Borough of Richards Bay.
@ Figure of 6850 is an average of two Rights, one of 7600 between May and December and one of 6100 between January and April.
  This Right also includes water supplied to Felixton by the sugar Mill for Mondi staff.
! Tongaat-Hulett pump in excess of this as they pump for Felixton and Mondi Board as well.

As their coastal dune mining operations move southwards towards Richards Bay, RBM will require additional water within the study catchment. In anticipation of this, MWB commissioned consultants in December 1989 to design a new pipeline from Lake Nsezi to supply raw water to RBM. It is expected that the new pipeline will be commissioned by mid-1991. RBM have requested that three tariffs be quoted namely for 25 000, 50 000 and for 78 000 m^3/d. MWB is planning to construct an oversized pipe (at the Board's cost) from Lake Nsezi so as to supply the RBM demand, including the current allocation from Lake Mzingazi, (thus the pipeline would have to be sized to supply 45 000, 70 000 or 98 000 m^3/d). RBM have indicated in discussions that they would require 50 000 m^3/d of additional water from MWB by 1995 and this has been allowed for in our estimates.

Demand in 2020 is more difficult to assess, as by then mining in the study catchment may be complete and mining operations will have moved north. The smelter will, however, still require water and a demand of 70 000 m^3/d in 2020 was assumed. This figure may require updating as RBM may in future draw water from the Mfolozi river. Consultants have already investigated a supply from this source.

3.2.2 Alusaf

Alusaf have a water court order entitling them to withdraw 6364 m^3/d from Lake Mzingazi. At present they are using about 4250 m^3/d on average. A future doubling of the plant, which is contemplated, would require more water but by recycling water the demand will not exceed the water court entitlement. Accordingly the demand in 1995 and 2020 is estimated as 6364 m^3/d. Alusaf at present produces some 4500 m^3/d of effluent which is pumped to the sea along with the large quantities of seawater used for cooling purposes.

3.2.3 Mondi Paper Mill

MWB supplies water to Mondi Paper Mill from Lake Nsezi. The mill currently uses 92 000 m^3/d and produces about 94 000 m^3/d of effluent. The volume of effluent exceeds that of the water used because water is produced in the wood pulping process. Recently (March 1990) the mill requested an increased allocation from the MWB and from April 1990 their demand will increase to 150 000 m^3/d as a result of recent changes to their process.

A proposed future doubling of the paper mill would increase water demand and effluent discharge to an as yet undisclosed amount but estimates range between 220 000 to 300 000 m^3/d.

Although Mondi have not announced their plans, it seems they could have the extended plant in operation by 1995. However, as higher demand figures are not firm and no date for expansion has been set demand from Mondi Paper Mill has been set at 150 000^3/d at 1995 and 2020. When the plant is doubled these figures would require review.

Mondi effluent is pumped to the sea via the sea outfall pipeline operated by the Mhlatuze Water Board.

3.2.4 Mondi Board Mill

The Mondi board mill holds a water permit (no 172N, ref. no B33/2/2110/5) to abstract water from the Mhlatuze river. As the feedstock for the mill (bagasse from the sugar mill) is seasonal, the permit allows two abstraction rates, namely, 7600 m^3/d from May to December and 6100 m^3/d from January to April. Table 3.3 records 6 850 m^3/d which is merely an average of the two allowable rates.

Mondi abstracts raw water from the Mhlatuze river, downstream of the Tongaat-Hulett pumpstation, to supply process water for the mill. Potable water is bought from Tongaat-Hulett to supply both the mill and part of Felixton town and the quantity is offset against the Mondi board mill permit. The split of potable water used in the mill and that used in the town is not clear; we have allocated potable water use to Felixton town. Mondi board mill holds a permit for the water bought from the sugar mill.

Average daily use in 1989 was about 90% of that covered by the permits, viz. the raw water from the Mhlatuze river, that pumped by the Mondi pumpstation and used in the mill (4825 m^3/d), and the potable water from the Mhlatuze river supplied by Tongaat-Hulett for Felixton town (1550 m^3/d).

A major reconstruction of the plant is being planned at the moment. It is anticipated that the plant capacity will be increased by 40% and the water demand by 20%. The work was scheduled (in 1989) to be complete by 1992 but there have been delays and it is now expected that the upgrading of the plant will be completed in 1993. Table 3.3 reflects 20% higher consumption figures for 1995.

The rotation system used to consider expansion/upgrading of the Mondi plants is such that Mondi board mill will not be due for further upgrading/expansion before 2020. Table 3.3 reflects projected water demands in 2020 as similar to those in 1995.

3.2.5 Indian Ocean Fertilisers

The Borough of Richard Bay supplies water to Indian Ocean Fertilisers (IOF) from Lake Mzingazi. Current usage is about 15 000 m^3/d. Effluent is mainly gypsum which is mixed with about 20 000 m^3/d of the Mondi effluent and pumped to sea for disposal through the sea outfall pipeline operated by the Mhlatuze Water Board.

There are no plans for expansion of the factory but a greater basket of products is envisaged. To allow for production of the new products, water demand in 1995 would increase to about 21 000 m^3/d. As the quantity of gypsum for disposal would be roughly the same, effluent volumes would remain essentially unchanged.

It is not clear what the future of the IOF plant would be after 1995. The plant is already ageing and requires substantial renovation and upgrading. As the renovations would require substantial capital expenditure by IOF, expansion after 1995 seems improbable so that water demand for 2020 is presumed to be the same as for 1995.

3.2.6 Tongaat-Hulett Sugar Mill

Tongaat-Hulett pump water directly from the Mhlatuze river to supply the sugar mill as well as the already-mentioned potable water supply to Mondi board mill and Felixton. A water court order entitles Tongaat-Hulett to 4904 m^3/d. Current abstraction is about 4000 m^3/d (plus 1550 m^3/d for the Mondi board mill and Felixton potable water requirements which are offset against Mondi's permit).

Because water is produced in the cane milling process, effluent exceeds water usage, but it is not known by how much. To err on the conservative side effluent from the mill is assumed to equal the water usage.

No expansion of the mill is planned at present, and a number of factors will delay possible future expansion plans. These include the fact that the mill is currently running at only about 60% of capacity as a result of insufficient feedstock. Tongaat-Hulett are actively engaged in expansion of both dryland and irrigated cane-growing areas in an attempt to increase the cane supply to the mill.

A proposed bagasse pulping plant, converting the waste that is not sold to Mondi board mill, may provide a new source of income for the mill. This development would require a new water supply and is discussed separately later.

In the light of the above a nominal increase in water demand up to the mill's full water right of 4904 m^3/d has been allowed for in 1995. No further expansion is anticipated before the year 2020.

3.2.7 KwaZulu Handcraft Centre

The KwaZulu handcraft centre has an authority from DWA in terms of Section 56(3) of the Water Act to abstract 1200 m^3/a(±3 m^3/d) from Goedertrouw dam. No increase in demand is envisaged.

3.2.8 Possible future industrial development

A number of new industries may establish in the area in the near future. Those that have been identified are discussed here.

Sentrachem - A proposed plant to produce chemicals, plastics and fuels at a site in Richards Bay. Initial and ultimate estimated water demands as well as effluent flows were obtained from the DWA Regional Director in Durban. Negotiations regarding a site for the plant are underway and it is assumed that the plant will start operating in 1995. Indications are, however, that the plant may be in operation as early as 1993.

S A Sugar Association - A proposed ethanol fuel plant. No site has yet been chosen but one at or close to Felixton would be favoured. Estimated water demands were obtained from the DWA Regional Director in Durban. Although no official statement has been released, recent indications are that the ethanol fuel plant would be shelved.

Tongaat-Hulett Sugar Mill, Felixton - Tongaat-Hulett are currently studying the feasibility of a bagasse pulping plant to produce pulp from excess bagasse not sold to Mondi board mill. The pulp would probably be exported. Estimates are that the plant could be in operation by about 1994, so its water demand is included in demand figures for 1995. Expected water demand figures were obtained from the mill. Effluent figures are uncertain, so we have notionally allowed 30%.

Rhombus Mining - Proposed mining on the southern bank of the Mhlatuze river south of Felixton. Water demand and effluent volumes were obtained from the DWA Regional Director in Durban. No starting date has been set and for conservatism the demand is included in the 1995 figures.

3.3 Domestic water demand

This section deals principally with domestic water demand but consumption figures in the larger towns include light industrial use.

With the exception of some of the very small towns, current water usage can be established fairly accurately. Projection of future water demand, however, is more difficult. Sporadic steps in growth result whenever a large new industry comes on stream, whereas the increased domestic water demand is generally gradual and results from the associated increase in the population.

Accuracy in estimating population growth rates is difficult. In the literature review population growth rates ranging from zero in some areas to as high as 16% in places like Nseleni township have been noted. Although it is possible that some areas may experience very high growth rates during certain periods, these rapid growths generally result from the establishment of one or more large industries which draw people to the area. Such steep growth rates cannot be sustained in the long term.

Table 3.5 Domestic and Small Industrial Water Demand

Description	Water right $10^6 m^3/a$	Usage in 1989 $10^6 m^3/a$	Assumed growth (%)	Demand in 1995 $10^6 m^3/a$	Assumed growth (%)	Demand in 2020 $10^6 m^3/a$	Current Effluent $10^6 m^3/a$	Effluent in 1995 $10^6 m^3/a$	Effluent in 2020 $10^6 m^3/a$	Water Source
Domestic Demand from within the Mhlatuze Basin:										
Empangeni Borough	5.404	3.005 *	4	3.802	4	10.135	1.644	2.080	5.545	Nsezi Lake
Melmoth Borough		0.676 *	4	0.855	4	2.280	0.068	0.086	0.230	Mfulazana river
Richards Bay Borough	16.439	7.306 *	8	11.594	4	30.907	3.653	5.797	15.453	Mzingazi Lake
Felixton	!	0.566	1	0.601	1	0.771	0.731	0.776	0.995	Mhlatuze river
Babanango		0.000	0	0.000	0	0.000	0.000	0.000	0.000	Boreholes
Kwambonambi			4	0.000	4	0.000	0.000	0.000	0.000	Nsezi Lake(?)
Nkandla		0.140	4	0.177	4	0.473	0.000	0.000	0.000	Boreholes
Mtambanana		0.000	0	0.000	0	0.000	0.000	0.000	0.000	Boreholes/Streams
Ekhuphumuleni	0.031	0.011 *	4	0.014	4	0.037	0.004	0.005	0.012	Mhlatuze river
eSikawini		2.217 *	5	2.971	5	10.063	1.607	2.154	7.294	Cubhu Lake
Nseleni Township		0.674 *	3	0.805	3	1.685	0.329	0.393	0.822	Nsezi Lake
Ngwelezana		2.369 *	4	2.998	4	7.991	0.718	0.908	2.421	Mpangeni Lake
University of Zululand		0.395 *	4	0.499	4	1.331	0.278	0.351	0.936	Mangeza Lake
Sub-Totals	21.874	17.359		24.316		65.671	9.031	12.550	33.710	
Demand from other basins:										
Eshowe Borough		1.827 *	4	2.311	4	6.161	0.000	0.000	0.000	Mlalazi river
Supplement Required		0.298 +		0.782		4.632				Mhlatuze river
Mtunzini Borough		0.283 *	4	2.550	4	3.147	0.000	0.000	0.000	Mlalazi river
Supplement Required		0.000 +		0.000		0.590				Mhlatuze river
Sub-Totals		0.298		0.782		5.222	0.000	0.000	0.000	
Rural Water Demand		2.502		3.653		11.240	0.000	0.000	0.000	Mhlatuze river
Domestic/Industrial Demand		20.159		28.751		82.218	9.031	12.550	33.710	

Notes:

* Estimates obtained directly from users.
+ Supplementary supply required from the Mhlatuze river.
! Felixton town Water Right is included in the Water Rights held by Mondi Board.

3.3.1 Empangeni Borough

A Water Court Order entitles Empangeni to withdraw 14 794 m^3/d from Lake Nsezi. The town operates its own water purification works which can treat about 13 600 m^3/d, i.e. far in excess of the town's current water usage of some 8225 m^3/d. The works, however, are dated and the town experiences problems with water quality during certain times of the year. It is possible that the Mhlatuze Water Board may take over the supply of water to Empangeni in the foreseeable future.

The town also operates an effluent treatment plant which treats on average 4500 m^3/d. Effluent is discharged to the Empangeni stream, a tributary of the Mhlatuze river.

Empangeni hosts a number of service industries but none with large water demands.

Growth in the town is stable and there is no reason to expect an increase in growth rate in the foreseeable future. A growth rate of 4% has been adopted in Table 3.5.

3.3.2 Richards Bay Borough

The borough of Richards Bay holds a permit under section 13 of the Water Act entitling it to withdraw 45 000 m^3/d from Lake Mzingazi. The town currently abstracts about 35 000 m^3/d of which some 15 000 m^3/d is sold to Indian Ocean Fertilizers. Thus domestic and light industrial use is some 20 000 m^3/d.

Richards Bay is the major development centre within the catchment and more than half of the possible future industrial development identified in the previous chapter is expected to establish in or close to the town. Accordingly, an annual growth rate of 8%/a has been assumed to 1995. For the long

3.3.8 Mtambanana

Mtambanana is a small Black township with a new clinic. At present water is supplied from a few small boreholes and abstracted by the local population from a number of small streams including the Mtambanana river. Because of water shortages, the new clinic has never been opened. It was not possible within the scope of this study to establish current water usage which in any event is expected to be low; exclusion of actual figures will hardly affect the results of the study. Nevertheless, a new water source is required so that the clinic can be opened. No doubt once that happens water demand will increase rapidly. Although no figures are available, the town has been listed in Table 3.5 for the sake of completeness.

3.3.9 Ekhuphumuleni

Ekhuphumuleni is a small town which houses a new hospital. The hospital is the major water user in the town. The KwaZulu Department of Works holds a water permit to abstract 85 m^3/d from the Mhlatuze river to supply the town and hospital. Current water usage is about 30 m^3/d and a growth rate of 4% has been assumed.

3.3.10 eSikawini

The town eSikawini provides accommodation for blacks working in Richards Bay. Its main water source is Lake Cubhu and present usage is about 6070 m^3/d. Growth of the town is linked to development in Richards Bay and the assumed growth rate has therefore been taken to be similar to that for Richards Bay (5%).

3.3.15 Water demand from outside the study catchment

3.3.15.1 Mtunzini

Mtunzini draws water from a weir in the Ntuzi river, a tributary of the Mlalazi river. The weir has a firm yield of some 7000 m^3/d which is well in excess of the town's current usage of 775 m^3/d. The town is expected to grow steadily in future and under these circumstances would have an adequate water supply for the next 50 years.

However, Severin propose to mine titanium from the dunes in the vicinity of Mtunzini and are expected to require water from mid-1991. Mining would be by a dry process which will require much less than the wet process used by RBM. Water demand is estimated at about 6000 m^3/d from mid-1991. In discussion with Severin it appears that water demand is not expected to increase over the first twenty years of production. Raw product would be exported initially but preliminary plans for a smelter in the Richards Bay area are being considered. The programme and resulting water demand from the Mhlatuze system for this project are at present unknown.

Table 3.5 presents two sets of figures for Mtunzini. The first line indicates total water requirements and the second line indicates the likely supplementary supply required from the Mhlatuze river.

3.3.15.2 Eshowe

The borough supplies water both to Eshowe and to the adjacent black residential area of Gezinsila which falls under the jurisdiction of the KwaZulu Government. Eshowe draws water from the Rutledge Park dam and the Eshlazi dam, both on the Mlalazi river, and from the Mpushini Falls weir on the Mpushini river, as well as from a borehole in Havelock St.

in Table 3.6, for the slow development scenario, irrigation demands have been assumed to be similar to those for the fast development scenario.

Domestic and light industrial demands would increase in concert with population growth. Selection of population growth rates for use in projecting water demands is dealt with in section 3.3 (Table 3.4) and need not be repeated here. Domestic demands reflected in Table 3.6 were derived by linear interpolation between the demand figures for 1989, 1995 and 2020 but the projected demands as at 1995 and 2020 were projected at compounded growth. The result is a fast initial growth which declines with time. Domestic demand can be varied in the fast as well as in the slow development scenarios by changing the assumed growth rate percentages but, as domestic demand is small compared with irrigation and industrial demand, any change would have little significance and therefore in Table 3.6 identical figures for both slow and fast development scenarios have been adopted.

Industrial demand has the greatest growth potential and as such is the most sensitive parameter in prediction of future demands. Table 3.7 shows the assumed dates for expansion/commissioning of existing industries and identified new industries.

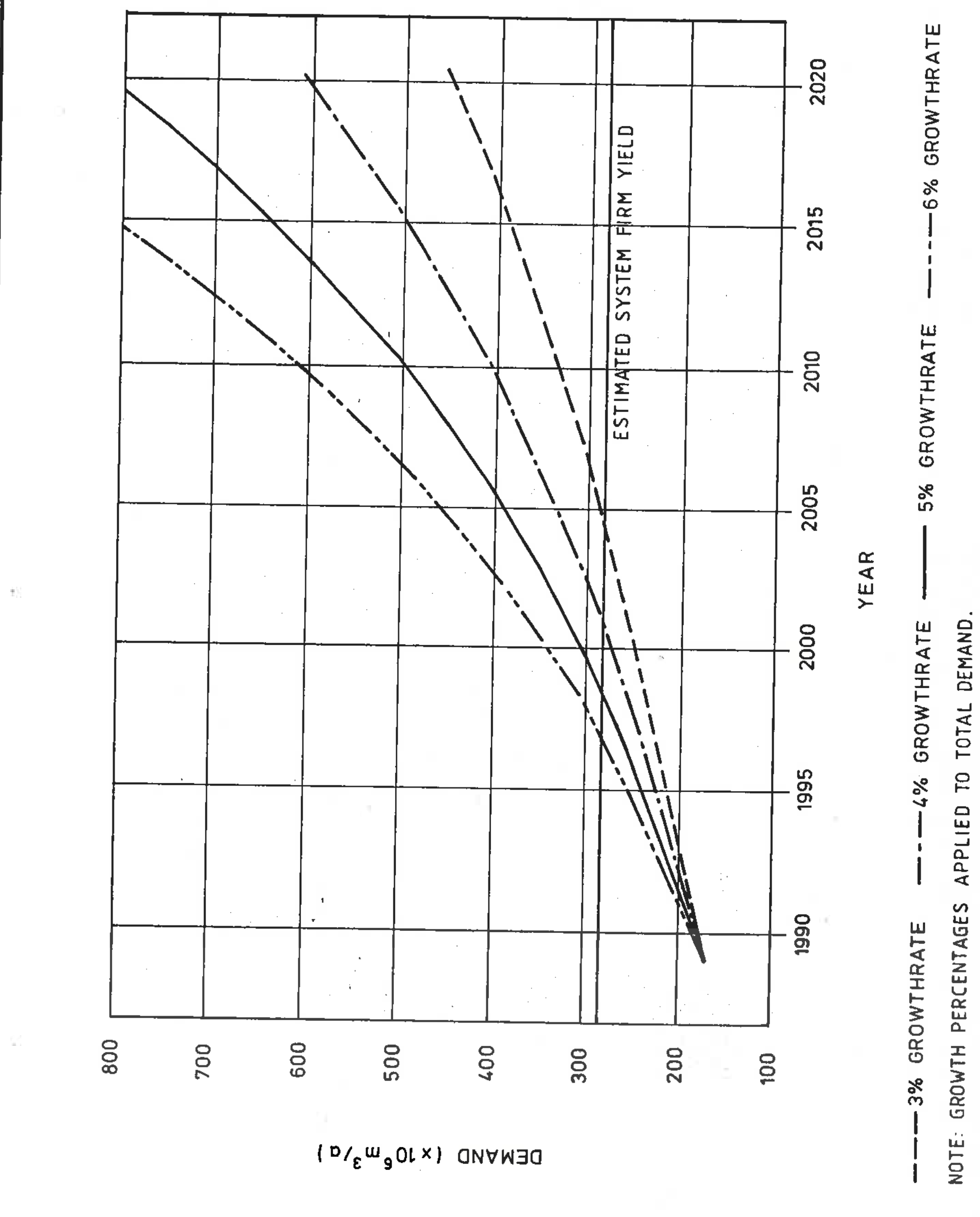
Table 3.7 Assumed commissioning dates of new development

	Fast development	Slow development
Richards Bay Minerals	Half in 1992 and half in 1995	As for fast development
Alusaf	1994	1999
Mondi Paper Mill	1994	1999
Mondi Board Mill	1992	1993
Indian Ocean Fertilizers	1991	Never
Tongaat-Hulett Sugar Mill	1993	1995
Chemical Industry	1994	1995
Ethanol Plant	1995	1997
Bagasse Pulping Plant	1994	1997
Mineral Mining	1992	1996

Potential new industries can be identified only once planning is in progress. As planning seldom projects more than five years ahead, the identified new industries have been scheduled to be in production within five years and, as a result, projected industrial demand after 1995 tends to flatten out significantly. To complete the picture, it is necessary to introduce percentage growth rates for the period between 1995 and 2020. Four percent, which is the same as the current annual population growth was used to project demands for one of the fast development scenarios and two percent, which is half of the population growth rate, was used to project demands for one of the slow development scenarios. As an alternative to projection of water demand on the basis of population growth rates, guidance was sought in the forecasts reported in the Vaal System Demands Study TR134 (DWA, 1988), in which worldwide water demand trends were examined. Table 3.8 lists some southern African long term trends in water demand prior to the drought of the 1980s.

Table 3.8 Some long-term trends in water demand

City/Region	Consecutive period (years)	Growth Trend (%/a)
Pretoria	58	4,93
Kimberley	61	5,21
Cape Town region	84,5	4,85
Umgeni Water Board area	54	4,95
Pietermaritzburg	54,5	2,94
Port Elizabeth	74	4,55
Harare (post UDI)	17	6,61
Vaal : principal abstractors	41	5,61
Johannesburg	42	4,56
Rand Water Board	41,25	5,41
RWB : Bulk Users	41	5,37
Durban	47,5	5,59
Average		5,08
Weighted average		4,91



WLPU CONSULTING ENGINEERS

R.S.A.: KWAZULU PERMANENT WATER COMMISSION
MHLATUZE CATCHMENT STEERING COMMITTEE

MHLATUZE RIVER CATCHMENT STUDY
PROJECTED WATER DEMANDS USING GROWTH PERCENTAGE

FIG. 3,3

Table 3.9 Total Water Demands using growth percentages

Year	Projected demand at 3% growth $10^6 m^3/a$	Projected demand at 4% growth $10^6 m^3/a$	Projected demand at 5% growth $10^6 m^3/a$	Projected demand at 6% growth $10^6 m^3/a$
1989	179.074	179.074	179.074	179.074
1990	184.446	186.237	188.028	189.818
1991	189.980	193.686	197.429	201.208
1992	195.679	201.434	207.301	213.280
1993	201.549	209.491	217.666	226.077
1994	207.596	217.871	228.549	239.641
1995	213.824	226.586	239.976	254.020
1996	220.238	235.649	251.975	269.261
1997	226.846	245.075	264.574	285.417
1998	233.651	254.878	277.803	302.542
1999	240.660	265.073	291.693	320.694
2000	247.880	275.676	306.277	339.936
2001	255.317	286.703	321.591	360.332
2002	262.976	298.171	337.671	381.952
2003	270.865	310.098	354.554	404.869
2004	278.991	322.502	372.282	429.161
2005	287.361	335.402	390.896	454.911
2006	295.982	348.818	410.441	482.206
2007	304.861	362.771	430.963	511.138
2008	314.007	377.282	452.511	541.806
2009	323.428	392.373	475.137	574.315
2010	333.130	408.068	498.893	608.773
2011	343.124	424.391	523.838	645.300
2012	353.418	441.366	550.030	684.018
2013	364.021	459.021	577.532	725.059
2014	374.941	477.382	606.408	768.562
2015	386.189	496.477	636.729	814.676
2016	397.775	516.336	668.565	863.557
2017	409.708	536.990	701.993	915.370
2018	422.000	558.469	737.093	970.292
2019	434.660	580.808	773.948	1028.510
2020	447.699	604.040	812.645	1090.221

4. HYDROLOGY

4.1 General

Discussed in this chapter are those catchment characteristics that influence both streamflow and groundwater behaviour, as well as the procedures whereby the water resources of the basin can be appraised.

The aim is to generate time series of streamflow at several nodes as inputs to a simulation model with which, by systems analysis, the optimum means of developing the water resources to meet future demands can be identified.

The work of the Hydrological Research Unit (HRU) of the University of the Witwatersrand, leading to the 6-volume survey of the surface water resources of South Africa, and in particular Report No. 9/81 (Pitman et al, 1981), was aimed at providing a means of appraising water resources at reconnaissance level in preliminary planning stages of a project; in other words, for just such a purpose as the study in hand.

With the advantage of a synoptic view of all the hydrometeorological and physiographical data available at the time, coupled with considerable hydrological experience, the HRU teams were able to provide better interpretations than would be possible from isolated data sets and, in many instances, were able to identify faulty gauges or ratings. On the other hand, users of the HRU work have pointed to errors in some parts of the country. Moreover, the countrywide drought of the 1980's has given cause for concern that the HRU reports may have overestimated the surface water resources and, in any event, more than 12 years of additional data have accumulated since the HRU analyses were performed. It is for these reasons that the Water Research Commission has recently commissioned a project to up-date the 1981 survey. It is also for these reasons that we have re-worked the available data for the Mhlatuze system.

Although rainfall data are reasonably adequate there are unfortunate gaps in coverage and the evaporation and streamflow data remain poor.

Neighbouring gauged rivers such as the Tugela and White Mfolozi have dissimilar characteristics while most of the shorter coastal rivers, such as the Mvoti, are as poorly gauged as the Mhlatuze.

The additional gaugings as Goedertrouw dam and the measurements at Nhlabane and Mzingazi, although short, proved valuable. Likewise a graphical representation of MAP-MAR relationships for a wide range of eastern escarpment and coastal rivers provided a basis for checking "average" runoff. It is unlikely that more attention to the hydrology than has been given in this chapter would greatly enhance the confidence with which the main conclusions affected by water resources could be drawn.

A separate chapter is devoted to of the coastal lakes in view of the unique nature of the Coastal Belt.

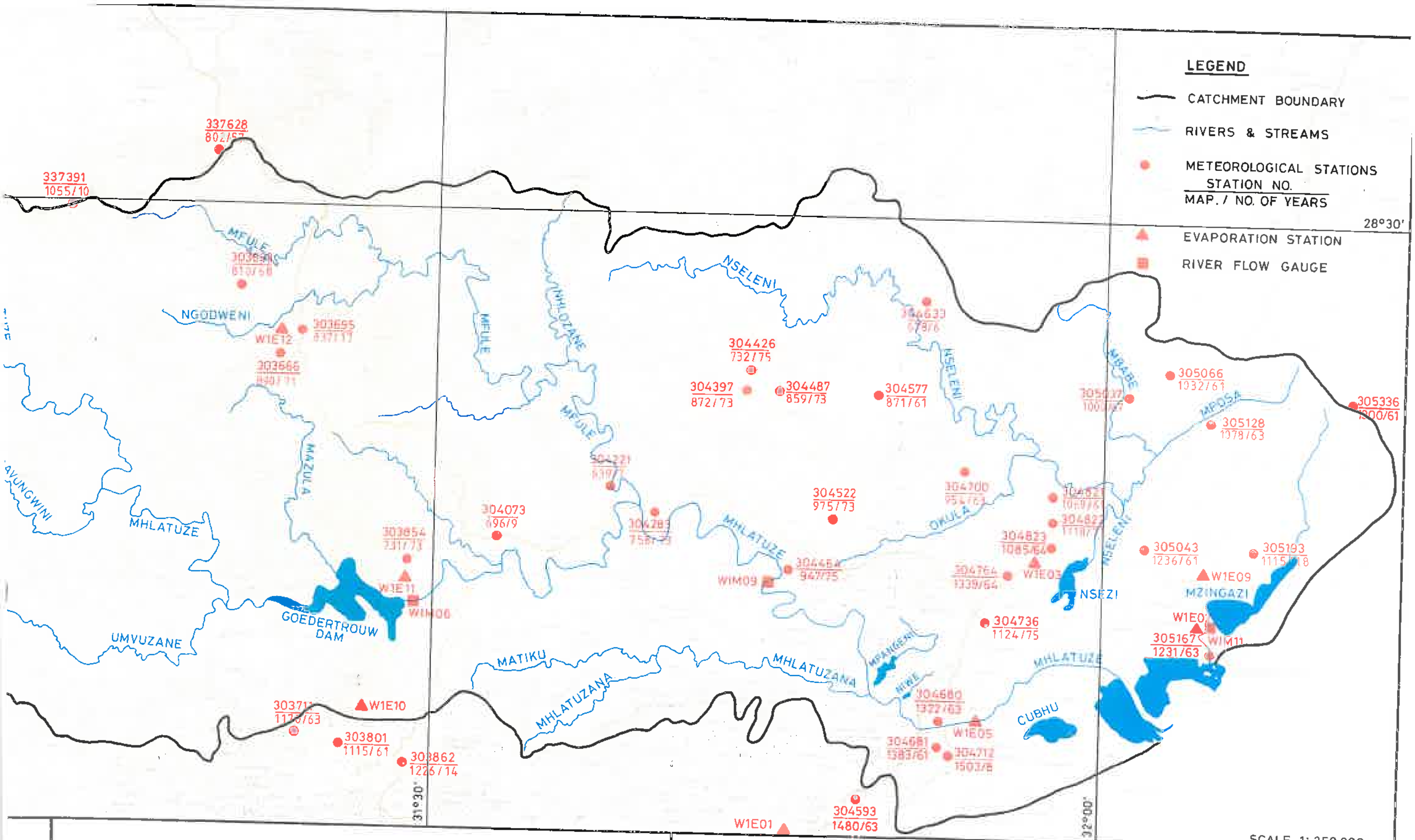
4.2 Vegetation and Land Use

The catchment feature that has the greatest influence on runoff is the natural vegetation, which generally reflects the integrated effects of climate, soil, relief and aspect. For this reason, mapping the vegetation provides valuable guidance to the process of extrapolating the runoff modelling parameters. Exotic vegetation - particularly afforestation and crops such as sugarcane - can substantially reduce the runoff that would be expected from the natural catchment. For this reason, areas of afforestation, dryland sugarcane and irrigated areas must be carefully mapped and the history of past development, as well as the projected future development of each, must be estimated.

Mapping of land use is being undertaken at the DWA Hydrological Research Institute from satellite imagery. The mapping was sufficiently far advanced for abstraction of afforestation and sugar plantations but not for reproduction of the maps.

4.3 Hydrometeorological records

Plate 3 at scale 1:250 000 shows the locations of rainfall gauges in or



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MHLATUZE RIVER CATCHMENT STUDY

HYDROMETEOROLOGICAL STATIONS

PLATE 3

near the Mhlatuze catchment. Also shown are the DWA stream gauging and evaporation stations.

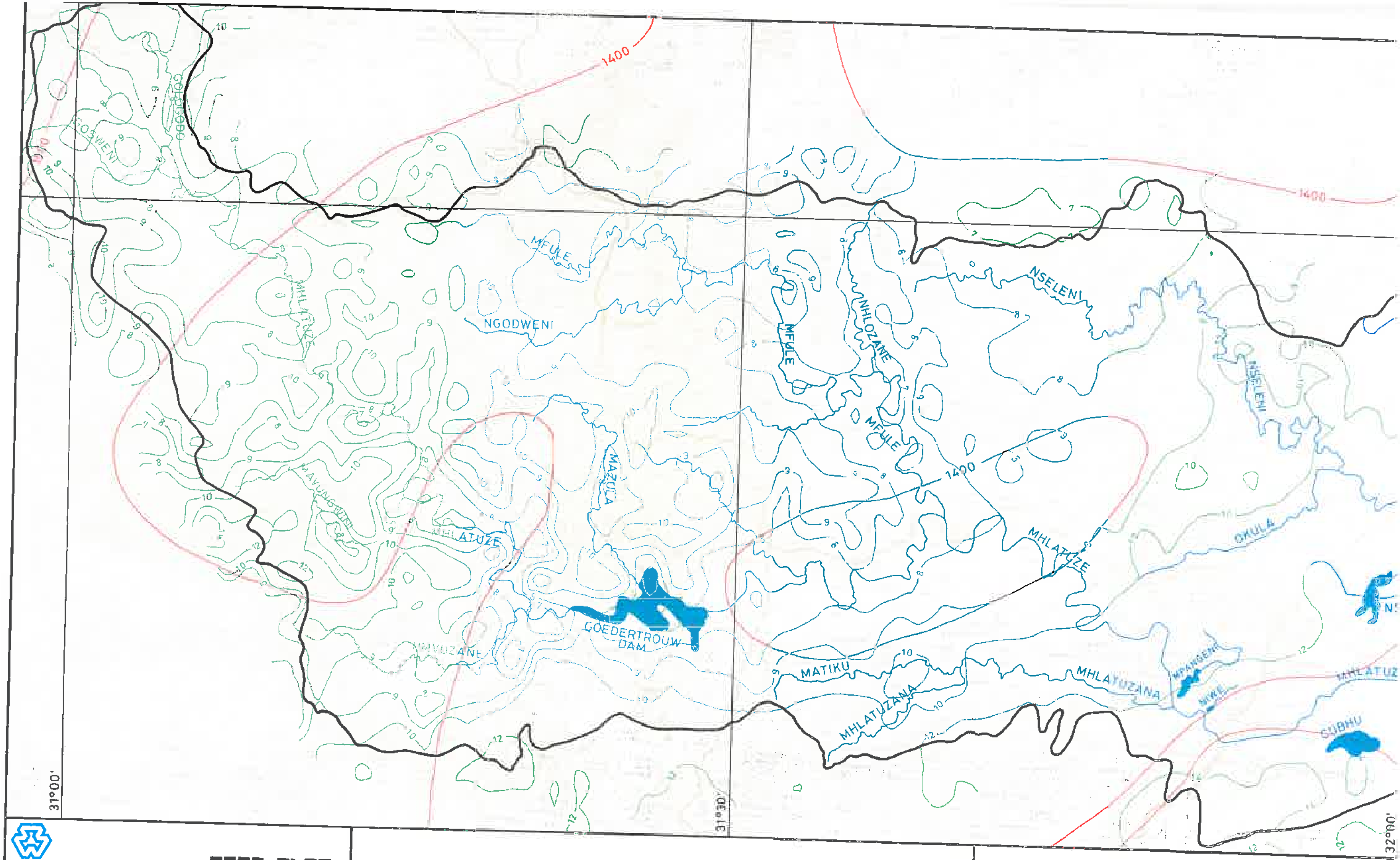
Records of rainfall throughout the country have been assembled at the Computing Centre for Water Research (CCWR), Pietermaritzburg. Insofar as possible, missing data were infilled and the resulting time series formed the primary data base for an isohyetal map produced by CCWR. Plate 4, to scale 1:250 000, is the CCWR rainfall map covering the study area.

The rainfall data base at CCWR is somewhat more extensive than that of the Weather Bureau in that it includes rainfall records from many other sources, principally the Sugar Association.

From the data base for the area surrounding the Mhlatuze catchment, stations suitably located and having reasonably long records were selected for the purpose of establishing the pattern of time distribution of precipitation over the catchment. The main criteria for selection of stations were: length of record, annual mean relative to that indicated by the isohyetal map and density of acceptable stations in the immediate vicinity. Mass plots of all rainfall records were used to check the acceptability of the records prior to their inclusion.

The monthly records from the stations used are reproduced in Appendix B, together with printouts of the output of program HYDP08 which averages, for each subcatchment, the dimensionless monthly rainfall. Catchment mean annual precipitation (MAP) values for each subcatchment were determined by planimetry from the CCWR isohyetal map, Plate 4.

Plate 3 shows the positions of evaporation stations in the vicinity of Richards Bay and Empangeni. Evaporation records (Symons tank and A-pan) were provided by DWA and by CCWR but proved to be short and discontinuous. The records, such as they are, are reproduced in Appendix C. Countrywide mapping of mean annual evaporation (MAE) is being undertaken by Prof. Roland Schultze at Natal University, Pietermaritzburg. He was unfortunately not able, however, to break



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routine to prepare the mapping of the Mhlatuze catchment within the time constraint imposed.

It is to be noted that the MAE map in the Addendum to Surface Water Resources of South Africa (Midgley, Pitman & Middleton, 1983) seems to underestimate MAE in the vicinity of Richards Bay. Revised isolines of MAE are shown overprinted on the isohyetal map, Plate 4. Average monthly evaporation values used in the runoff model were taken from the Addendum to Surface Water Resources, Zone EZ22A.

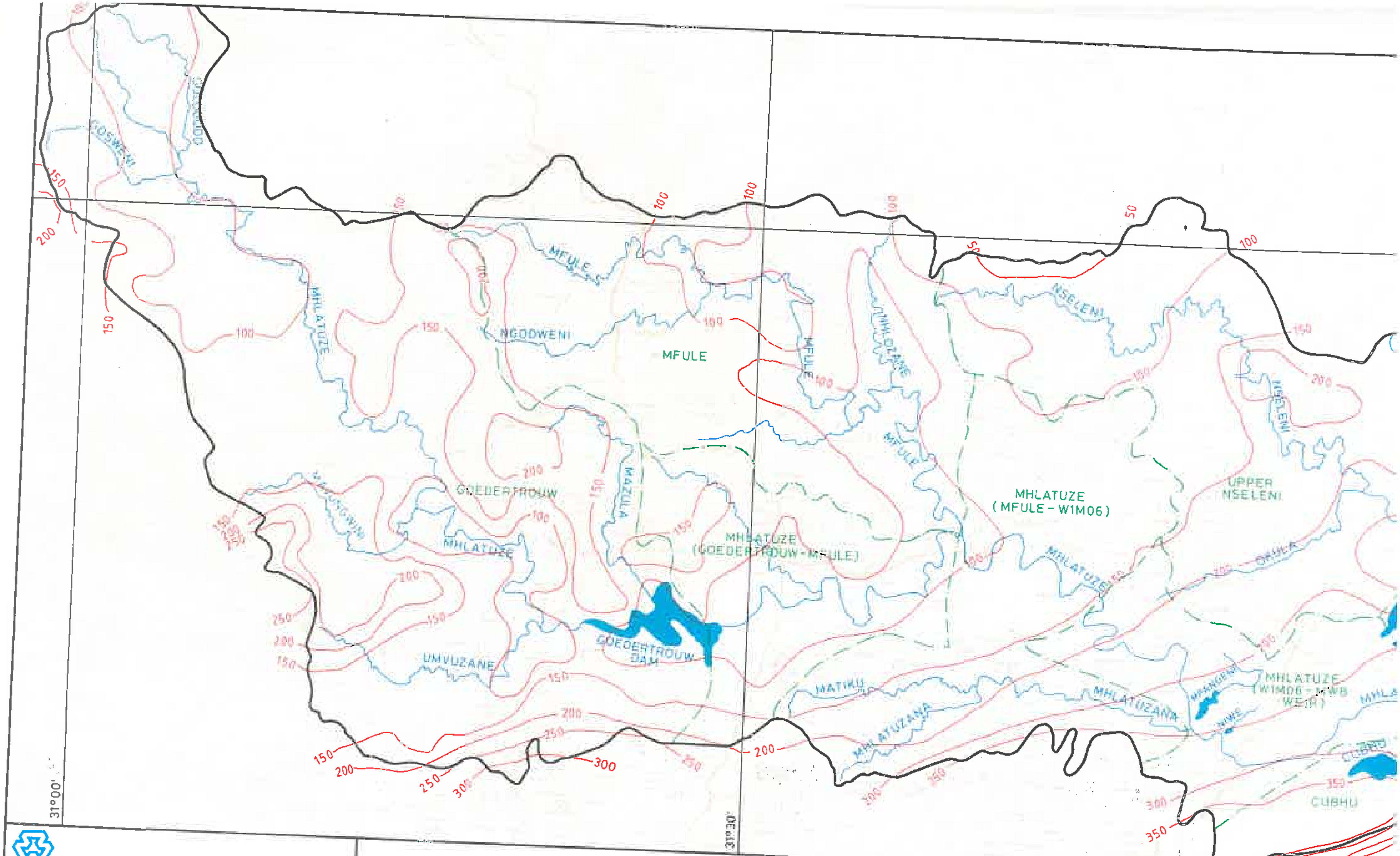
Not only are streamgauging stations in the region sparse but what records exist are relatively short and disjointed. The available records are reproduced in Appendix D.

4.4 Streamflow Modelling

Unfortunately there is only one point in the Mhlatuze system at which one can be reasonably certain of the flow in the river and that over only a relatively short period, namely at Goedertrouw dam, 1964-71 and 1979-86, of which only the years 1983-86 were complete. (DWA Hydro stations W1M06/W1R01). Fortunately, we were also able to get a feel for the characteristics of runoff on the coastal plain from the work done by Dr W V Pitman for Richards Bay Mining on Lake Nhlabane, coupled with a short DWA record of spill out of Lake Mzingazi.

To simulate the behaviour of the system in order to optimise the reconciliation of demand with supply, it is necessary to generate time series of streamflow (or groundwater flow) at convenient abstraction or control points in the system. With this in mind the catchment was subdivided as shown on Plate 5 and in Table 4.1.

Table 4.1 lists the subcatchments together with their areas and catchment-averaged mean annual precipitations (MAP). Included in Table 4.1 for convenience are also the naturalised mean annual runoffs (MAR) from each of the subcatchments and the MAR from the total study area. The means of deriving and naturalising these MAR values is discussed in what follows.



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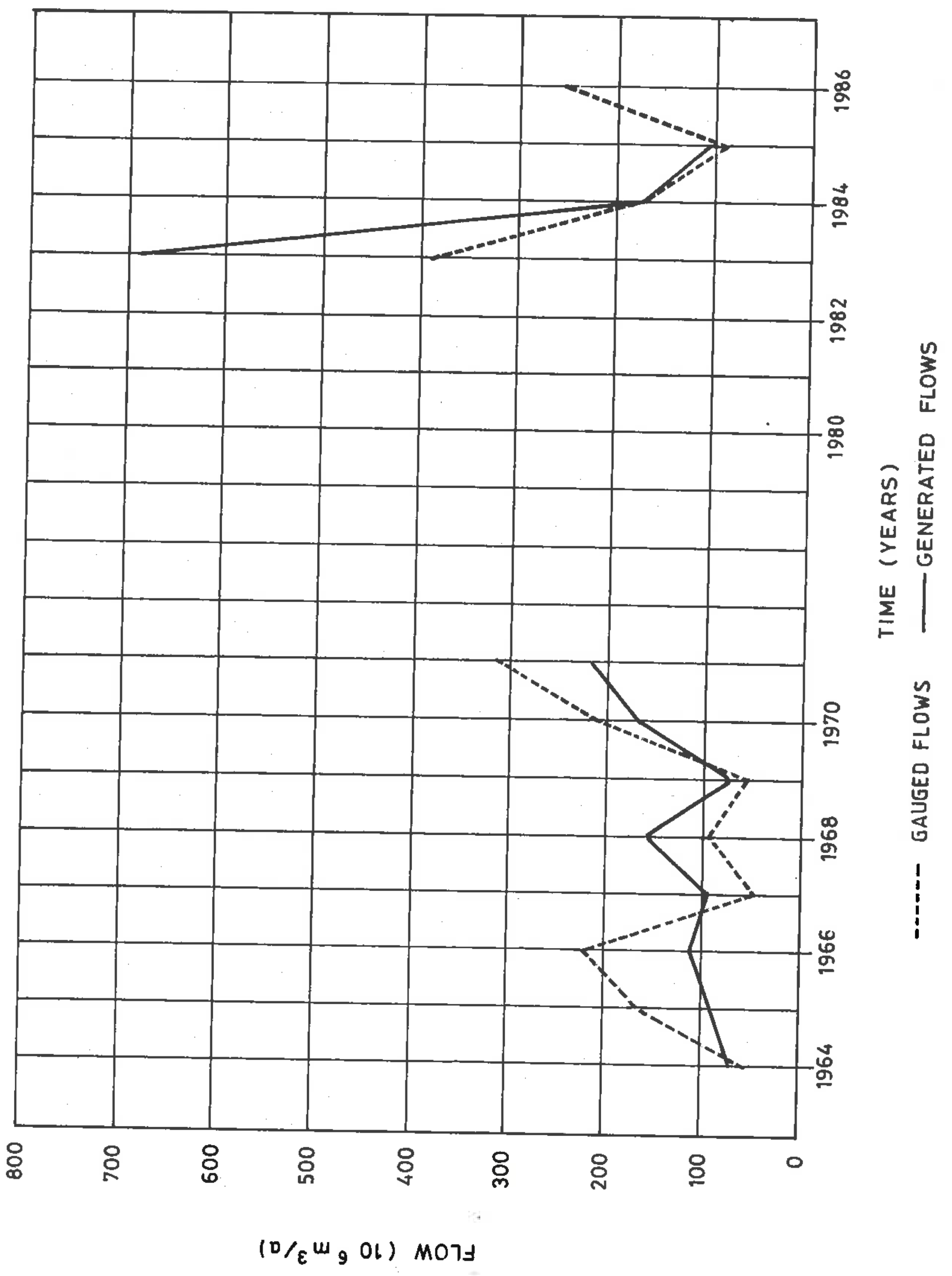
OF MEAN ANNUAL RUNOFF

Table 4.1 System subcatchments with hydrometeorological parameters

Subcatchment	Area	MAP	Naturalised MAR		Present MAR	Cumu-lative areas	Cumu-lative MAR
	(km^2)	(mm)	(mm)	($10^6m^3/a$)	($10^6m^3/a$)	(km^2)	(10^6m^3)
Mhlatuze at Goedertrouw	1295	930	140	181,5	176	1295	176
Mfule at Mhlatuze	620	851	122	75,4	68	620	68
Mhlatuze. Goedertrouw to Mfule confluence	280	850	123	34,5	25	2195	269
Mhlatuze. Mfule to WIM09	435	960	160	69,7	53	2630	322
Mhlatuze, WIM09 to MWB pumpstation	340	1165	255	86,8	66	2970	388
Nseleni at Lake Nsezi	810	1080	158	128,1	113	810	113
Lake Cubhu	74	1290	265	19,6	18	74	18
Lake Mzingazi	171	1220	145	41,9	33	171	33
Totals						4025	552

Streamflow was generated at Goedertrouw by means of the Pitman model (Pitman, 1973) using first the regional parameters recommended in Surface Water Resources of South Africa, (Pitman et al, 1981). The parameters were then modified until reasonably satisfactory conformity was achieved with the relatively short records at gauges WIM06 and WIR01.

Figure 4.1 shows the comparison between the simulated series and actual records at gauges WIM06 and WIR01. Figure 4.2 shows a comparison between the simulated series and the relevant series published in HRU 9/81. The same parameters were then adopted for the Mfule and for the Nseleni catchments (except for the far eastern sector of the latter, as indicated later).



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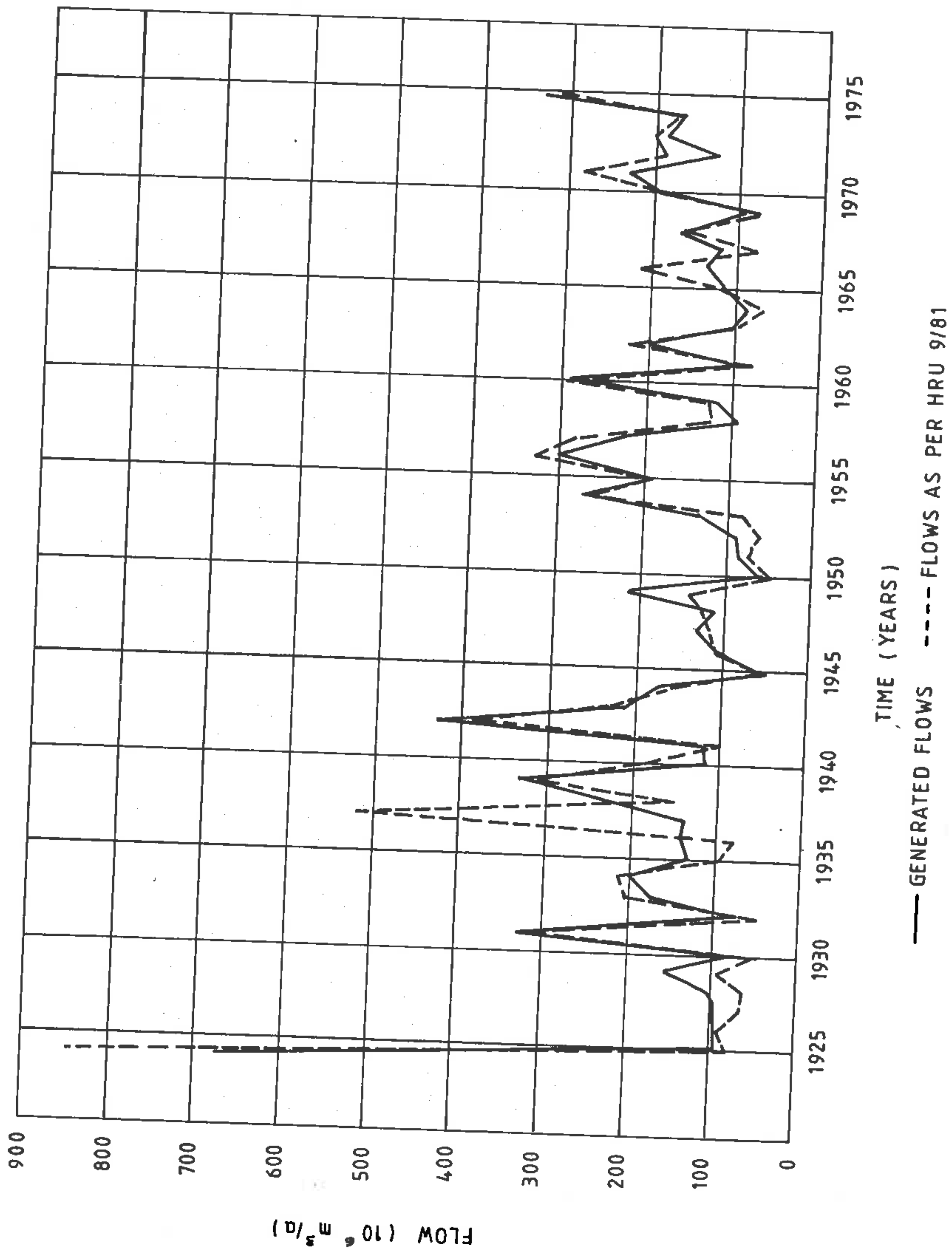
GOEDERTROUW DAM
FLOW COMPARISON WITH GAUGED RECORD

FIG. 4,1



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GOEDERTROUW DAM
FLOW COMPARISON WITH HRU 9/81

FIG. 4,2

Runoff into Lake Mzingazi was then modelled using parameters suggested by Dr Pitman who had calibrated his model for runoff into Lake Nhlabane. Although the catchments are physiographically similar, except for the extent of afforestation, the resulting inflow to Lake Mzingazi did not match well with the sum of the known abstractions and outflow. In consultation with Dr Pitman the model parameters were modified to achieve a fit with the mass balance at Mzingazi. The resulting parameters were thereupon transposed to the Cubhu catchment for the modelling of runoff into that system.

It was then postulated that the eastern part of the Nseleni catchment should exhibit model parameters similar to those of the Mzingazi catchment. For the lower Mhlatuze, too, a slight modification of the parameters was introduced in recognition of the possibility that runoff from the wide valley of gentle gradient downstream of Goedertrouw dam was likely to be lower than from the steep upper catchment.

In Appendix E are listed simulated time series of runoff from the natural catchments (ie. without allowance for changed land use and abstractions). These time series run from 1921 through 1985, ie. 65 years, and form the primary input to the simulation model dealt with in chapter 6.

4.5 Distribution of runoff

Approximate relationships between MAR and MAP for the various types of terrain in the study area were derived and, using the isohyets as a guide, approximate isolines of MAR have been overprinted on Plate 5 to provide a rough picture of the distribution of natural average annual runoff over the catchments.

4.6 Flood Hydrology

Maximum allowable operating levels in the three coastal lakes are subject to a number of criteria. One of concern here is that adequate freeboard must be provided to ensure the passage of floods through the lakes without inundating upstream property. To assess the required freeboard it is necessary to compile flood hydrographs for various recurrence intervals for the three lakes. This was accomplished with the aid of the computer program, DETFLOOD, Alexander (1989). Flood peaks were estimated using the Rational method, in accordance with DWA practice. Flood hydrographs and peaks were also estimated using the unitgraph method in accordance with HRU Report 1/72 Hydrological Research Unit (1979) and modification by Prof. Alexander. A typical printout is shown in Appendix F.

Table 4.2 summarizes the flood peaks estimated by the different methods.

<u>**Table 4.2 Estimated flood peaks for the coastal lakes**</u>

Lake	Recurrence interval (years)	Rational (DWA) (m^3/s)	Unitgraph (HRU 1/72) (m^3/s)	Unitgraph (Alexander) (m^3/s)	Accepted peak (m^3/s)
Mzingazi	2	49	74	52	52
	5	73	118	112	112
	10	99	168	169	169
	20	135	228	235	235
	50	213	331	338	338
	100	310	444	428	428
Nsezi	2	120	141	75	75
	5	180	231	161	161
	10	249	336	241	241
	20	343	471	336	336
	50	553	717	488	488
	100	820	1000	630	630
Cubhu	2	19	43	23	23
	5	28	69	48	48
	10	39	98	73	73
	20	53	134	101	101
	50	85	196	145	145
	100	124	262	184	184

The hydrographs developed by unitgraph method (Alexander, 1989) were then routed through the lakes. Sample printouts are shown in Appendix G.

Tables 4.3, 4.4, and 4.5 summarise the results.

Table 4.3 Lake Mzingazi floodrouting results

Recurrence interval (years)	Peak inflow (m^3/s)	Routed peak outflow (m^3/s)	Attenuation (%)	Maximum water level (m MSL)	Surcharge (m)
2	52	3	94	3,67	0,67
5	112	9	92	3,75	0,75
10	169	22	87	3,82	0,82
20	235	53	77	3,87	0,87
50	338	115	66	3,95	0,95
100	428	177	59	4,01	1,01

Table 4.4 Lake Nsezi floodrouting results

Recurrence interval (years)	Peak inflow (m^3/s)	Routed peak outflow (m^3/s)	Attenuation (%)	Maximum water level (m MSL)	Surcharge (m)
2	75	50	34	6,59	0,09
5	161	123	23	6,67	0,17
10	241	196	19	6,74	0,24
20	335	280	16	6,80	0,30
50	488	431	12	6,9	0,40
100	630	591	6	7,0	0,50

Borehole surveys by Van Wyk (1963) and by Eksteen, Van der Walt & Nissen (1989) indicate low to very low borehole yields in Northern Natal and Zululand. Yields average about 0,1m^3/h; values of 1,0 m^3/h and higher are infrequent and are probably associated with extensive large-scale faulting and fracturing or intrusions of dolerite.

4.7.2 Coastal Belt

The surficial clayey sand, silt and mudstone succession along the coast is conducive to formation of leaky confined aquifers. The primary aquifer is the Miocene compacted coquina and calcarenite, the base of which is formed by the impermeable siltstones. Port Durnford sands and silts of varying degrees of consolidation and cementation constitute the aquitard that overlies the Miocene. The coastal lakes are surface expressions of the groundwater table.

Worthington (1978) established the following hydraulic parameters of the overlying aquitards and of the Miocene aquifer:

- Surficial sands:
  Hydraulic conductivity: 0,2-0,5 m/day

- Port Durnford formation (aquitard):
  Mean vertical hydraulic conductivity: 0,1 m/day

- Miocene aquifer:
  Mean horizontal hydraulic conductivity: 2,5 m/day
  Average coefficient of transmissivity: 15-20 m^2/day
  Coefficient of storage: 0,0057
  Mean effective porosity: 20%
  Baseflow: 80 000 m^3/day

With these relatively low hydraulic parameters poor borehole yields are to be expected. Yields of boreholes drilled for

Worthington's work ranged between 2,7 and 12 m^3/h with an average of around 5,3 m^3/h. His report (Worthington, 1978) has the following estimates of groundwater reserves in the Coastal Belt:

- Exploitable groundwater resources: 500-600 $m^3/day/km^2$
- Storage in the Miocene aquifer: 1,6 $x10^6 m^3/km^2$
- Estimated assured yield of Lake Mzingazi: 80 000 m^3/day

Worthington's estimate of groundwater resources is based on his recharge value of 187 mm/a which appears to be far too high for leaky confined aquifer conditions. Moreover, his estimate of 20% for porosity of the partially cemented Miocene aquifer also seems excessive. Aquifer storage calculated from the average coefficient of storage, viz. 0,0057, would be 4560 m^3/km^2, which is considerably less than Worthington's figure of 10 $000^3/km^2$.

The coastal lakes are dealt with in some detail in the next chapter but it is clear that in order to exploit the groundwater within the catchment of Lake Mzingazi on a large scale one would require a multiplicity of boreholes spread over a wide area.

4.7.3 Lower Mhlatuze

The wide flood plain of the lower Mhlatuze is likely to exhibit extensive deposits of alluvium but the lateral and vertical extents have not been surveyed. Worthington (1978) considered the alluvial plain to be a groundwater source quite independent of the Coastal Belt, with expected borehole yields of up to 2000 m^3/day and storage of the order of $2,1x10^6 m^3/km^2$ (based on average aquifer thickness of 8½ m and porosity 25%).

In view of the fact that similar riverine deposits in the northern Transvaal have borehole yields of the order of 6000 m^3/day Worthington's estimates of yield are by no means too high. Given adequate volume of storage the assured yields of alluvial aquifers are primarily determined by the frequency and duration of inundation by surface flow.

Worthington was of the opinion that groundwater could be exploited from near Lake Nsezi without fear of salt water intrusion and that to meet the Richards Bay demand (45 000 m^3/day) would require about ten production holes.

Although the Mhlatuze flood plain overlies a substantial body of groundwater that could be abstracted with considerably greater efficiency than from the coastal belt, the principal constraint would be environmental. Worthington recommended that this potential groundwater resource should be investigated. This has not been done but it stands to reason that major depression of the groundwater would dry out the existing wetlands and cause excessive ecological trauma. Clearly, grandscale exploitation of the groundwater on the Mhlatuze flats would surely have to be a last resort. It must be emphasized that a comprehensive geophysical and geohydrological investigation would be required in order to evaluate the potential of the Mhlatuze flats as recommended by Worthington. As this has not yet been done this potential resource has been omitted as an input to the systems analysis to follow.

5. THE COASTAL LAKES

5.1 Lake Mzingazi

Worthington (1978) attempted a water balance for the lake based on his findings:

- that the surficial geological formations are generally of low permeability, with groundwater levels following closely the surface topography.

- that the pronounced groundwater level depressions around the lake and streams would indicate that the system is being continuously fed from the groundwater.

- that fluctuations of groundwater level are minimal, implying steady-state conditions (outflow from the system in balance with inflow, and changes of groundwater storage negligible).

On the basis that change of storage was negligible Worthington felt justified in adopting the simplified water balance equation with which he deduced that what he called infiltration, I, (meaning percolation to groundwater recharge) would average 187 mm per annum. In the simplified equation : I = Ps - Es - Rs, he put:

	Ps (average annual precipitation, MAP)	= 1523 mm
	Es (average annual evapotranspiration MAE)	= 956 mm
and	Rs (surface runoff and throughflow)	= 380 mm
	so I = Ps - Es - Rs	= 187 mm

According to Worthington, then, the so-called recharge would average 12,3% of rainfall, i.e. much the same as that estimated by Van Wyk (1963) for the Karoo sediments of northern Natal and Zululand lowveld.

The values adopted by Worthington in his mass balance equation do not tally well, however, with currently accepted average values. In order to check Worthington's calculations, the mass balance was recalculated for two periods during which the lake was not spilling, abstracted from records of lake levels by Geustyn, Forsyth & Joubert (pers. comm 1989). The results presented in Table 5.1 indicate that the summations of calculated total inflows to the lake during these periods conform closely with values simulated by Pitman model, as may be seen by comparing the totals in the last two columns.

Although not an entirely independent check, as the Pitman model was calibrated against similar lake outflows calculated by DWA, the results in Table 5.1 nevertheless clearly show that the model is reflecting the total response of the catchment, whether groundwater or surface water.

One could distinguish and attempt to evaluate the several components of catchment response at the lake, viz:-

G : Groundwater flux from the Miocene aquifer

IF : Interflow from the upper soil layers into the catchment streams and lake periphery

DR : Direct surface runoff

L : Leakage to the sea or beneath the embankment to the canal and Bay

Despite the fact that the Miocene aquifer outcrops below sea level, leakage to the sea must be minimal because of the relatively low impoundment level relative to sea level and the substantial distance of the freshwater/salt water interface from the lake periphery. By the same token leakage to the canal cannot be greater than that represented by slow diffusion through the fresh/saltwater interface. Worthington (1978) using Darcy's law (Q = kiA), calculated the average seepage outflow to be 1350 m^3/day. (Possible movement of the interface upriver towards the lake from the canal is referred to later under environmental constriants).

Table 5.1 Lake Mzingazi. Mass Balance during periods of no spillage

Date	Lake Level (mm) *	Level Change (mm)	Storage ($10^6 m^3$) $	Storage Change ($10^6 m^3$)	Rain (mm) #	S Tank Evap (mm) #	Lake Evap (mm) %	Rain ($10^6 m^3$)	Lake Evap ($10^6 m^3$)	Draft ($10^6 m^3$)	Inflow ($10^6 m^3$)	Pitman Inflow ($10^6 m^3$)
Period 1												
1 Aug 80	-80.00		33.19									
1 Sep 80	-415.00	-335.00	30.21	-2.98	18.00	85.00	68.85	0.17	0.65	0.83	-1.67	0.60
1 Oct 80	-135.00	280.00	32.70	2.49	150.00	87.00	65.25	1.47	0.64	0.97	2.63	0.73
1 Nov 80	-200.00	-65.00	32.12	-0.58	54.00	140.00	105.00	0.53	1.02	0.80	0.72	0.91
1 Dec 80	-225.00	-25.00	31.90	-0.22	101.00	152.00	126.16	0.98	1.22	0.61	0.63	0.86
1 Jan 81	-490.00	-265.00	29.54	-2.36	33.00	188.00	135.36	0.31	1.26	0.61	-0.79	0.71
1 Feb 81	-400.00	90.00	30.34	0.80	174.00	181.00	123.08	1.65	1.16	0.62	0.94	0.73
1 Mar 81	-380.00	20.00	30.52	0.18	108.00	174.00	104.40	1.02	0.99	1.12	1.26	0.83
1 Apr 81	-420.00	-40.00	30.16	-0.36	85.00	182.00	145.60	0.80	1.37	0.51	0.72	0.78
1 May 81	-290.00	130.00	31.32	1.16	132.00	114.00	91.20	1.27	0.88	0.28	1.04	0.74
Totals				-1.87	855.00		964.90	8.19	9.20	6.34	5.48	6.89
Period 2												
1 Jan 83	-105.00		32.97									
1 Feb 83	-315.00	-210.00	31.10	-1.87	72.00	207.00	140.76	0.69	1.35	0.83	-0.38	0.78
1 Mar 83	-405.00	-90.00	30.30	-0.80	105.00	160.00	96.00	0.99	0.91	0.54	-0.35	0.67
1 Apr 83	-505.00	-100.00	29.41	-0.89	58.00	146.00	116.80	0.54	1.09	0.86	0.52	0.60
1 May 83	-680.00	-175.00	27.85	-1.56	28.00	114.00	91.20	0.25	0.83	0.76	-0.22	0.50
1 Jun 83	-830.00	-150.00	26.51	-1.34	21.00	105.00	90.30	0.19	0.80	0.93	0.21	0.43
1 Jul 83	-795.00	35.00	26.82	0.31	89.00	68.00	58.48	0.79	0.52	0.78	0.82	0.43
1 Aug 83	-690.00	105.00	27.76	0.93	179.00	78.00	63.18	1.62	0.57	0.72	0.60	0.51
1 Sep 83	-400.00	290.00	30.34	2.58	133.00	76.00	61.56	1.26	0.58	0.74	2.65	0.71
1 Oct 83	-410.00	-10.00	30.25	-0.09	51.00	110.00	82.50	0.48	0.78	0.79	1.00	0.87
1 Nov 83	-400.00	10.00	30.34	0.09	116.00	117.00	87.75	1.10	0.83	0.89	0.71	0.95
1 Dec 83	-185.00	215.00	32.25	1.91	159.00	137.00	113.71	1.55	1.11	0.77	2.24	1.25
Totals				-0.71	1011.00		1002.24	9.46	9.36	8.61	7.80	7.70

Notes:

Lake overflow level 3.03 MAMSL
Surface area at FSL 10km^2

* Lake levels as recorded by Geusteyn, Forsyth and Joubert.
$ Storage calculated from storage - elevation curve for lake Mzingazi.
\# Data for gauge WIE02 from DWA.
% S Tank evaporation changed to lake evaporation using conversion factors as used by Geldenhuys and Perkins (Department of Water Affairs, 1985).

The leakage is small enough to be neglected. Therefore:

$L = 0$

The groundwater and interflow components can also be evaluated by Darcy's equation with Worthington's values of mean hydraulic conductivity (k) and mean hydraulic gradient (i).

For the groundwater discharge to the lake from the Miocene aquifer (G) we have taken the lake perimeter to be 30 000 m and derived the area (A) using a thickness of aquifer of 8 m, viz. $A = 240\ 000\ m^2$. According to Worthington, k = 2,5 m/day and i = 0,01. Therefore:

$G = 6000\ m^3/d$ or $2,2\ x10^6 m^3/a$.

For the interflow component we took the stream density of the catchment to be 1,5 km/km^2 and the saturated thickness of the surficial soils to average 2 m, providing an area $A = 540\ 000\ m^2$, including allowance for the lake periphery. A value of k = 3,3 m/day has been adopted for the surficial sandy formation and the hydraulic gradient was unchanged. Thus:

$IF = 17\ 820\ m^3/day$ or $6,5\ x10^6 m^3/a$.

The simulated total catchment response under the present-day afforested condition averaged 28,4 $x10^6 m^3/a$ and therefore the breakdown to the three components G, IF and DR, in millimetres and in percentages of rainfall and of total runoff, will be as in Table 5.2.

Table 5.2 Components of Inflow to Lake Mzingazi

Component	$10^6 m^3/a$	mm/a	%MAP	%MAR
G	2,2	13,6	1,1	7,7
IF	6,5	38,0	3,1	21,5
DR	19,7	125,4	10,3	70,8
Total Response	28,4	177,0	14,5	100,0

As may be noted, percolation to the confined aquifer is little more than 1% of the average rainfall - an order of magnitude less than that estimated by Van Wyk for the Karoo formations of northern Natal and Zululand.

Attention may now be turned to the effect of lake drawdown on the groundwater regime.

Adopting an average coefficient of storage (as before, 0,0057) we can estimate bank storage of groundwater around the lake at 4560 m^3/km^2. Indications are therefore that bank storage cannot be substantial.

Worthington's finite element modelling of the groundwater system indicated that lowering of the lake level would take 492 days to affect groundwater levels 4,5 km away from the lake edge. Because of the relatively low permeability of the formations around the lake, response of the groundwater to rainfall and sudden changes of lake level can be expected to be pronounced in close proximity to the lake edge but some distance away the groundwater is slow to respond.

Increased hydraulic gradients as the result of lowering the lake will be likely to increase the discharge from the Miocene aquifer only to the extent shown in Table 5.3.

Table 5.3 Lake Mzingazi: Increase in yield as a function of drawdown

Lake level (m MSL)	Miocene aquifer flux (m^3/day)
3,03 (overflow level)	-
3	6000
0	6400
-3	6800
-6	7200

As may be noted, the increases in main aquifer flux as the result of lowering of the lake are not significant. Discharge from the surficial sands could be more impressive but only during prolonged periods without rain; otherwise, the water table gradient would steepen only locally.

5.2 Lake Cubhu

Hydrological information about Lake Cubhu is scarce. Geustyn, Forsyth & Joubert (GFJ) (1976) assessed the useful draft at 30 000 m^3/day with an arbitrarily chosen limit on drawdown to 2,6 m MSL. The live storage above this level would be only about 1,0 $x10^6m^3$ and therefore a useful draft of the order of 11 $x10^6m^3$/a (30 000 m^3/d) seems somewhat optimistic.

The lake is shallow and it is unlikely that the bed intersects the Miocene aquifer. GFJ assumed the lake floor to be sealed and this is probably true also of the other lakes in the area. Groundwater inflows are low and changes of lake stage are a function of recent rain.

Apart from possible environmental considerations there seems to be no reason why Lake Cubhu cannot, if necessary, be safely drawn down to 0,6 m MSL.

5.3 Lake Nsezi

Detailed geological and hydrogeological information and hydrological measurements at Lake Nsezi are lacking. Hemens et al (1981) assessed the assured yield at probably less than 10 000 m^3/day with the drawdown level limited to 6,3 m MSL.

Our own estimates of yield of lakes Nsezi, Mzingazi and Cubhu will emerge from the systems analysis dealt with in Chapter 6.

5.4 Water Resources

From what has been revealed it is apparent that the water resources of the coastal belt and its lake system cannot be significantly increased by tapping the groundwater. In other words, there is not a separately identifiable groundwater resource of significant magnitude. Each of the lakes can to all intents and purposes be construed as a tight-bottomed reservoir the inflow to which is that generated by the Pitman model. Abstraction of groundwater from the catchment on a substantial scale would be an unattractive proposition requiring the establishment of an extensive wellfield of relatively low yield production holes.

Depression of the water table in the catchment would certainly reduce the frequency with which the lakes presently spill but with the onset of drought it would be difficult to deny that drying-out of the lake was the result of groundwater abstraction in the catchment.

The associated environmental factors are dealt with in the next section.

5.5 Environmental Constraints

5.5.1 Pollution

Although residential and industrial development and other sources of pollution are relatively remote from the Lake Mzingazi shoreline, the lake is vulnerable to pollution through migration of pollutants along surface drainage lines and through interflow. Worthington (1978) recommended that special care be taken in areas having high density of surface drainage lines.

Lake Nsezi is subjected to pollution from the approximately 1000 m^3/d of secondary sewage effluent that is discharged from the Nseleni Township to the Mposa river upstream of the confluence with the Nseleni river. The resulting eutrophication is reflected in the widespread luxuriant growth of water hyacinth and papyrus in and around the lake.

5.5.2 Saltwater Intrusion

A major concern that has been widely aired is the possibility of saltwater intrusion with lowering of lake levels. The likelihood of ingress of seawater by way of the Miocene aquifer where it outcrops below sea level, as has been indicated earlier, is remote because of the small driving head between the lake and the sea. The possibility of intrusion of saltwater by way of the Ngodwani and Mzingazi canals, which are in communication with the Bay and subject to tides, has been addressed by G J van Tonder and Prof. J F Botha (1983). Finite element modelling has revealed that the saltwater/freshwater interface will move less than 100 m in a year. This slow movement is consistent with the low permeability of the clayey sand formations in the area between canal and lake.

In normal circumstances the interface is some 1600 m downstream of the lake overflow but, should the system suffer prolonged drought, the interface could invade the Mzingazi river to reach the embankment. By the Gyber-Herzberg principle, however, the likelihood that the interface could intrude below the embankment even at low lake level is remote.

Although the above remarks are well justified it may be necessary to review them after the results of the Department of Water Affairs current drilling exercise around Lake Mzingazi become available.

5.5.3 Ecological aspects

Possible ecological effects of anthropogenic fluctuations of lake levels on plant life around and downstream of Lake

Mzingazi were investigated by Boshoff (1983) at the University of Zululand. Major adverse effects are primarily related to the degree and rate of lake level fluctuations as well as the season at which these occur. The report concludes that:

- the present composition of plants will change and certain types that are important to the maintenance of bird life may be obliterated

- submergence of rotting plant material due to raising of the lake level will cause fluctuations in the algal content of the water, with adverse consequences

- the unique character of the area between the lake and the canal would possibly be severely damaged or extinguished. This would be serious as this is a sole remnant of its type in the area.

Investigations by G Begg (1978) have indicated that to maintain the ecology of the Mhlatuze Sanctuary will require about 49 $x10^6 m^3/a$, mostly in the form of floods. This alleged requirement will have to be revised, however, in the light of the ecological transformation currently taking place in the sanctuary as a result of the large-scale deposition of silt in the sanctuary and the altered pattern of tidal exchange in the estuary.

At Lake Cubhu extensive areas of papyrus reeds would die if the wetlands surrounding the lake were to be drained by lowering of the lake surface. The mangroves can, however, tolerate fluctuating lake levels.

At Lake Nsezi the water level, according to the CSIR report (1983), should be maintained at 6,25 m MSL ± 0,25 m in order to preserve the valuable riverine forests and the lake ecosystem.

To further refine allowable minimum and maximum operating levels for the lakes would require a detailed environmental impact assessment. Such an assessment would include the following:

- Detailed mapping of fauna and flora in and around each of the lakes and identification of ecologically sensitive or valuable features.

- Assessment of the effect of changes in water level on each of the identified areas, quantifying damage and/or loss relative to that in other sensitive areas.

- Identification of areas where prolonged inundation or desiccation cannot under any circumstances (or at any cost) be tolerated.

- Setting of preferred and maximum allowable ranges of operating levels.

Such a study would require several months of work by specialists and is clearly outside the scope of this report. Meanwhile, in the simulations which follow, all lakes have been operated within present operating limits. If improved or different operating ranges come about as the result of future studies the analyses can be adjusted in a later phase of the project.

6. SYSTEMS ANALYSIS

6.1 System Model

The Acres Reservoir Simulation Program (ARSP) operating on the Department of Water Affairs Computer in Pretoria was used to model the Mhlatuze River System.

ARSP is a linear programming model which requires the system to be described as a network of nodes and channels. Although the program allows for numerous different channel types, these all fall into either of two categories, namely: flow channels of which the carrying capacities are split into discrete ranges, with a penalty (or cost) assigned to flow in each range, and demand channels having penalties imposed for failure to meet the specified demand (or flow).

Nodes can be either reservoir nodes or junction nodes. Reservoir nodes are points in the system having natural inflow in addition to other inflows or outflows and are either with or without storage. Junction nodes have no storage and merely interconnect various channels.

Reservoir storage is subdivided into layers called zones. To each zone is assigned a penalty to represent the cost (or value) of the water in the reservoir.

A rule curve is associated with each reservoir in the system. Water stored below the level defined by the rule curve has a value but water stored above the rule curve level is stored at a cost to the system.

All penalties assigned to flow into, out of or through the various components are relative. However, although the penalties have no real meaning, ARSP operates the system to minimize total penalties. Thus the penalties serve to define the operating rules and the priorities within the system. There is no unique solution for a workable set of penalties and the onus is on the user to select appropriate relative penalties to ensure that the system will operate as envisaged.

6.2 Network description

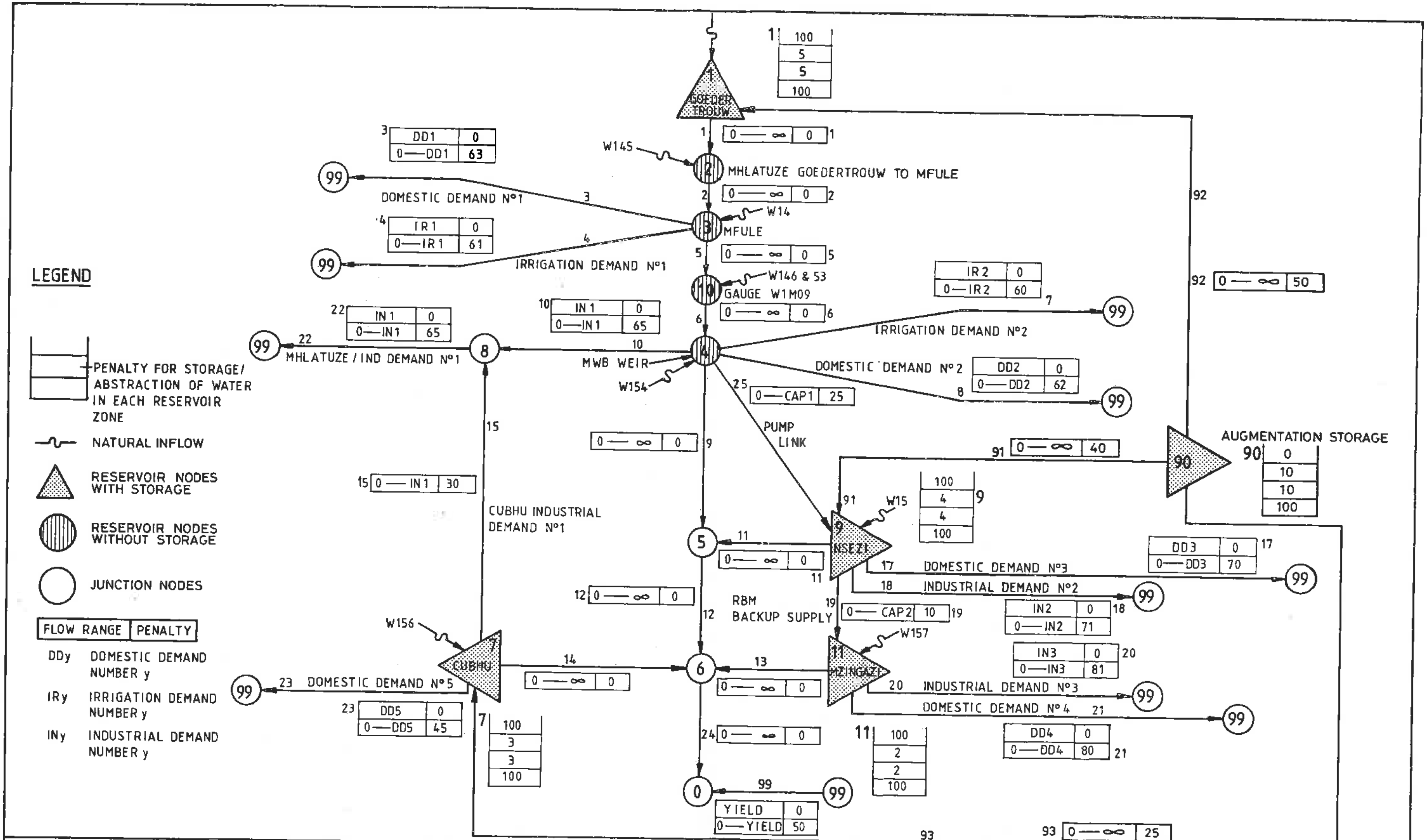
The Mhlatuze river system is represented in the ARSP as a network. The components of the network are described in the following paragraphs with reference to figure 6.1. In the simulation analysis the nodes and channels are referred to by the numbers allocated in the following tables.

6.2.1. Reservoir nodes

Table 6.1 lists the reservoir nodes that have storage and table 6.2 lists those that do not have storage.

Table 6.1 Reservoir nodes with storage

Node number	Reservoir name	Remarks
1	Goedertrouw dam	Existing dam on Mhlatuze river
7	Lake Cubhu	Coastal lake (with artificial embankment and spillway)
9	Lake Nsezi	Coastal lake (with artificial embankment and spillway)
11	Lake Mzingazi	Coastal lake (with artificial embankment and spillway)
90	Augmentation storage	Large storage provided in the network to measure support required by the system in the future



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MHLATUZE RIVER CATCHMENT STUDY

PENALTY STRUCTURE DIAGRAM FOR ARSP NETWORK

FIGURE 6.1

Watermeyer, Legge, Piésold & Uhlmann

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Table 6.2 Reservoir nodes without storage

Node number	Description
2	At Mhlatuze - Mfule confluence. Incremental natural inflow from Mhlatuze.
3	At Mhlatuze - Mfule confluence. Natural inflow from Mfule.
4	At MWB weir. Incremental natural inflow between gauge WIM09 & MWB weir.
10	At gauge WIM09. Incremental natural inflow between Mfule confluence & WIM09

6.2.2. Junction nodes

Junction nodes listed in table 6.3, are nodes in the system with no natural inflow. These nodes merely connect various inflow and outflow channels.

Table 6.3 Junction nodes in the network

Node number	Description
5	Confluence of outflow from Lake Nsezi with Mhlatuze river
6	Confluence of outflows from lakes Cubhu and Mzingazi with Mhlatuze river
8	Node to combine flow to industrial demand #1 supplied from the Mhlatuze river with backup supply from Lake Cubhu
99	Node to combine all demands to measure yield of the system
0	Spill from the system

6.2.3 Flow channels

Flow channels listed in table 6.4, in the Mhlatuze network are channels to transport water from one node to the other without restricting or affecting the flow in any way. Flow in these channels are not controlled and they are not used to describe the operating rules of the system.

Table 6.4 Natural flow channels in the system.

Channel number	Description
1	Mhlatuze river downstream of Goedertrouw dam and slightly upstream of Mfule confluence
2	Mhlatuze river downstream of Channel #1 dam and upstream of Mfule confluence
5	Mhlatuze river downstream of Mfule confluence and upstream of gauge WIM09
6	Mhlatuze river downstream of gauge WIM09 and upstream of MWB weir
9	Mhlatuze river downstream of MWB river and upstream of confluence with spill from Lake Nsezi
11	Spill from Lake Nsezi
12	Mhlatuze river downstream of Lake Nsezi and upstream of lakes Mzingazi & Cubhu infalls to Mhlatuze
13	Spill from Lake Mzingazi
14	Spill from Lake Cubhu
24	Spill to the sea/flow through the sanctuary
91	Augmentation link to Lake Nsezi
92	Augmentation link to Goedertrouw dam
93	Augmentation link to Lake Cubhu

6.2.4 Demand channels

Demand channels listed in table 6.5, are used to describe drawoffs (demands)) on the system. Relative penalties to under supply are used to set priorities if the system fails.

Table 6.5 Demand channels

Channel Number	Description
3	Domestic demand #1 : Melmoth + part rural
4	Irrigation demand #1 : Nkwaleni irrigation board
7	Irrigation demand #2 : Heatonville and Mfule irrigation boards plus KwaZulu
8	Domestic demand #2 : Ngwelezana, University of Zululand, Felixton + part rural
10	Industrial demand #1 : Mondi board mill and Tongaat-Hulett mill
15	Industrial demand #1 : Backup supply from Lake Cubhu
17	Domestic demand #3 : Empangeni, Nseleni Township + part rural
18	Industrial demand #2 : All industry not listed as industrial demand #1 or #3
19	Augmentation link between lakes Nsezi and Mzingazi
20	Industrial demand #3 : Alusaf and Richards Bay Minerals
21	Domestic demand #4 : Richards Bay plus part rural
22	Industrial demand #1 : combined supply plus backup
23	Domestic demand #5 : eSikawini plus part rural
25	Pump link between MWB weir and Lake Nsezi
99	Yield channel to combine all demand channels

6.2.5 Operating rules for the system

The following operating rules were adopted for the systems analysis:-

- Storage in the coastal lakes was drawn down first, with Goedertrouw dam acting as backup storage to the lakes. Working storage in the lakes was limited to that in the top 1 m (i.e. between FSL and FSL-1 m) except in the case of Lake Nsezi where the operating range was only 0,5 m because at Nsezi turbidity becomes a problem at lower drawdown levels. (Operation was thus in accordance with current operating rules but will have to be reviewed after a full environmental impact assessment has been completed).

- The link between the MWB weir and Lake Nsezi can transfer flow from the river subject to a 6 m^3/s assumed upper pumping limit.

- The link from Lake Nsezi can transfer up to an assumed maximum of 4 m^3/s to Lake Mzingazi.

- The Cubhu backup supply to industrial demand #1 will supply water only if insufficient flow is available in the Mhlatuze river to satisfy the Felixton demand.

- No specific demand is specified for the sanctuary.

6.3 Simulation runs

System operation was simulated with the 65-year time series of streamflows based on historical runoff for five demand scenarios, viz:

- Current demand (1989)
- Demand in 1995 based on fast growth
- Demand in 2020 based on fast growth
- Demand in 1995 based on slow growth
- Demand in 2020 based on slow growth

Selected pages of the ARSP printouts for these simulation runs are included in Appendix H.

Projected water demands for the five demand scenarios were taken from table 3.6. Domestic and industrial demands were assumed to remain constant throughout the year but agricultural demand was varied according to crop requirements. The time distribution of irrigation water demand used in the analysis (expressed as a percentage of total abstraction) is reflected in table 6.6 and is the same as that used in the Geldenhuys-Perkins report (Department of Water Affairs, 1985).

Table 6.6. Monthly irrigation abstraction rates

Month	Irrigation requirement as % of annual total
October	11,06
November	10,04
December	11,25
January	7,90
February	5,86
March	9,85
April	9,29
May	6,78
June	6,51
July	7,06
August	8,27
September	6,13

Dryland cane affects runoff in a way similar to afforestation. The basin also has abundant natural bush and/or forest which reduces surface runoff as well as groundwater recharge. Accordingly the area designated as afforested in the simulation runs is greater than that indicated as commercial forest (see table 3.2). Afforested areas thus included also the assessed areas of both natural forest and dryland cane. Land use in Natal is currently being mapped from satellite imagery in the Hydrological Research Institute. Mapping is not sufficiently far advanced, however, for the results to be included in this report but preliminary assessments made by the Institute were used as a check against estimates made by other means. Table 6.7 indicates the "afforested" areas used in the simulation.

Table 6.7 List of afforested areas

Catchment	Area of catchment (km^2)	Area of forest (km^2)	Percentage of catchment
Goedertrouw (W13)	1295	100	7,7
Mzingazi (W157)	171	108	63,2
Cubhu (W156)	74	22	29,7
Mhlatuze (W145)	280	190	67,9
Mhlatuze (W146 & 53)	435	300	69,0
Mhlatuze (W154)	340	250	73,5
Nseleni (W15)	145	98	67,6
Mfule (W14)	620	146	23,5
Upper Nseleni (W152)	665	500	75,2
Totals	4025	1714	42,6

Water abstracted in accordance with riparian rights along the Nseleni river was modelled using an irrigation abstraction file. In this way the demand would be met from streamflow rather than from Lake Nsezi.

Results of the various simulations are summarised in table 6.8 and a plot of yield versus demand is shown on figure 6.2. From the figure it may be seen that the firm yield of the system is estimated at some 284 $x10^6m^3/a$. This is to be compared with the estimate of 320 $x10^6m^3/a$ in the White Paper Q-'73.

From figure 6.2 it is evident that, unless demand management is introduced soon, the system will require augmentation prior to 1995.

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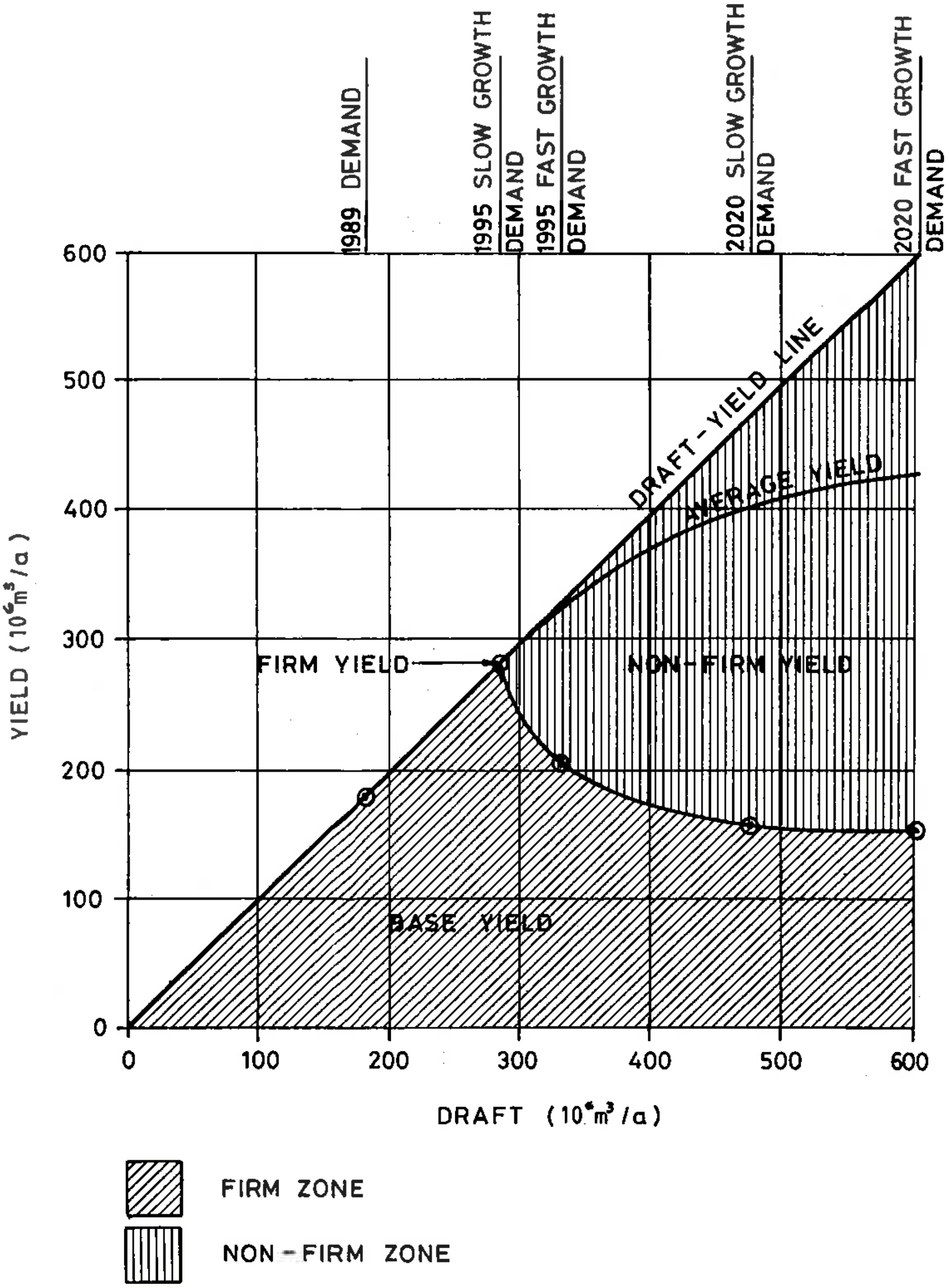

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AVERAGE DRAFT / YIELD RESPONSE DIAGRAM

FIG. 6,2

Table 6.8 Summarised results of simulations of the Mhlatuze system

DEMAND	Total Demand		Base Yield		Average Yield		Maximum augmentation		Average augmentation	
	$10^6m^3/a$	m^3/s	$10^6m^3/a$	m^3/s	$10^6m^3/a$	m^3/s	$10^6m^3/a$	m^3/s	$10^6m^3/a$	m^3/s
1989	178,9	5,67	178,9	5,67	178,9	5,67	0	0	0	0
1995 slow	284,0	9,00	284,0	9,00	284,0	9,00	0	0	0	0
1995 fast	330,1	10,46	205,1	6,50	325,6	10,32	125,0	3,96	4,4	0,14
1995 fast+ Mfule dam	330,1	10,46	203,0	6,43	327,7	10,39	127,1	4,03	2,4	0,08
2020 slow	475,3	15,06	156,7	4,97	403,9	12,80	318,4	10,09	71,4	2,26
2020 fast	600,8	19,04	156,6	4,96	429,3	13,60	444,2	14,08	171,6	5,44

To examine the degree to which it might be possible to delay importation, we assumed that additional storage would be provided within the Mhlatuze system. Accordingly, live storage in the Mfule, equivalent to the MAR at the confluence with the Mhlatuze, was assumed to be operative and the results for this scenario are shown in detail in Appendix I and in summary in Table 6.8.

In assuming that flow could be abstracted at the Mhlatuze weir at rates up to 6 m^3/s (i.e. of the order of 16.10^6m^3 per month), it was implied that the necessary balancing storage was available at the diversion site to permit the analysis to be performed at monthly time resolution. It followed therefore that the additional storage would have to be substantial to have an effect on the calculated yield. As may be noted from Table 6.8, introduction of the one MAR dam in the Mfule did not significantly improve the augmentation situation; storage of considerably greater storage would be needed to capture the larger floods, the smaller floods having already been diverted to demand distribution points from the run-of-river.

The average yield for this scenario, viz. $327,7.10^6m^3/a$, is roughly 60% of the system MAR, given in Table 4.1 as 552.10^6m^3. In view of the relative absence of storage potential in the downstream parts of the system, utilisation on average of 60% MAR is plausible.

Because of the time constraints set for completion of the reconnaissance study it was not possible to include the stochastic component of the analysis which would provide confidence limits to the curve in figure 6.2. The overall conclusion, however, is unlikely to change substantially.

6.4 Discussion of results

The following should be borne in mind when interpreting the results:-

- o Goedertrouw dam was allowed to be drawn empty during the analysis but no limit was placed on the rate at which it could be drawn down. Physical constraints at the dam, such as the size of low level outlets, may require that abstraction from the dam, at least below a certain level, be limited to a maximum rate. This may have some effect on the results.

- o The rate at which the base yield drops after demand passes the firm yield point seems very rapid. This indicates that the firm yield based on historical hydrology may have been overestimated, and may drop when stochastic hydrology is used in the analysis.

- o Irrigation demand was assumed to be reduced to 40% of full demand for 25% of the time. Rather than introduce rules for the imposition of the irrigation curtailment, the analysis was based on a constant average demand, viz. 85% of full demand. This approximation obviously has an effect on the results of the analysis but, until operating rules for Goedertrouw dam can be

By way of further elucidation of the results summarized in Table 6.8, attention is drawn to Fig. 6.3 which reflects summarised mass balances (a) over the whole simulation period for one demand scenario and (b) over the critical period. The critical period selected was the longest period from the simulated record during which Goedertrouw dam was drawn from full to empty. This was a period of 8,5 years (102 months) from May 1944 to October 1953. The demand situation for which Fig. 6.3 was prepared was the 1995 fast-growth scenario as this was the first level of rising demands that exceeded the firm yield of the Mhlatuze system, (i.e. the lowest of those simulated to show deficits).

From Fig. 6.3 it follows:

- that the average draft on the system would be some $329 \times 10^6 m^3/a$ (~60% MAR) and the average spill to the ocean about $223 \times 10^6 m^3/a$ (~40% MAR).

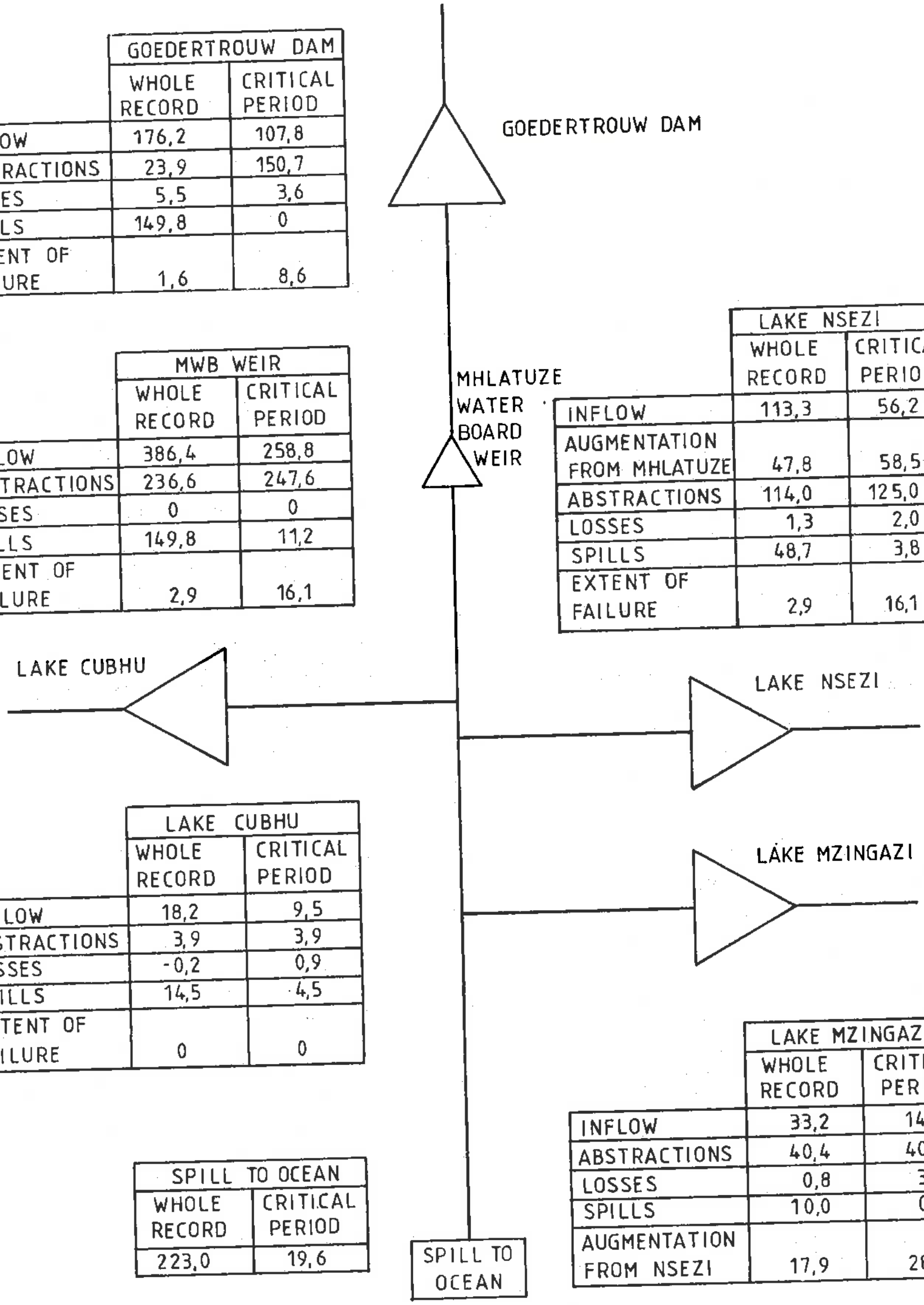
- shortfalls in supply would average about $4{,}5 \times 10^6 m^3/a$ (~1% of demand).

- during the critical period (which represents cumulative inflow of 5,2 MAR over the 8,5 years, estimated to have a recurrence interval of between 40 and 60 years) spillage to the ocean would decline to an average at about $20 \times 10^6 m^3/a$ (~4% MAR) while shortfall in supply would average about $25 \times 10^6 m^3/a$ (~8% of draft).

Although not evident from the summarised mass balance in figure 6.3 the extent of failure is of interest. For instance, during the worst year of the critical period (1952) the average shortfall was some $125 \times 10^6 m^3/a$ (38% of demand) whereas during the worst month the system was short by the equivalent of about $268 \times 10^6 m^3/a$ (81% of demand).

Clearly, during circumstance of extreme drought (roughly once in 50 years) most severe restrcitions would have to be imposed to avoid complete failure of supply.

NOTE: UNITS - $10^6 m^3/a$



	GOEDERTROUW DAM	
	WHOLE RECORD	CRITICAL PERIOD
INFLOW	176,2	107,8
ABSTRACTIONS	23,9	150,7
LOSSES	5,5	3,6
SPILLS	149,8	0
EXTENT OF FAILURE	1,6	8,6

	MWB WEIR	
	WHOLE RECORD	CRITICAL PERIOD
INFLOW	386,4	258,8
ABSTRACTIONS	236,6	247,6
LOSSES	0	0
SPILLS	149,8	11,2
EXTENT OF FAILURE	2,9	16,1

	LAKE NSEZI	
	WHOLE RECORD	CRITICAL PERIOD
INFLOW	113,3	56,2
AUGMENTATION FROM MHLATUZE	47,8	58,5
ABSTRACTIONS	114,0	125,0
LOSSES	1,3	2,0
SPILLS	48,7	3,8
EXTENT OF FAILURE	2,9	16,1

	LAKE CUBHU	
	WHOLE RECORD	CRITICAL PERIOD
INFLOW	18,2	9,5
ABSTRACTIONS	3,9	3,9
LOSSES	-0,2	0,9
SPILLS	14,5	4,5
EXTENT OF FAILURE	0	0

	LAKE MZINGAZI	
	WHOLE RECORD	CRITICAL PERIOD
INFLOW	33,2	14,7
ABSTRACTIONS	40,4	40,4
LOSSES	0,8	3,1
SPILLS	10,0	0,1
AUGMENTATION FROM NSEZI	17,9	28,9

SPILL TO OCEAN	
WHOLE RECORD	CRITICAL PERIOD
223,0	19,6

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SYSTEM DIAGRAM SHOWING MASS BALANCES

FIG. 6,3

7. FURTHER WORK

7.1 Risk Analysis

Augmentation to existing water supply should normally be planned to come on stream when the risk of failure becomes intolerable, or when the cost associated with failure exceed the cost of augmentation. To make this assessment for the Mhlatuze system, one needs more information than is presented in this report and this means that further work primarily in the form of statistical analysis and field exploration, will be required.

Figure 6.2, which illustrates the results of the systems analysis, implies that the system will not be capable of meeting the projected demands much beyond the year 1993, but there is as yet no indication of the risk of supply failure before that date, or the reliability with which one can predict the date when augmentation can no longer be safely delayed.

In order to optimise the system components and to assess the risks of failure, or the reliability with which both quantity and timing of augmentation can be predicted, it will be necessary to repeat the simulations using multiple stochastically-generated time series of river flow, so that the results can be statistically analysed.

7.2 Augmentation prospects

There is no doubt that the system cannot meet the projected 2020 demands without a substantial injection of water from an external source. This is the case even if it were feasible to provide massive storage within the Mhlatuze system, because the estimated demand even for relatively slow development will by 2020 exceed the total mean annual runoff of the system.

From a study of the system, both diagramatically on Fig 6.1 and geographically on Plate 1, it is evident that the important expanding demand centres can be most conveniently commanded from the Nseleni river and Lake Nsezi. Lake Nsezi thus represents a key distribution point and the aim would therefore be to route the augmentation flow through the Nseleni river.

Of possible external sources of augmentation only two are realistic: the Tugela river to the south and the Mfolozi to the north.

The Tugela is about 15 km distant from and nearly 700 m lower than the nearest point on the Tugela-Mhlatuze divide, i.e. at the head of the Mvuzana river which flows into the Mhlatuze upstream of Goedertrouw dam. The prospect of transferring large quantities of water by this route over some most difficult terrain is unattractive.

The White Mfolozi, on the other hand, is about 4 km distant from, and about 500 m lower than, the nearest part of the Mfolozi-Mhlatuze divide, i.e. at the head of the Mfule. However, an injection into the Mfule cannot conveniently be routed to the Nseleni and the Mfule carries an inordinately heavy sediment load, with obvious adverse implications for storage.

At its closest to the Nseleni divide, the White Mfolozi is about 6 km away but the difference in elevation only 200 m. Unfortunately, the White Mfolozi at this point lies within the Umfolozi Game Reserve and the Natal Parks Board would not take kindly to the prospects of a dam within the Reserve. There is a good dam site some distance upstream of the Reserve boundary and it may be feasible to provide the storage there and to pump from a pick-up weir in the Reserve, thus taking advantage of the shorter pumping distance.

Further downstream, on the Mfolozi itself, is the KwaMshaya site where a flood control dam was proposed some years ago by B G A Lund (1973 with the objective of providing protection to the Mfolozi flats as well as water for irrigation of the Nyalazi flats and for sweetening Lake St Lucia during times of hypersalinity. (See Plate 1). Foundatio conditions at this and several other dam sites in the Mfolozi syste have been investigated by the Department of Water Affairs. (Se Ondersoek en Eliminasie van Damterreine in die Mfolozi-opvanggebied DWA 1981).

Begg (1985), in a preliminary Environmental Impact Assessment of the proposed KwaMshaya dam, recommended that a wide-ranging comprehensive assessment be undertaken in view of the high priority accorded to the proposal by Umfolozi Cooperative Sugar Planters, Ltd. With the evident need for a water transfer to the Mhlatuze basin the KwaMshaya proposal takes on renewed importance. The possible need to establish a major link with the Nseleni system over 15 km of undulating terrain with good access would add to the merits of this multi-purpose proposal.

7.3 Operating storage

Beyond the year 1995 both Lake Mzingazi and Lake Nsezi will be operating much of the time at minimum drawdown. At first glance therefore it seems there would be little advantage, hydrologically speaking, to be gained by raising the full supply levels of either of these lakes to provide additional storage.

However, it is also evident from the ARSP model results that operation of Lake Nsezi between levels 6,5 and 6,0 mMSL (i.e. a working storage of only 3,4 $x10^6m^3$) becomes more and more difficult as the throughput increases. Ideally, from an operating point of view, one would require about one month's supply in Lake Nsezi. At year 2020, this would entail raising the lake level by about 5 m which would cause intolerable damage in the Nseleni reserve and along the periphery of the lake. On the other hand, it may be possible to provide local off-channel pumped storage to overcome the operational difficulties. Alternatively, if the balancing storage associated with the augmentation link has gravitational command of Lake Nsezi, it may well be feasible to operate the lake as at present. Without doubt, intensive studies would be needed before a satisfactory design could emerge.

Likewise, in the case of Lake Mzingazi, the merits of raising the lake wall can be properly assessed only after routing of multiple stochastically-generated time series through the ARSP model of the system. On the face of it, however, there seems little merit in the concept of raising the lake spillway.

7.4 Preservation of wetlands and estuary

In the simulations so far no allowance has been made for return flows from irrigated lands and from sewage treatment works that discharge to the river system. The thinking was that these unallowed-for quantities of water might serve to maintain the vast Mhlatuze wetlands and the sanctuary at the estuary mouth.

Now that the ARSP model is up and running, it may be wise to attempt a quantification of the return flows and to judge to what extent these can in fact serve to prevent a drying-out of the wetlands during drought.

The print-out of monthly flows to the ocean through the sanctuary indicates that, as may be expected, flood discharges are substantially less frequent than under natural conditions. There are in fact periods of up to three consecutive years with no flushing of the estuary. The environmental consequences of this situation must still be assessed.

7.5 Management of demand

Another aspect to be considered, in view of the high cost of managing supply, is the degree to which demand can be managed in order that augmentation from neighbouring catchments may be delayed. Wherever vigorous growth, backed by lucrative mining and industry, can be seen to be outstripping the local water resources, however, it invariably pays to take the necessary steps to import water rather than endeavour to stifle growth or translocate to areas where water is abundant. The initial infrastructure associated with inter-basin transfers is usually so expensive that, unless there are economies of scale and a ready market for the water, importation becomes a non-starter. It follows that where the growth core is vigorous, as is the case at Richards Bay, management of demand should be timed to follow - not precede - the laying down of the infrastructure for inter-basin water transfer.

The various procedures involved in planning, designing and constructing an augmentation scheme of the magnitude envisaged will involve several years' work but, as the system may require augmentation as early as 1993, it follows that a degree of demand management will be unavoidable. A study of the extent to which demands can be managed is essential for two reasons. First, such a study would provide a management plan for operation of the system so as to minimise risk until augmentation can be effected. Secondly, the study would enable the risks of supply failure to be assessed and provide the basis for weighing the costs of water shortage against the costs augmenting the system to avoid the risk of shortfall.

7.6 Proposals

The study has disclosed a strong possibility that should the demands, as projected, materialise the system will be dangerously stressed well before the year 1995. It goes without saying that to bring on stream before 1995 an augmentation of the magnitude envisaged is hardly practicable. Two categories of proposals are therefore presented:- short term proposals aimed at minimising risk until augmentation can be effected, and long term proposals that will ultimately lead to construction of an augmentation scheme.

7.6.1 Short term proposals

- Demand management. Despite what has been said about resorting to demand management ahead of interbasin transfer, there is unfortunately little option. Operating rules for Goedertrouw dam must therefore be devised to ensure that during severe drought the industrial demands can be met at the expense, where necessary, of irrigation and domestic users.

  The study has shown that farmers normally irrigate larger areas with their water quota than the areas for which they are scheduled. It follows that it may be fruitful to investigate the feasibility of revising the quotas.

- o Integrated environmental management (IEM). Environmental distress during extreme drought is inevitable and it is therefore proposed that the broad outlines of the long term proposals for augmenting water supplies to the Richards Bay area be revealed to the Department of Environment Affairs and that without delay a team of experts be appointed to commence the necessary studies leading to IEM guidelines.

  It can be expected that the studies associated with the augmentation scheme will be prolonged but of immediate concern is the degree to which existing constraints on the range of operating levels in the coastal lakes can be relaxed, so as to facilitate operation of the system in the face of rising demands.

7.6.2 Long term proposals

- o Augmentation prefeasibility. A pre-feasibility study for augmentation of water supply to the Mhlatuze basin would be aimed at devising a cost-optimised transfer scheme. To be addressed would be: optimum sizing of augmentation scheme, various potential scheme layouts, including a study of various dam sites (both external and within the Mhlatuze system), appropriate types of dam, improved hydrology to establish reliable yield, potential transfer routes, possible multiple purposes of storage, such as flood control on the Mfolozi flats, sweetening of Lake St Lucia and possible future water needs of Richards Bay Minerals in the north. New storage within the Mhlatuze system may also affect the firm yield of the system thus possibly allowing phased implementation of an augmentation scheme.

- o A detailed feasibility study of the preferred layout as recommended in the prefeasibility study. This study would refine the system layout and sizing of components to ensure that a viable, cost-optimised transfer scheme is offered.

- Preparation of design and tender documents for an approved layout. Tender adjudication and award.

- Detailed design and construction supervision.

Although the foregoing proposals are concerned with long term aims it is important to stress that the prefeasibility study should commence as soon as possible so that implementation of the required scheme will not be unnecessarily delayed.

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