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DEPARTMENT OF WATER AFFAIRS
AND FORESTRY

in association with

UMGENI WATER
Corporate Services Division

MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

MKOMAZI-MGENI TRANSFER SCHEME

SUPPORTING REPORT No 4

HYDROLOGY & WATER RESOURCES

Report No 2787D/7856
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MKOMAZI/MOOI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY
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MKOMAZI / MOOI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

PREFACE

In January 1997, the Department of Water Affairs & Forestry: Directorate of Project Planning, in conjunction with Umgeni Water: Corporate Services Division, invited various firms of consulting engineers to submit proposals to undertake a Pre-Feasibility Study for a scheme to transfer water from the upper Mkomazi River to the Mgeni System. In July 1997, a multi-disciplinary team led by Ninham Shand was appointed.

This Study follows on from the Mgeni River System Analysis Study carried out between 1991 and 1994, in which the Mkomazi River was identified as a potentially viable source of water for augmentation of the Mgeni System, and the Mooi-Mgeni Transfer Feasibility Study carried out in 1995, in which the first phase scheme to augment the Mgeni System from the Mooi River was investigated in detail and possible second phase schemes were identified.

This Study comprises two distinct parts; a pre-feasibility investigation of augmentation schemes on the Mkomazi River preceded by scheme identification and reconnaissance investigations, and a pre-feasibility investigation of second phase transfer schemes from the Mooi River. A comparison of the two main augmentation options is made at the culmination of the Study. The report structure is given overleaf.

Sub-consultants employed by Ninham Shand to undertake various aspects of the Study included:

- IWR Environmental: Environmental studies and IEM co-ordination
- Scott Wilson: Social studies
- Keeve Steyn: Engineering aspects of tunnels and pumpstations, and involvement with Basin Studies
- Simmer Biggar and Associates: Infrastructure aspects.

As part of the Study Team, the following Client departments were involved:

- Council for Geoscience: Geological Survey
- Department of Water Affairs & Forestry: Project Planning (East)
- Department of Water Affairs & Forestry: Environment Studies
- Department of Water Affairs & Forestry: Hydrology
- Umgeni Water: Corporate Services Division: Water Resources Planning
- Umgeni Water: Scientific Services Division: Water Quality
- Umgeni Water: Scientific Services Division: Hydro-biology.

EXECUTIVE SUMMARY

This report describes the hydrology and yield analysis task of this Study. The first section of the report describes the present development hydrology, as well as a summary of the future 2040 hydrology produced during this Study. The second section of the report describes the yield analysis for the various schemes investigated.

Hydrology for the Mkomazi River was produced during the Mgeni River System Analysis Study and then updated as part of the Mkomazi/Mgeni/Mooi River Hydrology and Yield Update Study. The present development hydrology spans the hydrological years 1925 to 1995, inclusive.

The Mkomazi River catchment was previously divided into 4 subcatchments for modelling purposes, matching proposed dam sites, with the present development hydrology produced for these subcatchments. This Pre-Feasibility Study was carried out at quaternary catchment level and the present development hydrology was disaggregated from the modelling subcatchments, each extending over more than one quaternary catchment, to quaternary catchment level. Disaggregation of the present development natural runoff, irrigation and afforestation demand sequences were based on the ratios of quaternary and modelling subcatchment areas and mean annual precipitation, and the present irrigation and afforestation areas.

In addition to the present (1995) development hydrology, estimates were made of possible future 2040 irrigation and forestry areas in the Mkomazi River catchment in order to determine the effect of increasing development on the MAR of the catchment. (Refer to Supporting Report No 3: Reconnaissance Basin Study). Estimates of the 2040 development were made for three demand scenarios, namely a high, middle (most likely) and low road scenario. Irrigation and forestry demands were calculated for each quaternary catchment. The present development runoff sequences for each quaternary catchment, were not revised as no re-calibration of the hydrological runoff-models were conducted. Irrigation and forestry demand sequences were produced for the middle road scenario for use in the yield analysis.

Industrial demands in the Mkomazi River catchment are limited to a present demand of about 53 million m^3/a for SAPPI/SAICCOR near the bottom end of the catchment.

The environment was found to be the largest sectoral demand for both present and future (2040) middle road conditions, at about 29% of the natural MAR. This was followed by forestry at about 5% and 8%, irrigation at 3% and 6% for present and future (2040) middle road conditions respectively. The industrial demand at SAPPI/SAICCOR is at about 5% of the natural MAR. Both forestry and irrigation activities are concentrated in the middle reaches of the catchment. Domestic and livestock demands amount to less than 1% of the natural MAR and were ignored for the purposes of this analysis.

The Water Resources Yield Model (WRYM) was configured for the Mkomazi River catchment to conduct the yield analysis. The yield analysis was carried out to determine scheme yields for a number of different schemes and development conditions.

Demands placed on the system included irrigation, afforestation, the SAPPI/SAICCOR demand and Instream Flow Requirements (IFR). Allowance was made for an IFR drought flow of once in every 10 years on average. IFR's were met only from run-of-river water without any augmentation from the dams.

The following schemes were investigated:

- *Impendle Phase 1 Scheme (five different sizes)*
- *Smithfield Phase 1 Scheme (one size)*
- *Smithfield Phase 2 Scheme, assuming a single capacity for Smithfield Dam and two different sizes of Impendle Dam*
- *Smithfield Phase 2 Scheme with a 1,5 MAR Impendle Dam, with three different capacities for a Lower Mkomazi Dam*
- *Impendle Dam (1,5 MAR) with transfer to the Mgeni System (preliminary)*
- *Smithfield Phase 2 with transfer to the Mgeni System (preliminary).*

*The results of the historical yield analyses are shown in **Table E1** below.*

Preliminary yield analyses were conducted for the Mgeni System with transfers from the Mkomazi River catchment. Although the critical draw-down periods of the Mooi/Mgeni and Mkomazi Systems coincide, the Mkomazi System has a slightly longer critical period. The preliminary results indicated that the total Mgeni System yield is, depending on the operating rules, approximately equal to the sum of the individual Mooi/Mgeni and Mkomazi System firm yields. The analysis also indicated that the total system yield is relatively insensitive to the capacity of the transfer from the Mkomazi River schemes.

TABLE E1: RESULTS OF HISTORICAL YIELD ANALYSIS

Scheme Name	Dams in Scheme	Dam Volume Mm^3 (% MAR)	Firm Yield (Mm^3/a) for Development Level		
			Natural Conditions	Present Development	2040 Middle Road Scenario
Impendle	Impendle	135 (25)	126	120	
		270 (50)	223	204	
		543 (100)	314	293	276
		675 (125)	341	318	
		810 (150)	358	335	304
Smithfield	Smithfield	137 (19)	157	131	112
Smithfield Phase2	Impendle Smithfield	543 (100) 137 (19)	397	357	331
	Impendle Smithfield	810 (150) 137 (19)	454	413	385
Lower Mkomazi	Impendle Smithfield Lower Mkomazi	810 (150) 137 (19) 517 (50)		122	
	Impendle Smithfield Lower Mkomazi	810 (150) 137 (19) 1 033 (100)		186	
	Impendle Smithfield Lower Mkomazi	810 (150) 137 (19) 1 549 (150)		246	

The reduction in yield for the future middle scenario was, apart from the Smithfield Phase 1 scheme, less than 10% in all cases. A possible future dam on the lower reaches of the Mkomazi was also evaluated, but its viability is doubtful, as a very large dam would be required in order to achieve a significant yield.

Long-term stochastic yield analyses were conducted for all schemes, except the Lower Mkomazi schemes, using present development hydrology, as well as for five schemes using future (2040) middle road hydrology. The long-term stochastic yield analyses were based on 201 71-year sequences. The results of the long-term stochastic yield analyses are shown in ***Table E2****.*

TABLE E2: RESULTS OF LONG-TERM STOCHASTIC YIELD ANALYSIS

Scheme	Firm Yield for Indicated Recurrence Intervals (Mm^3/a)				
	Historical	1:20yr	1:50yr	1:100yr	1:200yr
PRESENT DEVELOPMENT SCENARIO					
Imp 135 Mm^3	120	188	169	161	155
Imp 270 Mm^3	204	265	240	228	218
Imp 543 Mm^3	293	349	313	296	280
Imp 675 Mm^3	318	374	337	320	302
Imp 810 Mm^3	335	395	356	336	319
Smith 137 Mm^3	131	208	187	177	166
Smith + Imp 543 Mm^3	357	434	390	369	349
Smith+Imp 810 Mm^3	413	480	434	409	387
FUTURE DEVELOPMENT SCENARIO					
Imp 543 Mm^3	276	323	293	275	260
Imp 810 Mm^3	304	373	334	313	296
Smith 137 Mm^3	112	176	159	147	136
Smith + Imp 543 Mm^3	331	402	364	335	319
Smith+Imp 810 Mm^3	385	451	405	376	356

The reduction in stochastic firm yield (for the 1 in 100 year recurrence interval) for the middle scenario was, apart from the Smithfield Phase 1 scheme, again less than 10% in all cases.

The following further studies and actions are recommended for the feasibility phase of investigation:

- *Proceed with the determination of the Ecological and Basic Human Needs Reserves.*
- *Review projected forestry areas and other runoff-reducing activities in the light of catchment management initiatives, possible revisions to limits previously set and changes in policy.*
- *Assess the impact of river losses on IFR and other releases.*
- *Update hydrological and yield models accordingly.*

MKOMAZI-MGENI TRANSFER SCHEME

SUPPORTING REPORT NO 4: HYDROLOGY AND WATER RESOURCES

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Figures Included in Appendix A (cont'd)

MKOMAZI-MGENI TRANSFER SCHEME

SUPPORTING REPORT NO 4: HYDROLOGY AND WATER RESOURCES

1. INTRODUCTION

This report describes the hydrology and yield analysis tasks of this Study.

The first section of the report describes the available present day hydrology, as well as a summary of the future development hydrology produced during this Study. The second section of the report describes the yield analysis and various schemes investigated.

2. PURPOSE OF THE HYDROLOGY AND YIELD ANALYSIS TASKS

The Mkomazi River hydrological and yield analysis task consisted of the following, with the first two components also feeding into Supporting Report No 3 : Reconnaissance Basin Study:

- disaggregation of the present development hydrology of the Mkomazi River into quaternary catchment hydrology;
- determining the effect on mean annual runoff (MAR) of forestry and irrigation with revised data for the future 2040 development levels; and
- conducting historical and stochastic yield analyses using the Water Resources Yield Model (WRYM) for a number of schemes and development scenarios.

It should be noted that the terms of reference for this Study required that existing sources of hydrological data be utilised, and that no calibration of flow records would be required.

3. AVAILABLE HYDROMETEOROLOGICAL RECORDS

3.1 Introduction

The Mgeni River System Analysis Study (MRSAS) (DWAF and Umgeni Water, 1994) produced hydrology for, amongst others, the Mkomazi and Mooi River catchments. The hydrology of these rivers was updated by BKS (DWAF and Umgeni Water, 1998) as part of the Mkomazi/Mgeni/Mooi River Hydrology and Yield Update Study. The Mkomazi River catchment is shown in **Figure 1** and the quaternary catchments are shown in **Figure 2**, both in **Appendix A**.

The Mkomazi River catchment was, as part of the Hydrology and Yield Update Study, divided into four subcatchments to match proposed dam sites for modelling purposes. **Figure 3** in **Appendix A** shows these modelling subcatchments. All the hydrometeorological information of the 1998 BKS Update Study was made available for use in the current Study. The same subcatchment division used previously, was again employed in this Study. The following sections summarise the relevant hydrometeorological information from the BKS study. Details can be obtained from the source reports.

3.2 Rainfall

Catchment rainfall records are required as input to the hydrological (WRSM90) model, while point rainfall records are required for the WRYM model for calculating net evaporation from reservoirs.

BKS (1998) produced catchment rainfall records for the four modelling subcatchments, with record lengths of 71 years (1925 to 1995). Data from 16 rainfall gauges was used in producing these records, as summarised in **Table 3.1**.

TABLE 3.1: RAINFALL INFORMATION

Subcatchment Name	Area (km^2)	MAP (mm)	Rainfall File
Impendle Dam	1 422	1 068	Imp.ran
Smithfield Dam	632	1 000	Smi.ran
Ngwadini Dam	2 243	875	Ngw.ran
Mkomazi Mouth	91	855	Mkom.ran

3.3 Evaporation

Class A-pan evaporation data is used in the calculation of irrigation demands, while Symons pan (S-pan) data is used for the simulation of catchment evaporation. S-pan evaporation is converted to potential lake evaporation in order to simulate evaporation losses from reservoir surfaces. **Table 3.2** shows a summary of the relevant evaporation information for the period 1925 to 1995.

TABLE 3.2: EVAPORATION DATA

Sub-catchment Name	Pan Type	Monthly Evaporation (mm)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Impendle	S	120	130	140	140	120	120	90	80	70	70	100	120
	A	156	167	177	177	156	156	123	113	102	102	134	156
Smithfield	S	120	130	140	140	120	120	90	80	70	70	100	120
	A	156	167	177	177	156	156	123	113	102	102	134	156
Ngwadini	S	115	125	134	134	115	115	86	77	67	67	95	115
	A	150	161	171	171	150	150	119	109	99	99	130	150
Mkomazi Mouth	S	115	125	134	134	115	115	86	77	67	67	96	115
	A	150	161	171	171	150	150	119	109	99	99	130	150
S-pan to Lake Factors		0,81	0,82	0,83	0,84	0,88	0,88	0,88	0,87	0,85	0,83	0,81	0,81

3.4 Streamflow

Incremental natural streamflow records are needed for use in the WRYM model. BKS (1998) produced natural incremental runoff sequences for the four modelling subcatchments of the Mkomazi River catchment. The runoff sequences were produced by simulation of natural runoff using the WRSM90 runoff model and scaling of simulated sequences.

Table 3.3 gives a summary of the incremental natural runoff sequences for the hydrological period 1925 to1995, inclusive.

TABLE 3.3: NATURAL INCREMENTAL RUNOFF

Subcatchment Name	Area (km^2)	MAP (mm)	Natural Incremental MAR	
			(Mm^3/a)	(mm)
Impendle	1 422	1 068	567,9	399,4
Smithfield	632	1 000	163,2	258,2
Ngwadini	2 247	875	324,5	144,7
Mkomazi Mouth	91	855	11,3	124,2
Total	4 387		1 066,9	243,1 (ave.)

4. RECONNAISSANCE BASIN STUDY

4.1 Introduction

During the course of the reconnaissance phase of this Study (Supporting Report No 1: Reconnaissance Investigations), it was noted that no attempt had been made to date to quantify the present and future water demands within the Mkomazi River basin. It has historically been policy of the Department of Water Affairs & Forestry that the demands of a donor catchment should be met before water can be transferred to another catchment, that is, water cannot be transferred to another catchment to the detriment of the inhabitants of the donor catchment. An additional study (Supporting Report No 3: Reconnaissance Basin Study) was then carried out to determine the present and future water demands within the Mkomazi River basin. This study was done at reconnaissance level and carried out at quaternary subcatchment level.

Three demand scenarios were evaluated, namely a high, middle (most likely) and low road scenario, with the middle road scenario forming the basis of the current phase of planning and the other two scenarios being evaluated with a view to assessing sensitivity. The following user sectors were assessed:

- Domestic (Rural and urban)
- Agriculture (Irrigation and livestock)
- Forestry
- Industrial
- Environmental.

The next four sections summarise the information relevant to this report. For more detail the reader is referred to the Supporting Report No 3: Reconnaissance Basin Study.

4.2 Irrigation

The BKS (1998) investigation produced maximum irrigation areas in terms of the then proposed dam subcatchments for the Mooi River. These increases were used to develop individual percentage increases for each quaternary subcatchment on the Mooi River, as part of the current investigation in that basin, (see Mooi-Mgeni Transfer Scheme Supporting Report No 1: Reconnaissance Basin Study).

To develop similar characteristics for the Mkomazi River basin, a comparison was made of position in the overall catchment, topography, mean annual precipitation (MAP) and status of current irrigation development within each subcatchment. By comparing these parameters with quaternary subcatchments of the Mooi River basin, similar increases were adopted as and where appropriate.

In some subcatchments, no current irrigation has been identified. In these areas, an arbitrary (but limited) value has been assigned as a future area. The present farm dam and main stream irrigation areas and demands were updated by BKS (1998). It was assumed that the proportion of farm dam and mainstream irrigation would remain the same for the 2040 levels of development.

Table 4.1 shows the current and future irrigation areas for the three scenarios, at quaternary subcatchment level.

TABLE 4.1: CURRENT AND FUTURE IRRIGATION AREAS

Quaternary Catchment		Current development (km^2)			Future Development (Total) (km^2)		
Number	Area (km^2)	Main	Tributaries	Total	High	Middle	Low
U10A	418	4,87	1,63	6,50	17,08	8,13	7,31
U10B	392	4,57	1,53	6,10	16,03	7,63	6,86
U10C	267	3,11	1,04	4,15	10,90	5,81	4,98
U10D	337	3,92	1,31	5,23	13,74	8,37	6,80
U10E	327	0,00	0,00	0,00	6,00	4,00	2,00
U10F	379	0,00	0,00	0,00	6,00	4,00	2,00
U10G	353	1,16	9,42	10,58	18,30	15,87	13,23
U10H	458	1,50	12,17	13,67	23,65	20,51	17,09
U10J	505	1,65	13,44	15,09	26,11	22,64	18,86
U10K	364	1,19	9,68	10,87	18,81	15,22	13,04
U10L	307	1,00	8,20	9,20	10,84	11,50	10,35
U10M	280	0,00	0,00	0,00	4,00	2,00	1,00
Total	**4 387**	**22,97**	**58,42**	**81,39**	**171,46**	**125,68**	**103,52**

4.3 Afforestation

Details of current forestry areas and permits were obtained from the Department of Water Affairs & Forestry (DWAF, 1998), and Umgeni Water. The data currently being used by DWAF to determine existing areas of afforestation is a union of National Landcover (NLC) areas from the Council for Scientific and Industrial Research (CSIR), utilising satellite imagery, and information obtained by Umgeni Water using aerial photography. The existing forestry areas according to these two methods are shown in **Table 4.2**.

TABLE 4.2: EXISTING FORESTRY AREAS AS DEFINED BY DWAF AND UMGENI WATER

Quaternary Catchment		Afforested Area (km^2)		
Number	**Area (km^2)**	**CSIR 96**	**Umgeni Water**	**CSIR 96 *U* Umgeni Water (DWAF)**
U10A	418	2,98	2,35	5,09
U10B	392	10,46	8,74	17,92
U10C	267	12,76	38,86	45,60
U10D	337	5,38	15,53	20,37
U10E	327	33,18	40,76	50,66
U10F	379	47,32	69,31	81,43
U10G	353	54,60	62,87	86,81
U10H	458	132,88	138,25	174,84
U10J	505	146,55	134,37	172,72
U10K	364	80,30	76,90	102,08
U10L	307	15,39	9,82	20,43
U10M	280	0,00	0,24	2,43
Total	**4 387**	**541,80**	**598,00**	**780,38**

The basis of permit allocation by DWAF is an allowable percentage reduction in base flow runoff from the catchment. An additional factor is also applied for sub-optimal catchments (optimal catchments are given a factor of 1). The result is an allowable increase in afforestation up to a point where the base flow runoff is reduced to the level calculated using the above factor.

Note that it was assumed that other runoff-reducing activities, such as dry land sugar cane cultivation, will, in future, be controlled by Catchment Management Agencies in a similar manner to forestry. Maximum permissible reduction in runoff will be determined and future forestry areas described below were therefore assumed to include other runoff reducing activities.

High scenario

The higher DWAF existing area (CSIR 96 *U* Umgeni Water) was used as a baseline, to which was added all currently registered permit applications, whether approved or not. This was compared with the baseline area plus the allowable additional area calculated on the basis of percentage reduction in runoff, with the maximum of these two being accepted.

Middle scenario

The Umgeni Water base data, considered to be more accurate, was taken as the existing afforested area. To this was added the areas covered by any permits that have been approved to date, and the probable increment that will be applied by DWAF to achieve the maximum allowable area according to percentage runoff reduction. It was assumed that DWAF would calculate the increment on the basis of their own baseline data described under the High Scenario.

Low scenario

The Umgeni Water existing afforested areas were used as base areas, to which were added all currently approved permits.

Table 4.3 shows the future afforested areas for the three scenarios, at quaternary subcatchment level.

TABLE 4.3: FUTURE AFFORESTED AREAS FOR HIGH, MIDDLE AND LOW SCENARIOS

Quaternary Catchment		Afforested area for scenario (km^2)		
Number	**Area (km^2)**	**High**	**Middle**	**Low**
U10A	418	34,38	17,17	17,17
U10B	392	37,20	22,79	22,79
U10C	267	70,94	53,88	53,88
U10D	337	52,46	34,08	34,08
U10E	327	65,44	55,54	41,22
U10F	379	85,16	72,54	72,54
U10G	353	100,27	69,36	69,36
U10H	458	186,97	144,71	144,71
U10J	505	184,32	141,73	141,73
U10K	364	116,04	85,49	85,49
U10L	307	78,77	68,16	9,82
U10M	280	71,80	71,70	0,24
Total	**4 387**	**1 083,75**	**837,15**	**693,03**

It was assumed that in future, other runoff-reducing activities, such as dryland sugarcane cultivation, will be treated the same as forestry and that the limits set for future forestry areas would thus include these other activities.

4.4 Industrial

Industrial demands in the Mkomazi River catchment are listed in the BKS Hydrology Update Report (DWAF and Umgeni Water, 1998). The only demand that has any significant impact on the available water in the Mkomazi River is that of SAPPI/SAICCOR, situated near the river mouth in U10M. From the point of view of growth and future demands, it has been assumed that this demand will remain constant at the current demand of about 53 million m^3/a.

4.5 Environmental

Environmental demands are given in the form of Instream Flow Requirements (IFR) and Estuarine Freshwater Requirements (EFR), which have been derived as part of the current Pre-Feasibility Study process. These studies are described in detail in Supporting Report No 5: Environmental, and are therefore only briefly summarised here.

IFR's to maintain the river in a specific Desired Future State (DFS) were determined at four representative sites along the river, the most downstream site (IFR Site 4), with the greatest flow requirements being situated a few kilometres upstream of Goodenough Weir. Downstream of IFR 4 the river becomes significantly more degraded and the EFR becomes dominant.

4.6 Domestic and Livestock Demands

The present development domestic and livestock demands amounted to less than 1% of the natural MAR and were excluded from this analysis.

5. HYDROLOGY

5.1 Introduction

The Mgeni River System Analysis Study (MRSAS) (DWAF and Umgeni Water, 1994) produced hydrology for, amongst others, the Mkomazi and Mooi River catchments. The hydrology of these catchments was updated by BKS (DWAF and Umgeni Water, 1998) as part of the Mkomazi/Mgeni/Mooi River Hydrology and Yield Update. The purpose of the hydrology update was to re-evaluate the available water resources within the Mgeni River System, as well as the adjacent Mooi and Mkomazi River Systems, with consideration of various possible augmentation options.

The study of the Mkomazi River hydrology was previously not carried out to the same level of detail used for the rest of the study area. This was, however, corrected as part of the Hydrology Update Study by evaluating the hydrology of the Mkomazi River specifically with respect to the catchment developments. The present development hydrology was, as part of the Hydrology Update Study, extended to span the hydrological period October 1925 to September 1996, inclusive.

The Mkomazi River catchment was divided into four subcatchments for modelling purposes (see **Figure 3** in **Appendix A**), with catchment sub-division depending on the location of reliable flow gauges and possible future dam sites. BKS then produced present day (1996) hydrology for these four subcatchments.

The Mkomazi River hydrological analysis consisted of the following :

- disaggregation of the hydrology of the Mkomazi River into quaternary catchment hydrology, based on the hydrology created for the four subcatchments of the Mkomazi River; and
- determining the effect on MAR of forestry and irrigation with revised data for the future 2040 development levels.

5.2 Disaggregation of Present Development Hydrology

The four subcatchments previously modelled by BKS terminated at the possible Impendle, Smithfield and Ngwadini Dam sites, with the fourth subcatchment being the incremental area between the Ngwadini site and the Mkomazi River mouth. The individual modelling subcatchments however extended over more than one quaternary catchment.

5.2.1. Incremental natural runoff sequences

Naturalised runoff sequences were available for the four modelling subcatchments. Disaggregation of the runoff sequences into quaternary catchment sequences was based on the ratios of catchment area and mean annual precipitation (MAP) of the quaternary catchment and those of the modelling subcatchments. Catchment areas and MAP's for the modelling subcatchments were available from Update Study (BKS, 1998), while quaternary catchment information for the 12 quaternary catchments of the Mkomazi River were taken from the WR90 information (Midgley *et al*, 1994b).

The results of the disaggregation are shown in **Table 5.1**.

5.2.2 *Irrigation demands*

Irrigation in the Mkomazi River catchment consists of mainstream and diffuse irrigation. Mainstream irrigation is supplied from the main rivers and supported by the reservoirs, while diffuse irrigation is located away from the main streams and is supplied from smaller tributaries and farm dams.

There is limited irrigation in the Mkomazi River catchment, with a total present day irrigation demand of 49,7 million m^3/a. As this is only 4,7% of the natural runoff for the Mkomazi River catchment, disaggregation of the modelling subcatchment irrigation demands was based on the ratio of quaternary and modelling subcatchment areas, as well as the WR90 quaternary catchment irrigation areas. The proportions of mainstream and diffuse irrigation were maintained in the disaggregation.

Table 5.1 summarises the irrigation demands for each quaternary subcatchment.

5.2.3 *Afforestation demands*

Present development afforestation areas and demand sequences were available for the four modelling subcatchments, while a geographic information systems (GIS) coverage of afforestation area per quaternary catchment, was available from BKS. These figures included dryland sugarcane in the lower catchments, which has a similar impact on runoff to forestry.

The forestry demand files were disaggregated into quaternary demand files based on the ratios of forestry per quaternary (determined from the BKS GIS data) and forestry area per modelling subcatchment.

Although the rainfall variance between quaternary catchments should ideally also be acknowledged in disaggregating the forestry demands, the above approach was followed as the forestry demands are not significant when compared to the natural runoff in the catchment. For the Mkomazi River catchment as a whole, the forestry demand is about 5% of the total natural runoff.

Table 5.1 summarises the present development afforestation areas and demands for each quaternary catchment.

TABLE 5.1: MKOMAZI RIVER CATCHMENT PRESENT DEVELOPMENT HYDROLOGY

Quaternary Catchment				Afforestation		Main Stream Irrigation		Diffuse Irrigation	
Number	Area (km^2)	MAP (mm)	Natural Runoff (Mm^3/a)	Area (km^2)	Demand (Mm^3/a)	Area (km^2)	Demand (Mm^3/a)	Area (km^2)	Demand (Mm^3/a)
U10A	418	1287	186,85	2,35	0,42	4,87	3,07	1,63	1,03
U10B	392	1176	160,16	8,68	1,56	4,57	2,89	1,53	0,96
U10C	267	1091	101,09	39,02	7,03	3,11	1,96	1,04	0,65
U10D	337	999	116,99	15,26	2,74	3,92	2,47	1,31	0,82
U10E	327	1034	88,18	41,59	5,08	0,00	0,00	0,00	0,00
U10F	379	963	88,22	71,42	8,20	0,00	0,00	0,00	0,00
U10G	353	981	57,44	80,71	4,99	1,16	0,70	9,42	5,68
U10H	458	924	70,10	155,63	9,62	1,50	0,90	12,17	7,34
U10J	505	878	73,34	153,07	9,46	1,65	1,00	13,44	8,11
U10K	364	793	47,71	97,21	6,00	1,19	0,72	9,68	5,84
U10L	307	758	38,62	27,79	1,73	1,01	0,61	8,20	4,95
U10M	280	858	38,22	18,92	0,94	0,00	0,00	0,00	0,00
Total	**4 387**		**1 066,92**	**711,65**	**57,77**	**22,98**	**14,32**	**58,42**	**35,38**
Total as % MAR					**5,4**		**1,3**		**3,3**

Note: Afforestation areas and demands include dryland sugarcane in lower catchments.

5.3. Determining the Effect of Estimated 2040 Forestry and Irrigation on Mean Annual Runoff

5.3.1 Introduction

In addition to the present development hydrology, estimates were made of possible future 2040 irrigation and forestry areas in the Mkomazi River catchment in order to determine the effect of increasing development on the MAR of the catchment. Estimates of the 2040 development were made for three levels of development as described in Sections 4.2 and 4.3.

5.3.2 Incremental natural runoff sequences

The natural runoff sequences remained the same as no re-calibration of the hydrological model was attempted.

5.3.3 2040 irrigation demands

Table 5.2 shows the demands attributable to irrigation in the Mkomazi River catchment per quaternary subcatchment for the high, middle and low growth scenarios. The percentage of natural MAR (also shown) taken up by this demand sector gives an indication of the impact that irrigation has in the river basin.

As no recalibration of the hydrological model was done, future irrigation demands were calculated for the relevant irrigation areas using the in-house IRRDEM software. This program is similar to the irrigation module of the WRSM90 model. Input to the program includes a rainfall file and MAP, A-pan evaporation, crop factors and rainfall and irrigation efficiencies, as determined by BKS.

It follows from the Hydrology and Yield Update study (BKS, 1998) that there was virtually no growth in farm dam capacities since 1986 and in some cases even showed a decline. The present (1995) farm dam capacities were therefore accepted for the future 2040 scenario. Irrigation would be supplied according to the same proportion as used for the present development scenario.

TABLE 5.2: MKOMAZI RIVER CATCHMENT IRRIGATION DEMANDS

Quaternary Catchment		Irrigation Demand (Mm^3/a)			
Number	Natural MAR (Mm^3/a)	Current	Future		
			High	Middle	Low
U10A	186,85	4,10	10,66	5,08	4,57
U10B	160,16	3,85	10,01	4,76	4,29
U10C	101,09	2,61	6,81	3,24	2,92
U10D	116,99	3,29	8,58	4,08	3,68
U10E	88,18	0,00	3,72	2,47	1,24
U10F	88,22	0,00	4,97	3,41	2,26
U10G	57,44	6,38	10,92	7,89	7,10
U10H	70,10	8,24	14,11	10,20	9,18
U10J	73,34	9,11	15,58	11,25	10,13
U10K	47,71	6,56	11,22	8,11	7,30
U10L	38,62	5,56	6,47	6,86	6,18
U10M	38,22	0,00	2,30	1,74	0,56
Total	**1 066,92**	**49,70**	**105,35**	**69,09**	**59,41**
Total as % MAR		**4,7**	**9,9**	**6,5**	**5,6**

5.3.4 *2040 afforestation demands*

Afforestation demand sequences for the three levels of development were calculated using the BKS AFFDEM.EXE software with the CSIR Forestek curves. Input to the AFFDEM program includes catchment area, area of afforestation, natural runoff, evaporation, tree types and cutting cycles. The same combination of tree types and cutting cycles assumed in the Update Study, was used in this study. Demand sequences were calculated for each modelling subcatchment, after which the demands were disaggregated into quaternary catchment demands.

Table 5.3 shows the current and future demands generated by this sector in terms of each quaternary catchment and the total demand as a percentage of the natural MAR.

TABLE 5.3: MKOMAZI RIVER CATCHMENT AFFORESTATION DEMANDS

Quaternary Catchment		Forestry Demand			
Number	Natural MAR (Mm^3/a)	Current	Future		
			High	Middle	Low
		Mm^3/a			
U10A	186,85	0,42	5,92	2,99	2,81
U10B	160,16	1,56	6,40	3,97	3,73
U10C	101,09	7,03	12,21	9,38	8,82
U10D	116,99	2,74	9,03	5,93	5,58
U10E	88,18	5,08	17,92	14,80	12,57
U10F	88,22	8,20	7,83	6,70	5,59
U10G	57,44	4,99	6,27	4,39	4,12
U10H	70,10	9,62	11,69	9,16	8,60
U10J	73,34	9,46	11,52	8,97	8,43
U10K	47,71	6,00	7,25	5,41	5,08
U10L	38,62	1,73	4,92	4,31	0,58
U10M	38,22	0,94	0,76	0,63	0,38
Total	**1 066,92**	**57,77**	**101,72**	**76,64**	**66,29**
Total as % MAR		**5,4**	**9,5**	**7,2**	**6,2**

5.3.5 *2040 industrial*

The SAPPI/SAICCOR factory, situated near the Mkomazi River mouth in quaternary catchment U10M, has a permit allocation of 137 Mℓ/day (50 million m^3/a). This is the only industrial abstraction of any significance within the catchment.

Although it has been assumed that the permit allocation is being utilised, it should be noted that a portion of this abstraction is used to meet local domestic demands on the South Coast, outside the Mkomazi River basin. In future, the full allocation may well be used by SAPPI/SAICCOR themselves.

There is no indication that there is any intention to apply for any additional water allocations, neither is any other significant industrial development planned within the catchment.

5.3.6 2040 environmental

The provisional environmental reserve for the Mkomazi River catchment, in the form of IFR's, was derived as part of the current Pre-Feasibility Study and figures are assembled in Supporting Report No 5: Environmental. IFR's to maintain the river in a specific desired future state were determined at four representative sites along the river. In evaluating the IFR requirements at the four sites, IFR site 4, the most downstream IFR site, was found to have the greatest flow requirements.

IFR demand sequences were calculated for IFR sites 1, 2 and 4. IFR site 3 was not included in the subsequent yield analysis, as it was found not to be critical and was indicated as the least reliable site in the IFR study. Allowance was made for an IFR drought flow of once in every 10 years on average.

The total demand at IFR site 4, assuming that drought flows occur once in ten years, equates to 310 million m^3/a or 29,1% of the natural MAR. **Table 5.4** shows the monthly flow requirements at IFR sites 1, 2 and 4.

TABLE 5.4: INSTREAM FLOW REQUIREMENTS

IFR Site	Flow Condition	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
		Monthly IFR Maintenance Flows (Mm^3/month)											
1	High Flows	6,4	18,6	24,4	26,5	64,0	27,4	14,8	11,2	7,8	6,4	5,5	4,5
	Drought Flows	2,9	4,3	8,2	9,9	19,3	12,0	7,8	5,1	3,9	3,7	2,9	2,0
2	High Flows	8,4	16,7	32,2	35,0	73,9	53,6	19,4	14,7	10,4	8,6	7,2	6,0
	Drought Flows	4,0	5,7	10,7	13,2	22,8	15,7	10,4	6,7	5,2	4,8	3,9	2,7
4	High Flows	10,7	20,4	39,8	44,0	93,0	48,0	24,1	18,2	13,0	10,7	9,4	9,1
	Drought Flows	4,8	6,6	12,0	14,9	27,4	18,3	12,2	8,0	6,2	5,6	4,8	4,1

6. YIELD ANALYSIS

6.1 Introduction

Yield analyses were carried out to determine the yields of the proposed transfer schemes for natural and present conditions, as well as for the 2040 middle road scenario conditions. In addition, the yield of a possible future on-channel dam at the Ngwadini site on the Mkomazi River, hereinafter referred to as the Lower Mkomazi Dam, was determined to assess the viability of such a dam. Note that this dam should not be confused with the off-channel Ngwadini Dam under consideration by Umgeni Water.

The following schemes were investigated:

- Impendle Phase 1 Scheme (five different sizes)
- Smithfield Phase 1 Scheme (one size, maximum practical for the site)
- Smithfield Phase 2 Scheme, assuming a single size for Smithfield Dam with two different sizes for Impendle Dam
- Smithfield Phase 2 Scheme (with a 1,5 MAR Impendle Dam) with three different sizes for the Lower Mkomazi Dam
- Impendle Dam (1,5 MAR) with transfer to the Mgeni System
- Smithfield Phase 2 with transfer to the Mgeni System.

The WRYM model was configured for the Mkomazi river catchment. Configuration of the WRYM model for the different schemes was based on the WRYM models of the Impendle and Smithfield Dam schemes as configured by BKS. The same basic WRYM model was used for the different schemes, with only minor changes made to accommodate the different schemes. Further scheme details are given with each scheme description discussed hereafter.

The historical yield analyses were conducted for the hydrological period 1925 to 1995, inclusive. Both the firm yield (for the different schemes) and SAPPI/SAICCOR demand were met without any failures.

6.2 Catchment Development

The present development demands in the Mkomazi River catchment are relatively small when compared with the natural runoff (1066 million m^3/a) from the catchment. The major consumers of water are irrigation, afforestation and SAPPI/SAICCOR with present demands of about 49,7 million m^3/a, 57,8 million m^3/a and 50 million m^3/a, respectively. The proposed Middle South Coast Scheme involves the transfer of water from the Mkomazi Catchment and these demands should not be considered in basin demands. It will have to be largely supplied from the yield of the proposed Mkomazi-Mgeni Transfer Scheme dams.

Table 6.1 shows a summary of the catchment hydrology and demands and **Table 6.2** a summary of the farm dams and reservoirs included in the WRYM model. Area/depth/capacity curves for the reservoirs and farm dams are shown in **Figures 4** to **9** in **Appendix A**.

The WRYM model configurations for the future 2040 scenarios were adapted slightly to include one additional farm dam, in the Lower Mkomazi Dam incremental catchment, and mainstream irrigation in the Smithfield, Lower Mkomazi and Mkomazi mouth incremental catchments. The mainstream irrigation was supplied at 70% assurance (in years), introducing different zones in the proposed dams to achieve the required assurances.

TABLE 6.1: MODELLING CATCHMENT INFORMATION

Incremental Modelling Subcatchment				Afforestation				Irrigation			
Name	Area (km^2)	MAP (mm)	Natural Incremental MAR (Mm^3/a)	Area (km2)		Demand (Mm^3/a)		Area (km2)		Demand (Mm^3/a)	
				1995	2040	1995	2040	1995	2040	1995	2040
Impendle Dam	1 422	1 068	567,9	68,9	132,8	12,4	23,9	21,9	30,8	13,9	17,2
Smithfield Dam	632	1 000	163,2	107,1	120,9	12,8	14,5	0,0	8,0	0,0	4,5
Lower Mkomazi Dam	2 243	875	324,5	527,7	581,4	32,3	38,1	59,4	85,8	35,8	46,8
Mkomazi Mouth	91	855	11,3	8,0	2,2	0,3	0,1	0,0	1,0	0,0	0,6
Total	4 388		1 066,9	711,7	837,2	57,8	76,6	81,3	125,6	49,7	69,1

TABLE 6.2: RESERVOIRS AND FARM DAMS

Dam Name	Node Number[1]	Capacity (Mm³)	Full Supply Level (masl)	Full Supply Area (km²)
Impendle Dummy Farm Dam	71	2,78	115,00	1,32
Impendle Dam	72	135,00 270,00 543,00 680,00 810,00	1155,19 1169,88 1188,04 1195,00 1202,00	7,58 11,27 18,73 23,00 26,00
Smithfield Dummy Farm Dam	77	1,94	115,00	0,94
Smithfield Dam	81	137,00	915,00	5,83
Lower Mkomazi Dummy Farm Dam	83	11,85	116,00	4,98
Lower Mkomazi Dam	91	517,00 1 033,00 1 549,00	149,03 169,48 190,00	20,64 30,30 35,00

Notes : 1. Node numbers refers to node number on WRYM model schematic layout

6.3 Instream Flow Requirements

IFR's were modelled as part of the system demands. Allowance was made for an IFR drought flow of once in every 10 years on average.

Demand files were calculated for IFR sites 1, 2 and 4. IFR site 3 was not included in these analyses, as it was found not to be critical and was indicated as the least reliable site in the IFR study.

In order to meet the demands at the respective IFR sites without any augmentation from the dams, the demands for these sites were only supplied from the inflow to Impendle Dam or Smithfield Dam and any other incremental runoff available at that site. IFR site 4 requirements were modelled with all the different schemes and scenarios, as IFR site 4 was found to be the critical IFR site of the three included in the analysis. **Table 6.3** summarises the IFR information of the three sites used in the yield analysis.

TABLE 6.3: IFR INFORMATION

Site	Catchment Area (km^2)		Natural Runoff (Mm^3/a)		IFR Demand	
	Incremental	Total	Incremental	Total	Mm^3/a	% Total MAR
Impendle Dam	1 422	1 422	566,8	566,8		
IFR site 1	384	1 806	103,0	669,8	198,4	18,6
Smithfield Dam	248	2 054	60,5	730,3		
IFR site 2	877	2 931	126,9	857,2	247,3	23,2
Lower Mkomazi Dam	1 366	4 297	198,4	1 055,6		
IFR Site 4	43	4 340	5,3	1 060,9	310,1	29,1
Mkomazi Mouth	48	4 388	6,0	1 066,9		

6.4 Schemes Analysed

6.4.1 Impendle Scheme: Phase 1

The Impendle Scheme was analysed for five different sizes, ranging from a 0,25 MAR (135 million m^3) to a 1,5 MAR (810 million m^3) dam. Development upstream of Impendle Dam catchment included a dummy dam with diffuse irrigation for both the present and future development scenarios, as well as mainstream irrigation. IFR requirements downstream of Impendle Dam were met only from the inflow to Impendle Dam plus any incremental runoff available at the specific site. This prevented any support from the dams to IFR demands.

Any shortfall in the supply to the SAICCOR demand of 53 million m^3/a near the downstream end of the Mkomazi River catchment was supported from Impendle Dam.

The results of the yield analysis are shown in **Table 6.4**.The schematic layout of the Impendle Scheme (1,5 MAR) model is shown in **Figure 10** in **Appendix A**.

The same basic configuration was used for the 2040 scenario. Irrigation and afforestation demands were set at the 2040 middle road levels of development. The results of the yield analysis are shown in **Table 6.4**.

6.4.2 Smithfield Scheme: Phase 1

Only one size of Smithfield Dam, at 137 million m^3, was analysed. This is due to the topography limiting the full supply level of Smithfield Dam to about 915 masl. The Smithfield scheme yield analysis was conducted using the same assumptions as for the Impendle scheme.

Note that only IFR sites 2 and 4 were included in the analysis as IFR site 1 is located upstream of Smithfield Dam. IFR requirements were again only met from the inflow to Smithfield Dam and the incremental runoff available at the IFR sites.

The yield results are shown in **Table 6.4**. The schematic layout of the Smithfield Phase 1 Scheme is shown in **Figure 11** in **Appendix A**.

6.4.3 Smithfield Scheme: Phase 2

The Smithfield Phase 2 scheme consisted of dams at both the Impendle and Smithfield dam sites. The yield analysis was conducted using the single sized Smithfield Dam (137 million m^3) with firstly a 1 MAR and secondly a 1,5 MAR dam at the Impendle site. Both these scenarios were analysed for natural, present development and 2040 development conditions.

IFR requirements were modelled as before, limiting the IFR supply to what could previously be supplied for the individual Impendle and Smithfield schemes. This approach was followed to ensure that the IFR requirements were not supported from the dams.

A basic operating rule was used whereby the system yield demands were firstly met from Smithfield Dam and were only augmented from Impendle Dam once Smithfield Dam was empty.

The results of the yield analysis are shown in **Table 6.4**. The layout of the Smithfield Phase 2 Scheme (with a 1,5 MAR Impendle Dam) model is shown in **Figure 12**, while the layout for the future 2040 middle road scenario is shown in **Figure 13**, both in **Appendix A**.

6.4.4 *Smithfield Dam (137 million m^3), Impendle Dam (810 million m^3) with Lower Mkomazi Dam*

The on-channel Lower Mkomazi Dam was added to the Smithfield Phase 2 system to determine whether additional yield was available from the Lower Mkomazi Dam with the Smithfield Phase 2 system operated as described in Section 6.4.3 above.

The WRYM model was based on the Smithfield Phase 2 system consisting of the 137 million m^3 Smithfield Dam and 810 million m^3 Impendle Dam. All demands and operating rules remained the same as for the Impendle/Smithfield Scheme. Yield analyses were then conducted with three different sizes of the Lower Mkomazi Dam.

It was decided that IFR site 4 requirements should be supplied from the Lower Mkomazi Dam when necessary, in view of the major abstractions from the scheme upstream. The Lower Mkomazi Dam could not be supported by any of the upstream dams, apart from receiving spills.

It is clear from the yield results shown in **Table 6.4** that although some additional yield is available at the Lower Mkomazi Dam, large dams would have to be built in order to secure a significant yield. The schematic layout of the Smithfield Phase 2 Scheme with the Lower Mkomazi Dam is shown in **Figure 14** in **Appendix A**.

6.4.5 *Impendle Dam (810 million m^3) with transfer to the Mgeni River System*

The ultimate aim of this Study was to investigate the possible transfer of water from the Mkomazi River to the Mgeni River catchment. It was therefore decided to conduct preliminary yield analyses to determine the possible increase in the Mgeni System yield when augmented by a transfer from the Mkomazi River. As the Mooi/Mgeni system model and operating rules were not finalised yet at the time of writing this report, the results of the Mgeni System yield analysis described in Sections 6.4.5 and 6.4.6 should be regarded as preliminary and should be reviewed in the next phase of planning.

BKS configured the WRYM model for the Mgeni River System as part of the Mgeni River Augmentation System Analysis Update study (1998). The Mooi/Mgeni model includes the following:

- Mearns Dam with full supply level at 1387,5 masl
- Spring Grove Dam with full supply level at 1434,2 masl
- 4,3 m^3/s smooth pumping from Mearns Dam to Midmar Dam

- Midmar Dam with full supply level at 1048,48 masl
- the existing Albert Falls, Nagle and Inanda Dams
- the historical firm yields of both the Midmar Dam and Nagle Dam Systems are abstracted at these two dams and routed to the Mooi/Mgeni System yield point
- the capacities of both the above yield channels were set equal to the historical firm yields, which could be higher than the capacity of the water treatment works serving the respective dams.

For a more detailed description of the Mooi/Mgeni System the reader is referred to the Mgeni River Augmentation System Analysis Study (BKS,1998).

The final operating rules for the Mgeni/Mooi/Mkomazi System were not yet decided on when this report was produced. The following approach was followed during this preliminary transfer analysis:

- the Mooi/Mgeni System would be operated according to the existing operating rules and penalty structures (with a historical firm yield of 383 million m^3/a)
- transfer from Impendle Dam to the Mgeni System would be gravitated into Midmar Dam, with the transfer capacity set equal to the Impendle Dam scheme historical firm yield
- the capacity of the yield channel from Midmar Dam was increased by the Impendle transfer capacity in order to have adequate capacity on the abstraction from Midmar Dam to the system yield node
- transfer from Impendle Dam would commence when Midmar Dam started drawing down.

The historical firm yield of the combined Mkomazi/Mooi/Mgeni System using the above configuration is 718 million m^3/a. The Impendle Scheme (1,5 MAR with present development hydrology) has a slightly longer critical draw-down period than the Mgeni System, with the result that Impendle Dam still contains some water when the Mgeni System is empty.

Increasing the Impendle transfer capacity by 10% allows for Impendle Dam to be emptied as well as increasing the historical firm yield of the system by about 2% to 732 million m^3/a. A further increase of 10% in the transfer capacity results in a historical firm yield of 728 million m^3, with Impendle Dam emptying before the Mgeni System.

It is clear from the above that the system yield is relatively insensitive to an increase in the transfer capacity.

6.4.6 *Smithfield Phase 2 (Impendle Dam 810 million m^3) with transfer to the Mgeni River System*

The same approach as described in Section 6.4.5 above was followed for the transfer from the Smithfield scheme. Transfer from Smithfield Dam would, however, be directly to the water treatment works without utilising any storage in the Mgeni River catchment.

With the capacity of the transfer from Smithfield Dam set equal to the historical firm yield of the Smithfield Phase 2 Scheme (413 million m^3/a), the system historical firm yield is 796 million m^3, which is equal to the sum of the Mooi/Mgeni (383 million m^3/a) and Smithfield Phase 2 (413 million m^3/a) historical firm yields. An increase in the transfer capacity of 10% results in a decrease of the system historical firm yield by about 9% to 726 million m^3/a.

Another scenario was to change the operating rules and penalty structures in order for the transfer from the Mkomazi River to only take place when the Mgeni System is almost empty. With the transfer capacity set equal to the Smithfield Scheme historical firm yield of 413 million m^3/a caused the system firm yield to drop from 796 million m^3/a to 471 million m^3/a. Increasing the transfer capacity by 20% increased the system historical firm yield by only about 5,5% to 497 million $m^{3.}$

6.4.7 *Results of historical firm yield analysis*

The results of the historical firm yield analyses are shown in **Table 6.4** below.

The reduction in yield for the future middle scenario was, apart from the Smithfield Phase 1 scheme, less than 10% in all cases. A possible future dam on the lower reaches of the Mkomazi was also evaluated, but its viability is doubtful, as a very large dam would be required in order to achieve a significant yield.

The yield / capacity relationships for the present and future development scenarios are shown in **Figure 16** in **Appendix A**.

TABLE 6.4: RESULTS OF HISTORICAL FIRM YIELD ANALYSIS

Scheme Name	Dams in Scheme	Dam Volume (Mm^3)	Firm Yield (Mm^3/a) for Development Level		
			Natural Conditions	Present Development	2040 Middle Road Scenario
Impendle	Impendle	135	126	120	
		270	223	204	
		543	314	293	276
		680	341	318	
		810	358	335	304
Smithfield	Smithfield	137	157	131	112
Smithfield Phase2	Impendle	543			
	Smithfield	137	397	357	331
	Impendle	810			
	Smithfield	137	454	413	385
Lower Mkomazi	Impendle	810			
	Smithfield	137			
	Lower Mkomazi	517		122	
	Impendle	810			
	Smithfield	137		186	
	Lower Mkomazi	1 033			
	Impendle	810		246	
	Smithfield	137			
	Lower Mkomazi	1 549			

6.5 Long-term Stochastic Yield Analysis

Long-term stochastic yield analyses were conducted for present and future middle road levels of development. The long-term stochastic analysis was based on 201 71-year sequences.

It should be noted that the parameter file and stochastic hydrology as produced by BKS for the Hydrology Update Study, were used in the long-term stochastic analysis.
The results of the long-term stochastic yield are shown in **Table 6.5**.

TABLE 6.5: RESULTS OF STOCHASTIC YIELD ANALYSIS

Scheme	Firm Yield for Indicated Recurrence Intervals (Mm^3/a)				
	Historical	1:20yr	1:50yr	1:100yr	1:200yr
PRESENT DEVELOPMENT SCENARIO					
Imp 135 Mm^3 (0,25 MAR)	120	188	169	161	155
Imp 270 Mm^3 (0,5 MAR)	204	265	240	228	218
Imp 543 Mm^3 (1 MAR)	293	349	313	296	280
Imp 675 Mm^3 (1,25 MAR)	318	374	337	320	302
Imp 810 Mm^3 (1,5 MAR)	335	395	356	336	319
Smith 137 Mm^3 (0,19 MAR)	131	208	187	177	166
Smith + Imp 543 Mm^3 (1 MAR)	357	434	390	369	349
Smith + Imp 810 Mm^3 (1,5 MAR)	413	480	434	409	387
FUTURE DEVELOPMENT SCENARIO					
Imp 543 Mm^3 (1 MAR)	276	323	293	275	260
Imp 810 Mm^3 (1,5 MAR)	304	373	334	313	296
Smith 137 Mm^3 (0,19 MAR)	112	176	159	147	136
Smith + Imp 543 Mm^3 (1 MAR)	331	402	364	335	319
Smith + Imp 810 Mm^3 (1,5 MAR)	385	451	405	376	356

The reduction in stochastic firm yield (for the 1 in 100 year recurrence interval) for the middle scenario was, apart from the Smithfield Phase 1 scheme, again less than 10% in all cases.

Long-term stochastic yield reliability curves were produced for the 1.5 MAR Impendle Scheme and the Smithfield Phase 2 Scheme with the 1,5 MAR Impendle Dam. Details of the long-term stochastic yield reliability characteristics for present and future development conditions are shown in **Figures 17** to **20** in **Appendix A**.

The flows at IFR site 4 were assessed for the future development scenario in order to determine the assurances of IFR supply at the site. Boxplots of the flows at IFR site 4 produced during the stochastic analyses are shown in **Figure 21** in **Appendix A**. The required maintenance and drought flows are represented by dots with the corresponding numbers representing the percentage of sequences where the available flow was less than or equal to the required flow.

7. CONCLUSIONS

The Mkomazi River catchment is currently relatively undeveloped, with moderate development in the forestry and agricultural sectors projected. However, the reduction in yield of the proposed schemes under future (2040) middle scenario catchment development conditions is less than 10% when compared to the present development scenario. The future long term stochastic 99% assurance yield of the largest Impendle Scheme is 313 million m^3/a, approximately 17% less than the 376 million m^3/a of the largest Smithfield Scheme. The Smithfield Scheme therefore achieves the utilisation of a greater portion of the water resources of the Mkomazi System than the Impendle Scheme.

Under future (2040) middle scenario catchment development conditions and and the Smithfield Scheme in place, only 17% of the total natural MAR of the Mkomazi will be unutilised. This remaining volume could not be practically harnessed and it can therefore be stated that under these conditions, the Mkomazi River will be effectively fully utilised.

The following further studies and actions are recommended for the feasibility phase of investigation:

- Proceed with the determination of the Ecological and Basic Human Needs Reserves.
- Review projected forestry areas and other runoff-reducing activities in the light of catchment management initiatives, possible revisions to limits previously set and changes in policy.
- Assess the impact of river losses on IFR and other releases.
- Update hydrological and yield models accordingly.

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DWAF and Umgeni Water (1998), **MKOMAZI/MGENI/MOOI RIVER HYDROLOGY AND YIELD UPDATE**, *BKS, January 1998, Draft report.*

Midgley D C, Pitman W V and Middleton B J (1994a), **SURFACE WATER RESOURCES OF SOUTH AFRICA 1990**, *Volume VI, Book of Maps, WRC Report No 298/6.2/94.*

Midgley D C, Pitman W V and Middleton B J (1994b), **SURFACE WATER RESOURCES OF SOUTH AFRICA 1990**, Volume VI, Appendices, WRC Report No 298/6.1/94.

APPENDIX A : FIGURES

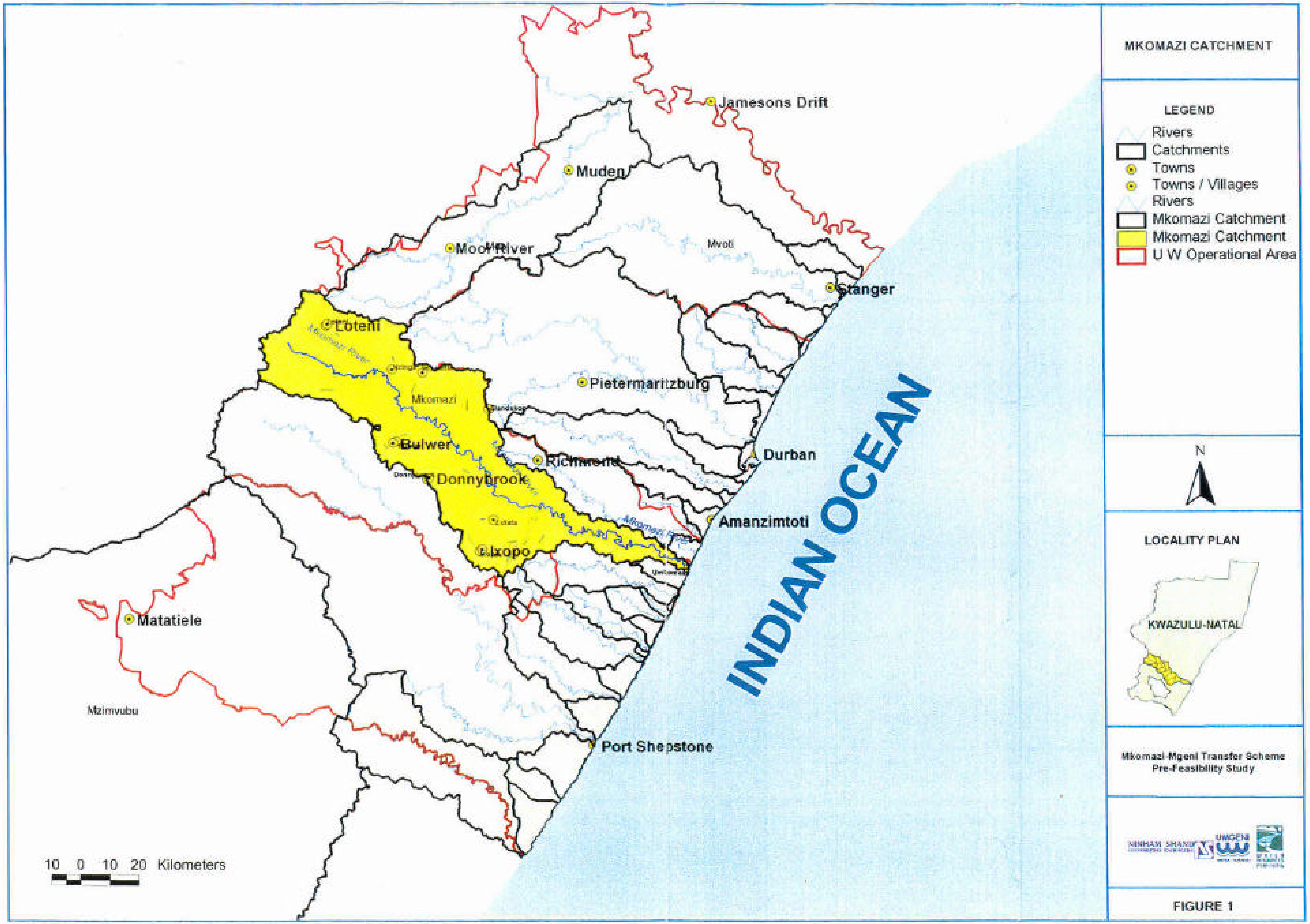
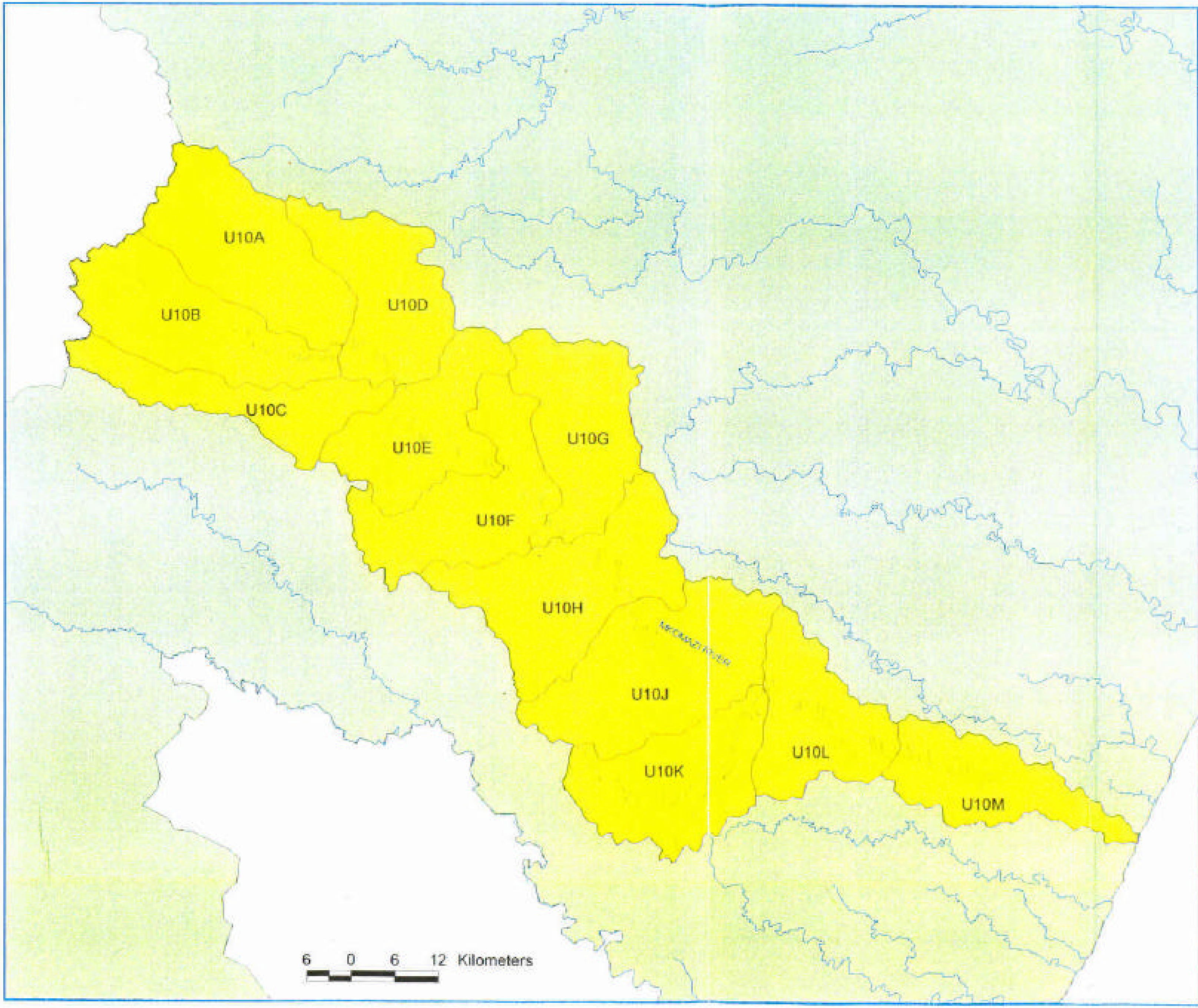

MKOMAZI CATCHMENT
LEGEND
Rivers
Catchments
Towns
Towns / Villages
Rivers
Mkomazi Catchment
Mkomazi Catchment
U W Operational Area
N
LOCALITY PLAN
KWAZULU-NATAL
Mkomazi-Mgeni Transfer Scheme
Pre-Feasibility Study
UMGENI
Jamesons Drift
Muden
Moor River
Mvoti
Stanger
Loteni
Mkomazi
Pietermaritzburg
Bulwer
Donnybrook
Richmond
Durban
Amanzimtoti
Ixopo
INDIAN OCEAN
Matatiele
Mzimvubu
Port Shepstone
10 0 10 20 Kilometers

FIGURE 1

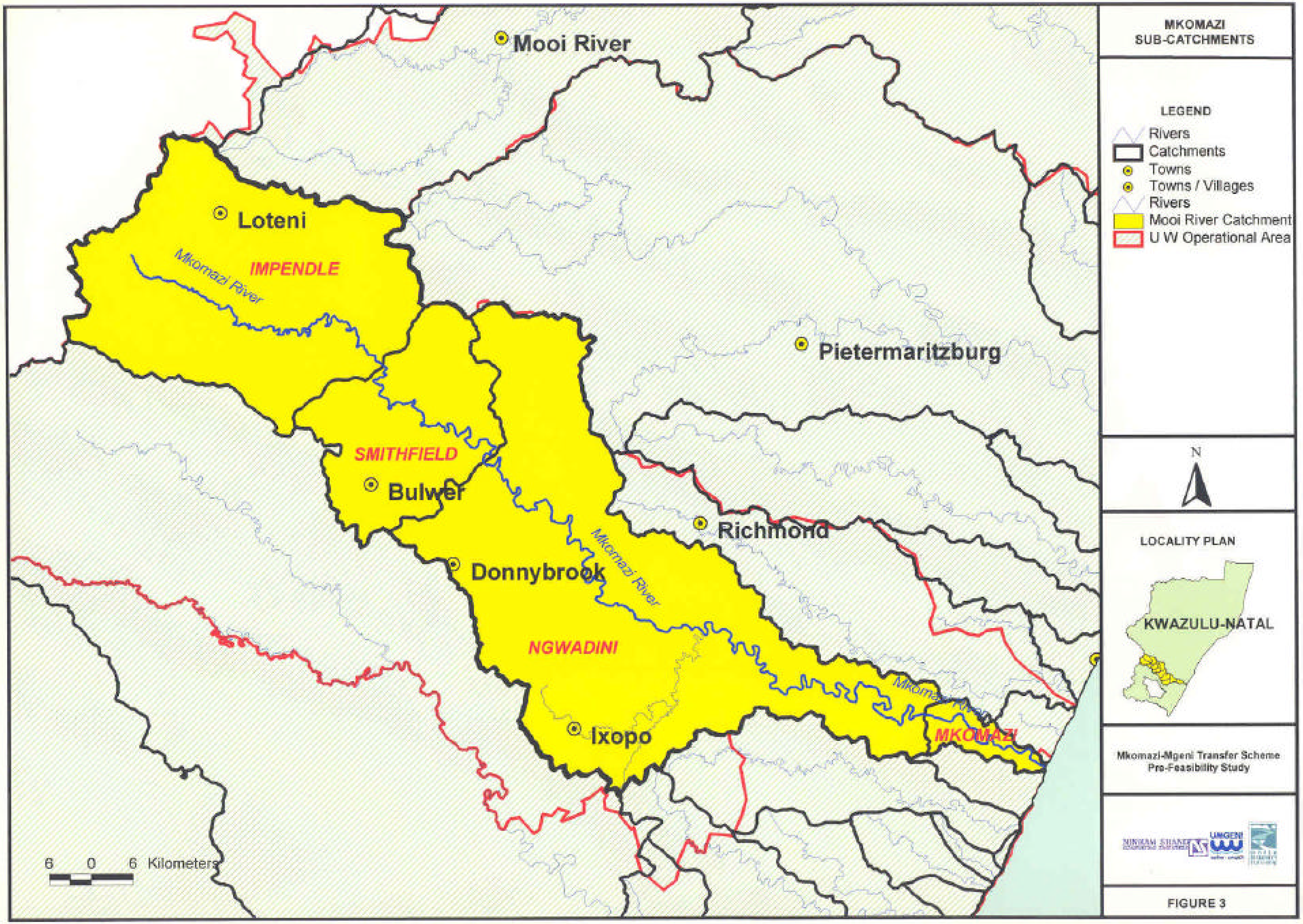


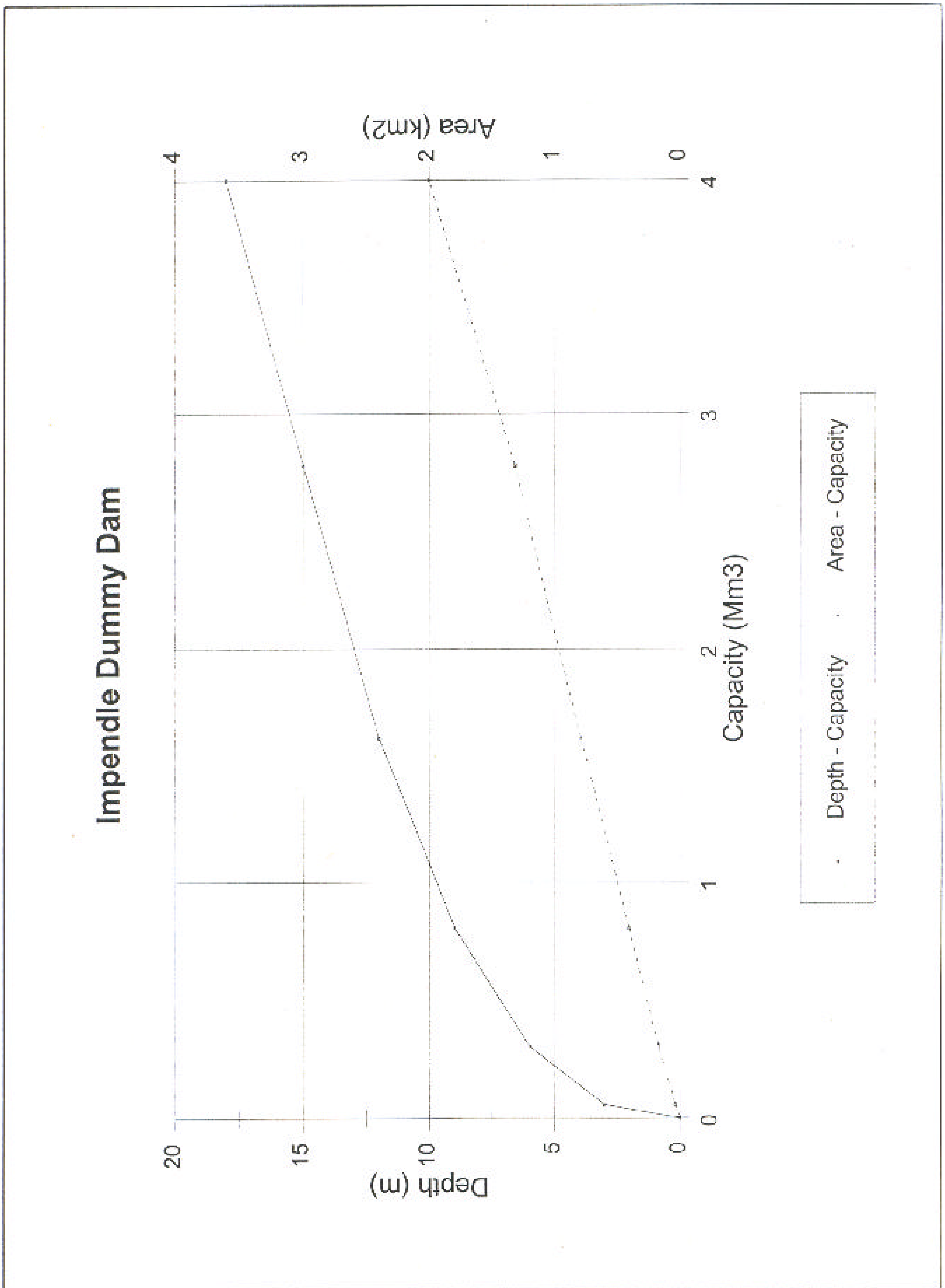
MKOMAZI RIVER - QUATERNARY CATCHMENTS

Mkomazi-Mgeni Transfer Scheme
Pre-Feasibility Study

NINHAM SHAND UMGENI

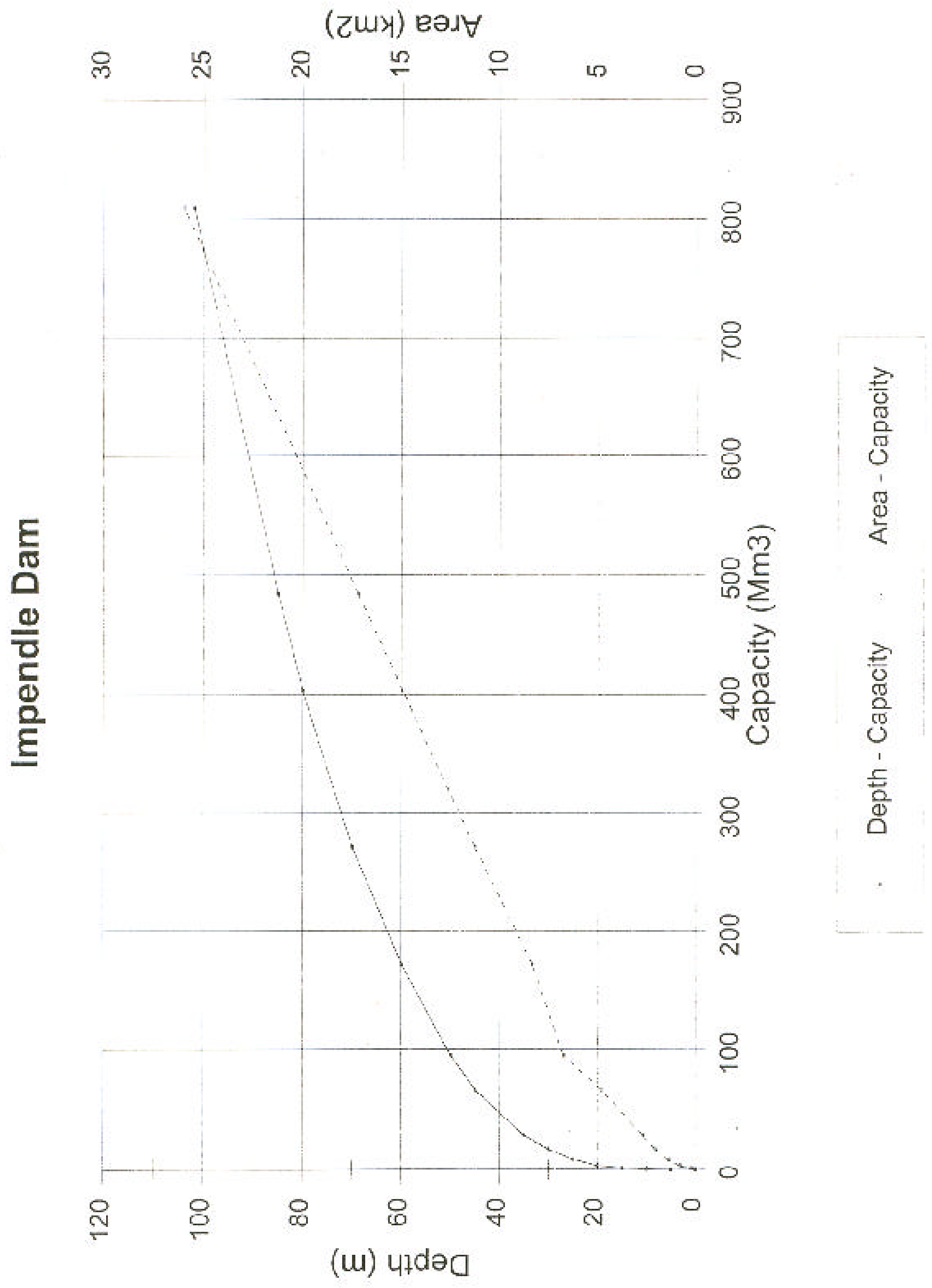
FIGURE 2


MKOMAZI
SUB-CATCHMENTS
LEGEND
Rivers
Catchments
Towns
Towns / Villages
Rivers
Mooi River Catchment
U W Operational Area
N
LOCALITY PLAN
KWAZULU-NATAL
Mkomazi-Mgeni Transfer Scheme
Pre-Feasibility Study
UMGENI
FIGURE 3
Mooi River
Loteni
IMPENDLE
Mkomazi River
Pietermaritzburg
SMITHFIELD
Bulwer
Richmond
Donnybrook
Mkomazi River
NGWADINI
Ixopo
MKOMAZI
6 0 6 Kilometers



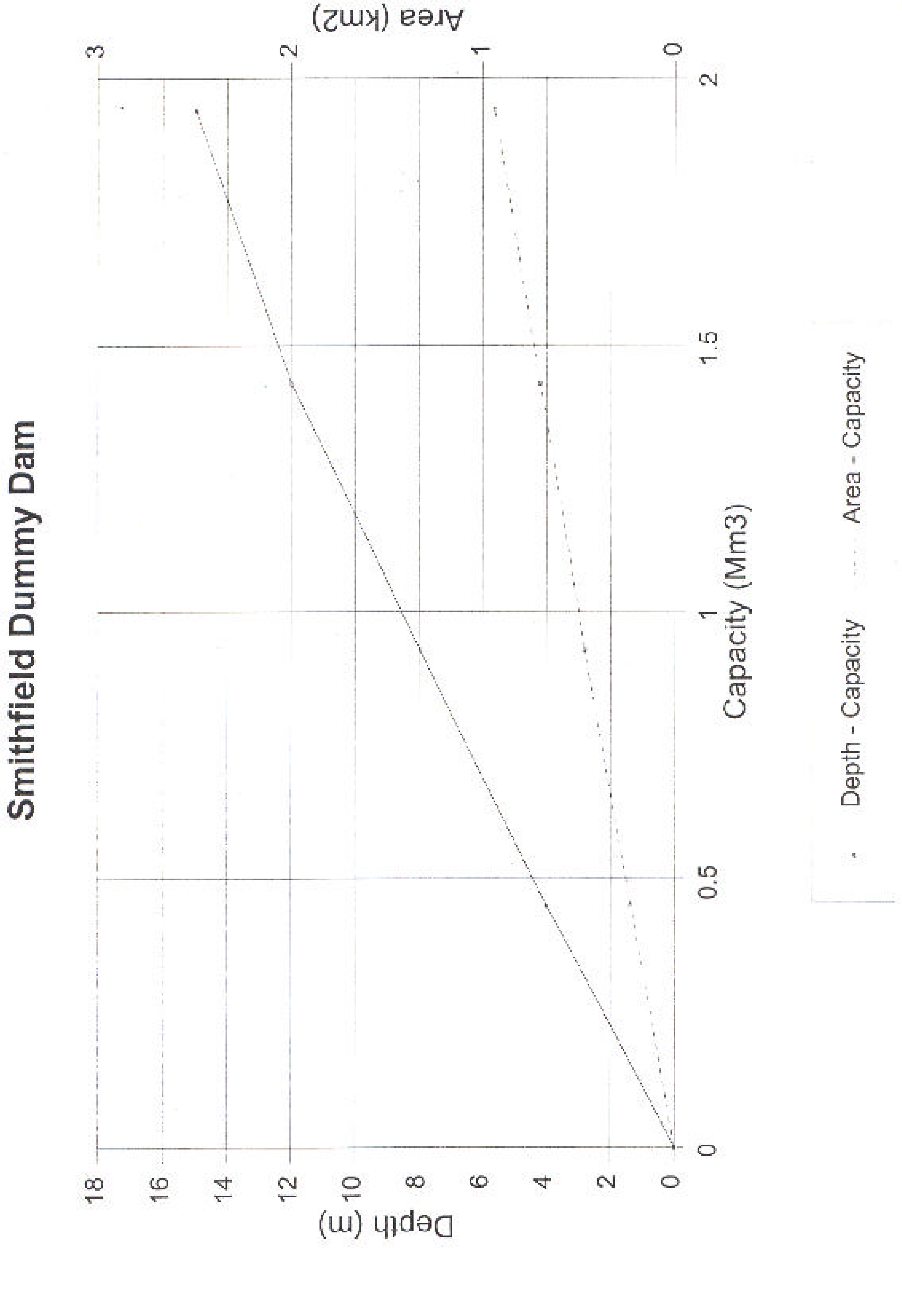
IMPENDLE DUMMY DAM DEPTH/AREA/CAPACITY

MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY	FIG. 4



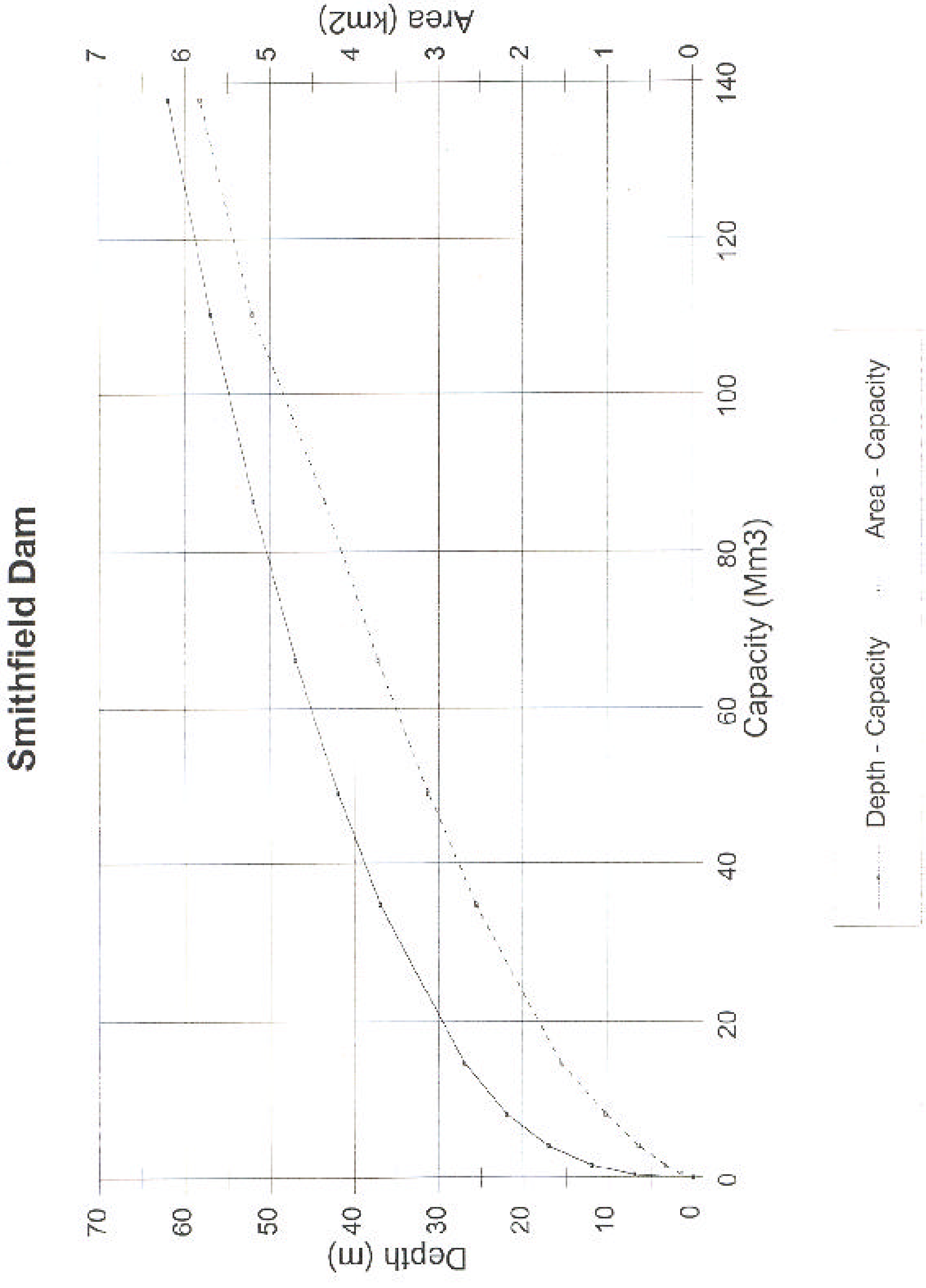
IMPENDLE DAM DEPTH/AREA/CAPACITY

MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY	FIG. 5



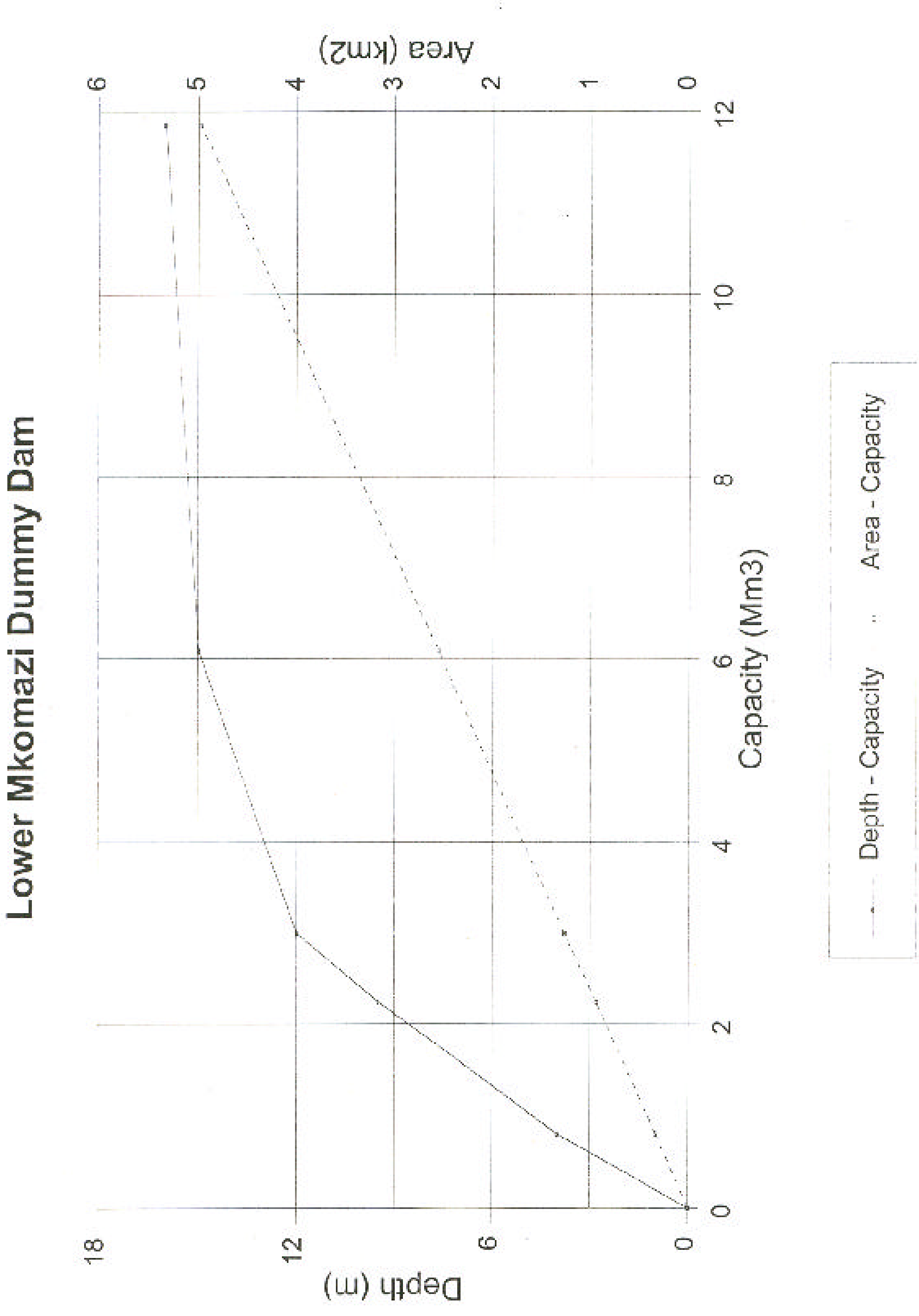
SMITHFIELD DUMMY DAM DEPTH/AREA/CAPACITY

MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY	FIG. 6



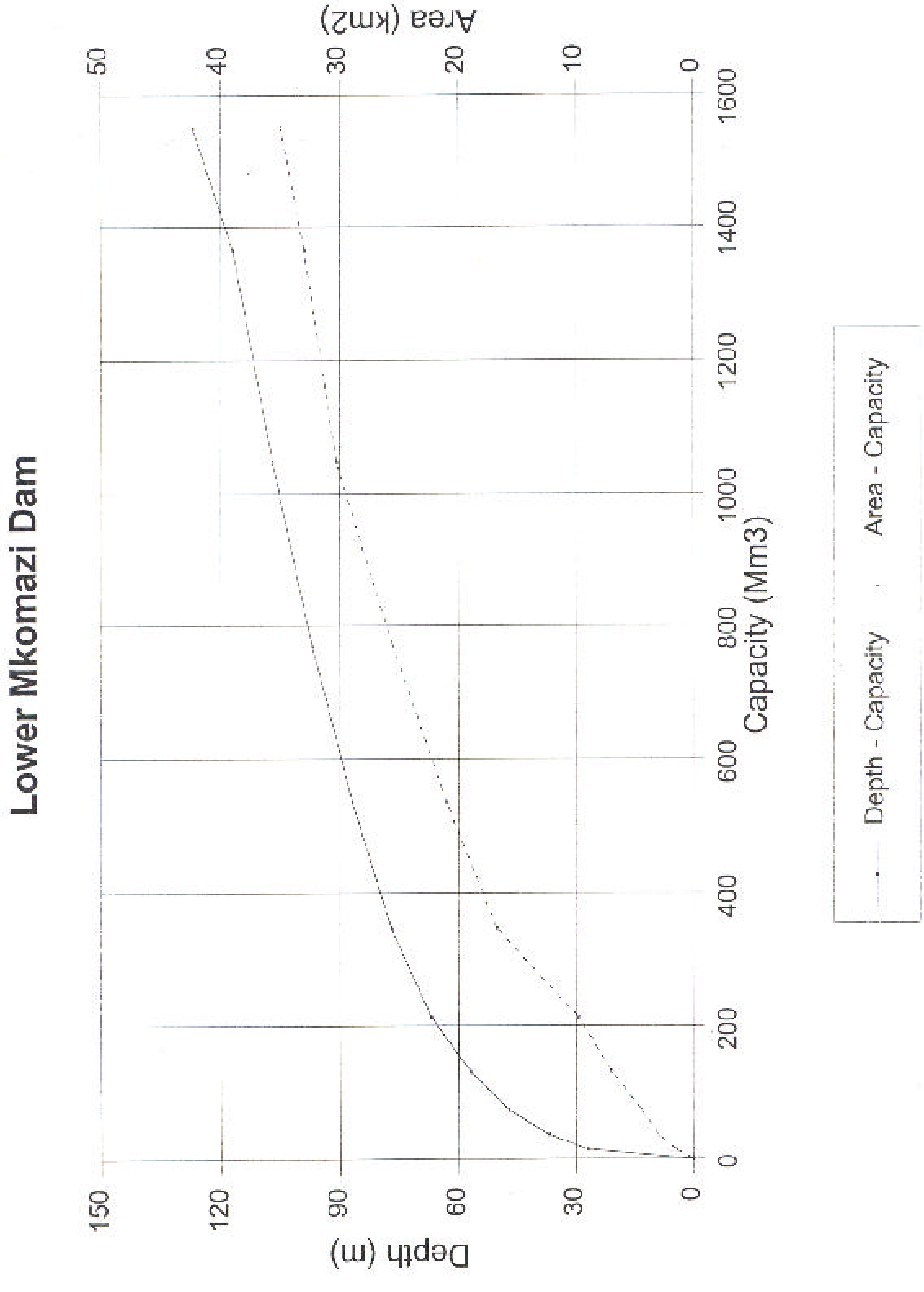
SMITHFIELD DAM DEPTH/AREA/CAPACITY

MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY	FIG. 7



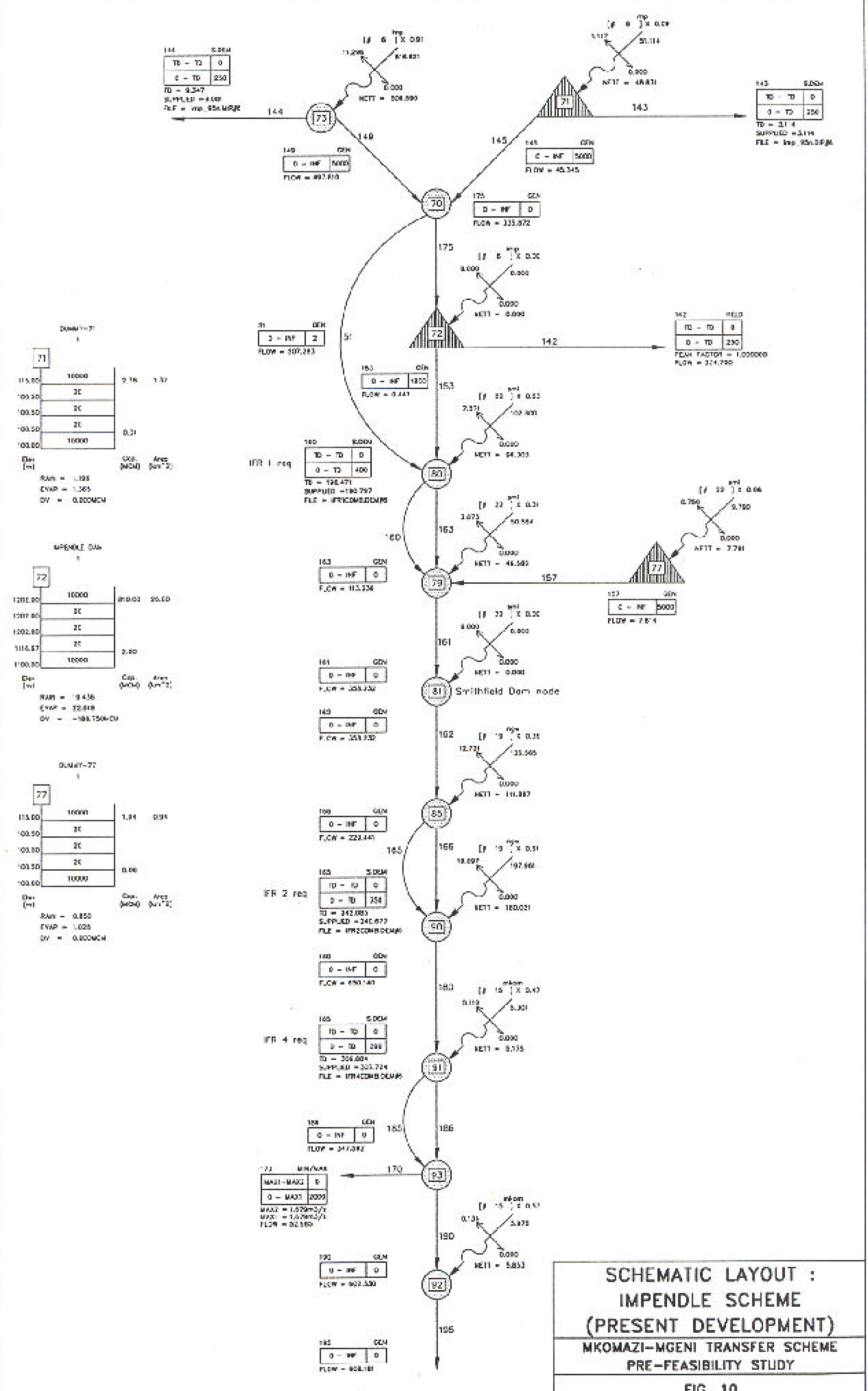
LOWER MKOMAZI DUMMY DAM DEPTH/AREA/CAPACITY

MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY | FIG. 8



LOWER MKOMAZI DAM DEPTH/AREA/CAPACITY

MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY	FIG. 9

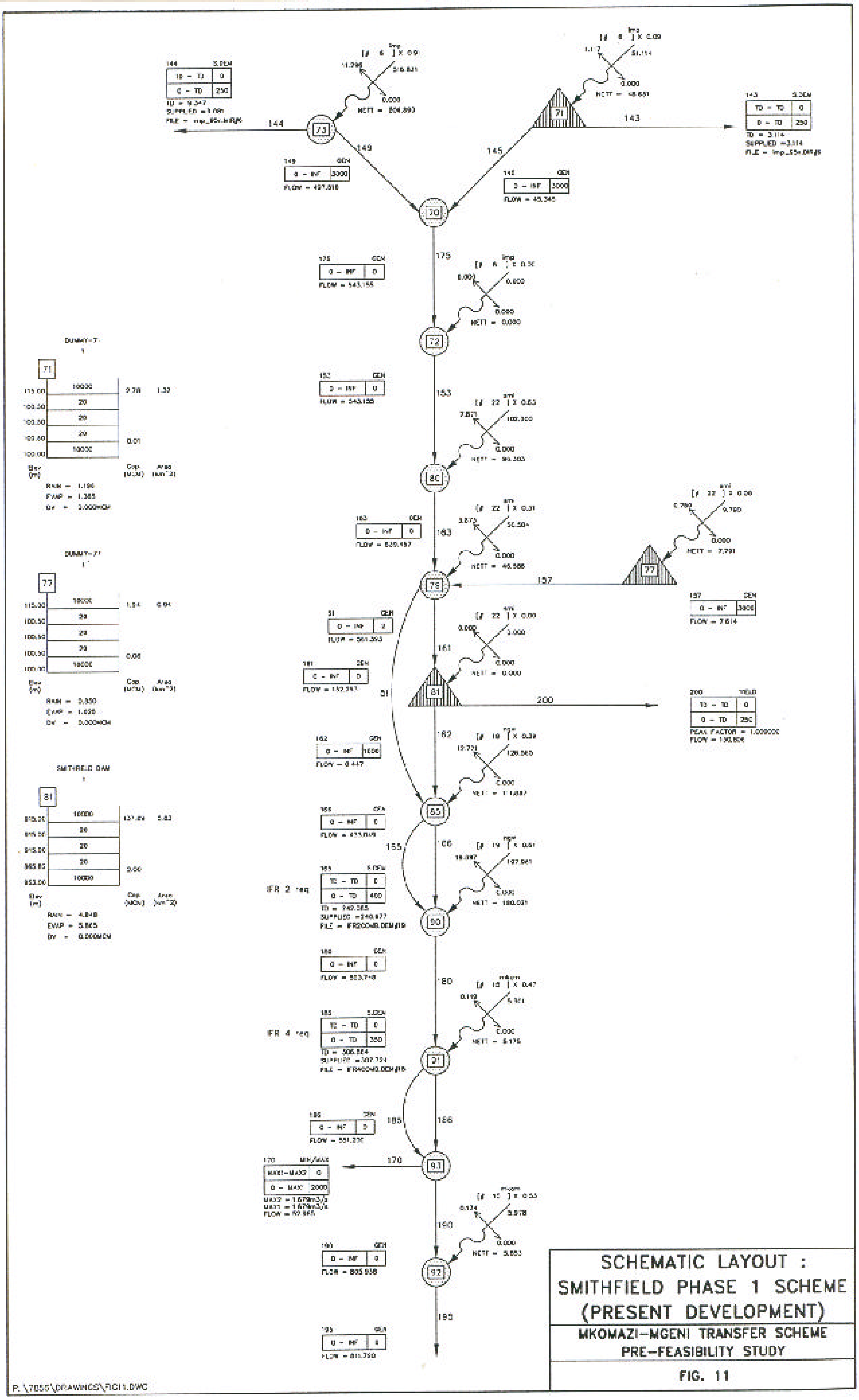


SCHEMATIC LAYOUT : IMPENDLE SCHEME (PRESENT DEVELOPMENT)

MKOMAZI-MGENI TRANSFER SCHEME
PRE-FEASIBILITY STUDY

FIG. 10

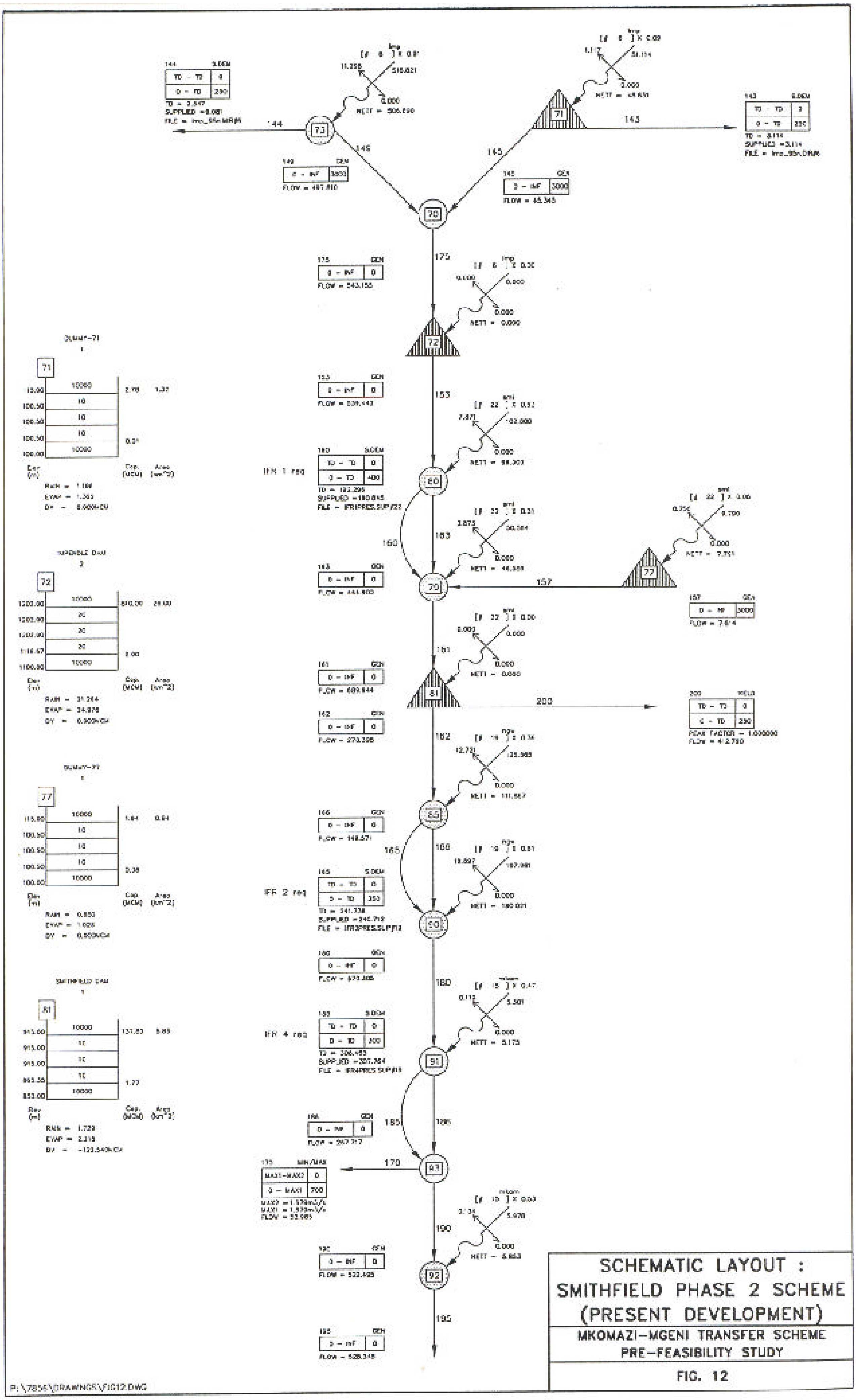
P:\7856\DRAWINGS\FIG10.DWG



SCHEMATIC LAYOUT : SMITHFIELD PHASE 1 SCHEME (PRESENT DEVELOPMENT)

MKOMAZI–MGENI TRANSFER SCHEME
PRE-FEASIBILITY STUDY

FIG. 11

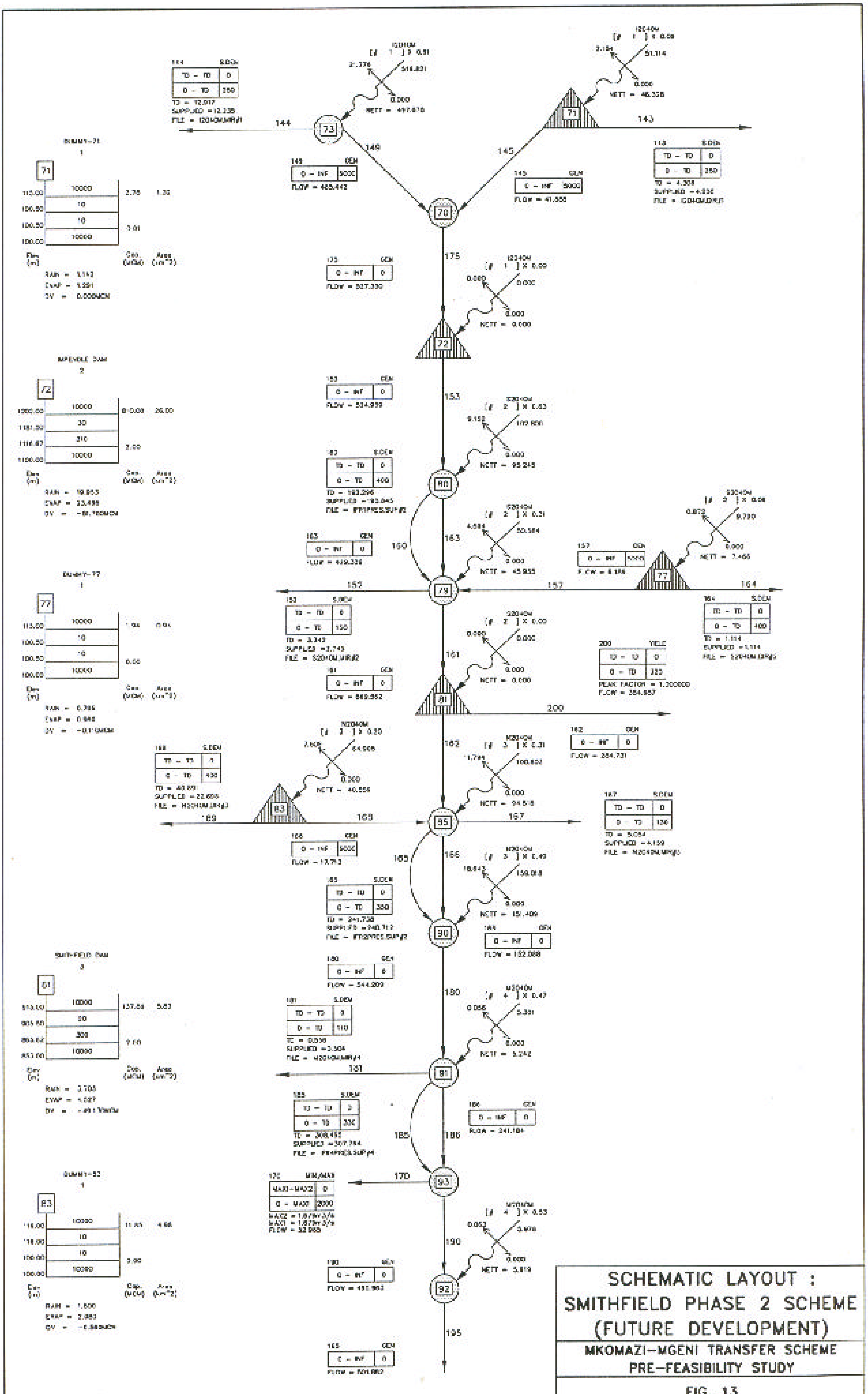


SCHEMATIC LAYOUT : SMITHFIELD PHASE 2 SCHEME (PRESENT DEVELOPMENT)

MKOMAZI–MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

FIG. 12

P:\7856\DRAWINGS\FIG12.DWG

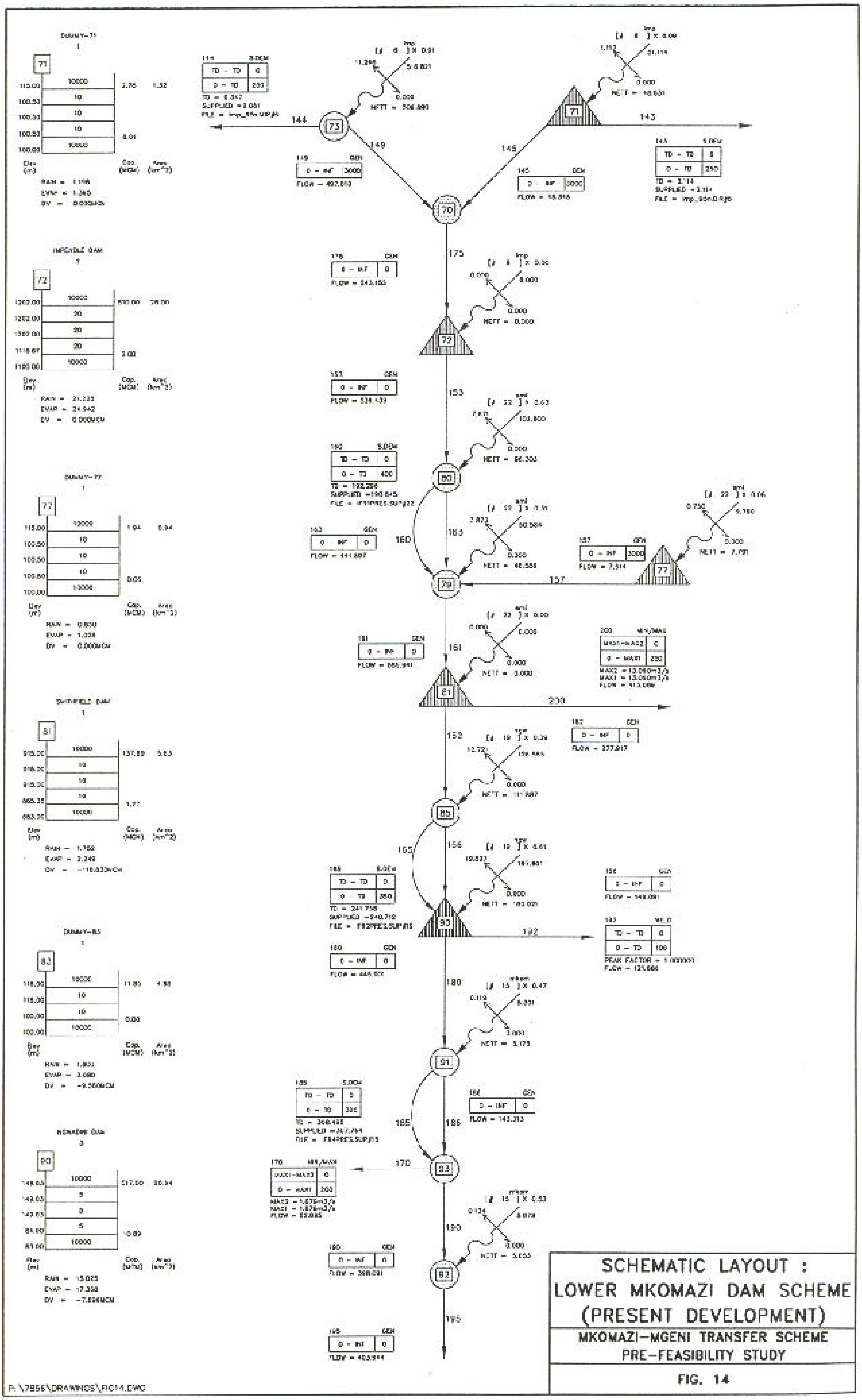


SCHEMATIC LAYOUT : SMITHFIELD PHASE 2 SCHEME (FUTURE DEVELOPMENT)

MKOMAZI–MGENI TRANSFER SCHEME
PRE–FEASIBILITY STUDY

FIG. 13

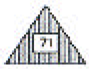
P:\7856\DRAWINGS\FIG13.DWG



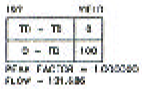
SCHEMATIC LAYOUT :
LOWER MKOMAZI DAM SCHEME
(PRESENT DEVELOPMENT)

MKOMAZI–MGENI TRANSFER SCHEME
PRE-FEASIBILITY STUDY

FIG. 14



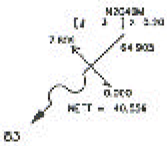
STORAGE (RESERVOIR)
NODE



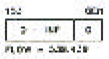
SUBSYSTEM YIELD

NODE

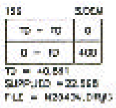
CHANNEL REACH
AND NUMBER



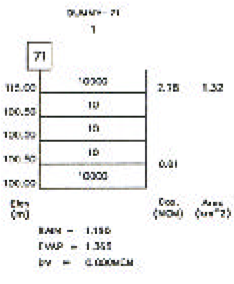
NATURAL INFLOW



ONE ARC CHANNEL REACH
PENALTY STRUCTURE



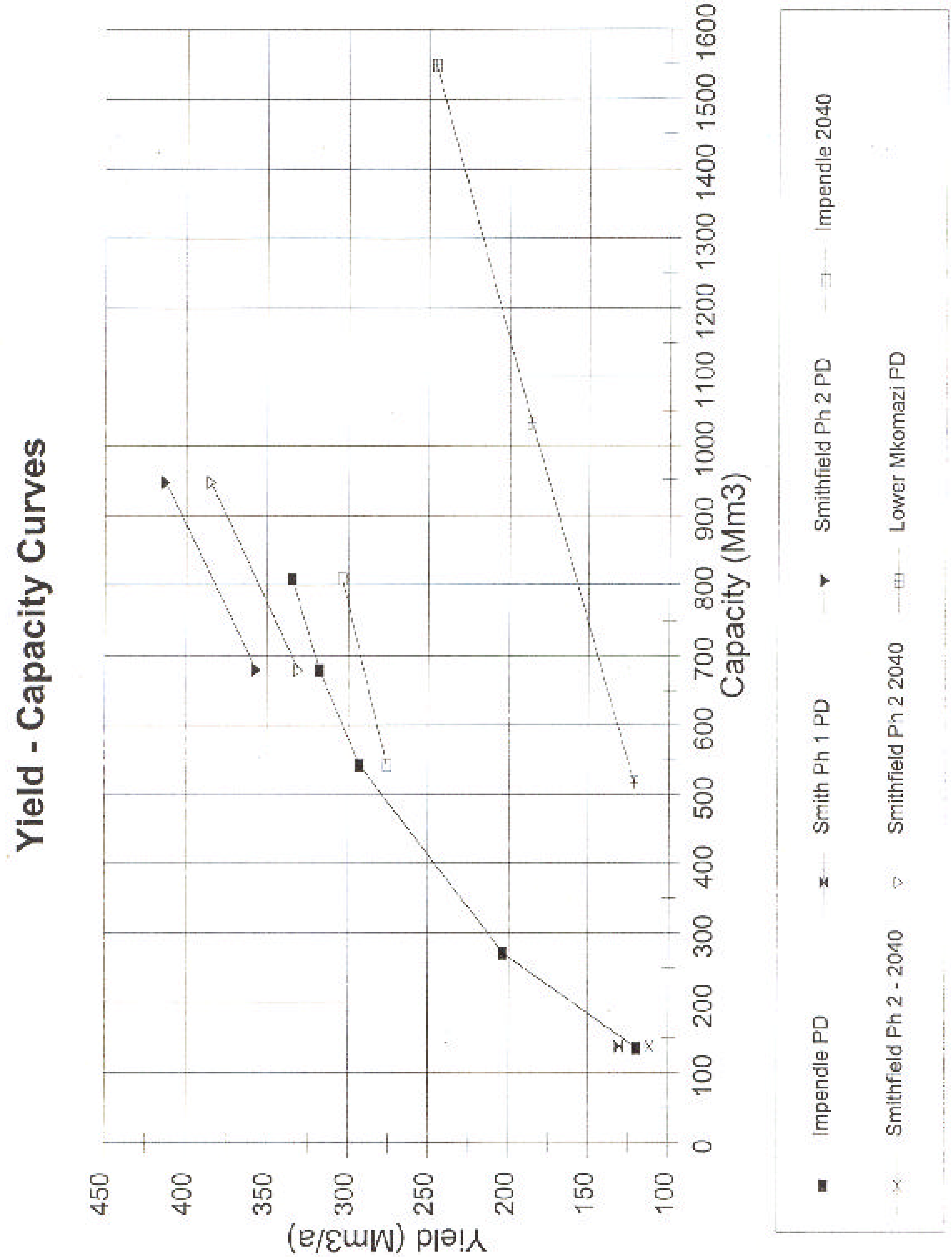
TWO ARC CHANNEL REACH
PENALTY STRUCTURE



RESERVOIR ZONE
(3 ZONE) PENALTY STRUCTURE

LEGEND TO SCHEMATIC LAYOUT FIGURES
MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY
FIG. 15

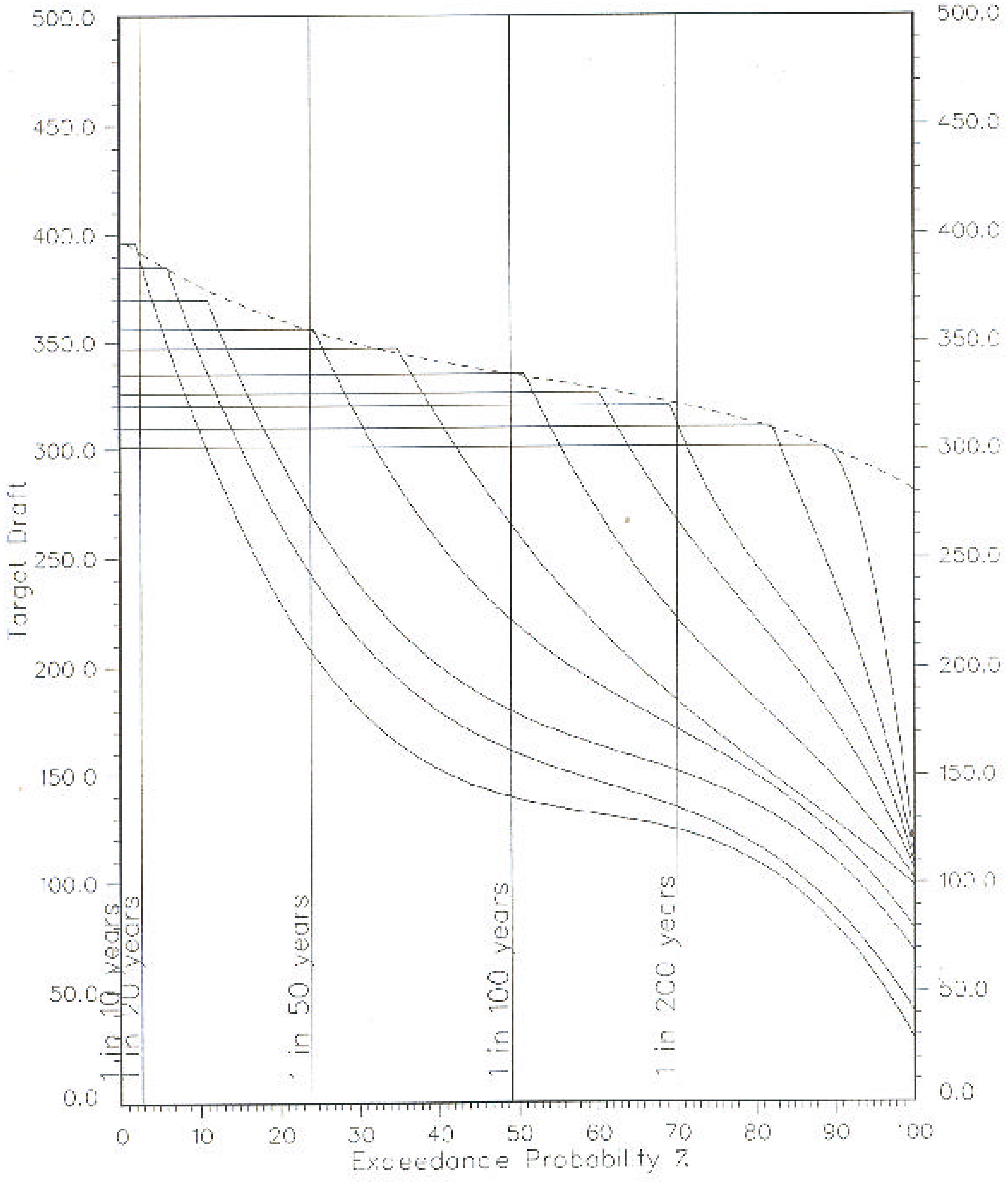
P:\7056\DRAWINGS\FIG15.DWG



YIELD CAPACITY CURVES

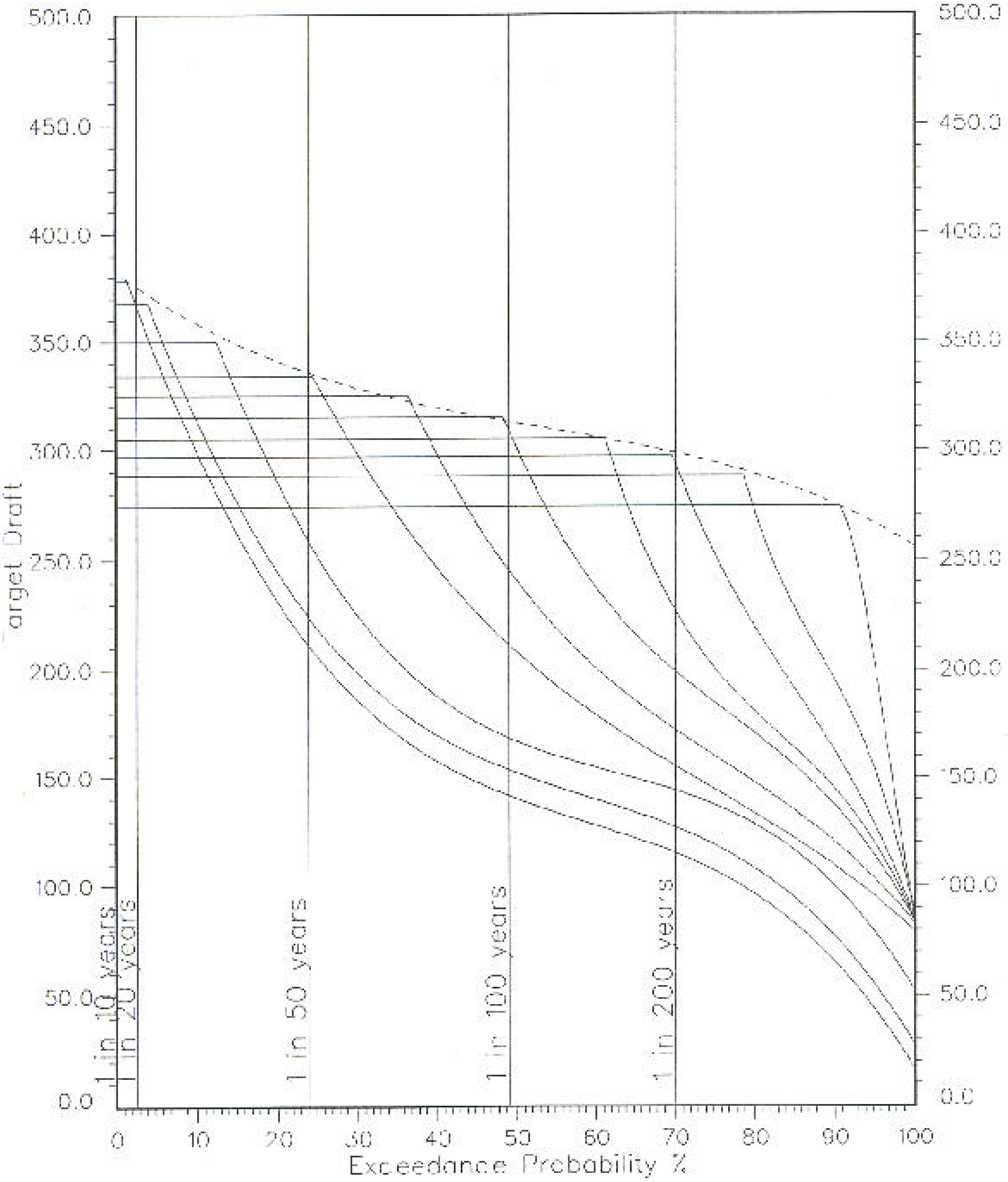
MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY

FIG. 16



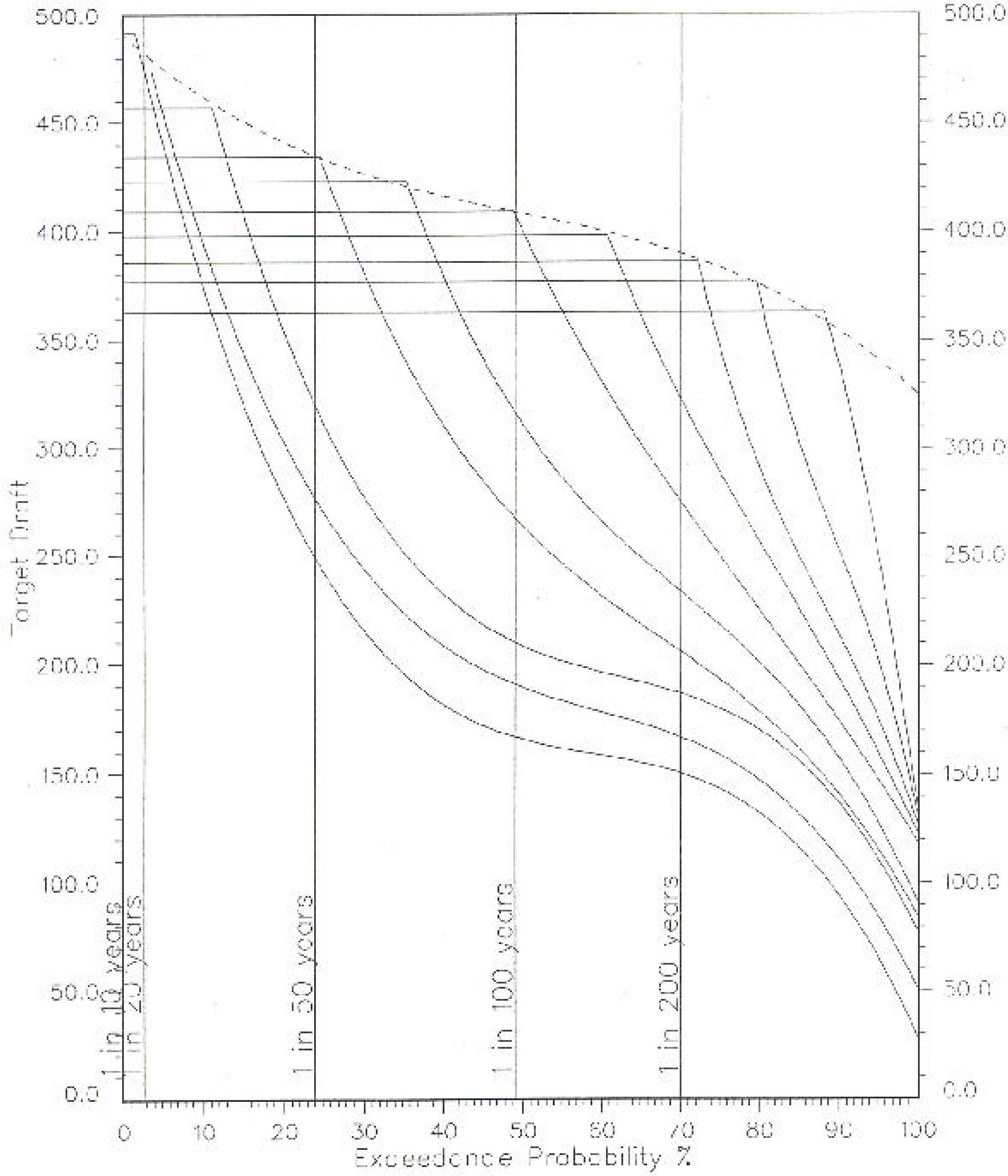
IMPENDLE 1.5 MAR LONG-TERM YIELD RELIABILITY CHARACTERISTICS
(PRESENT DEVELOPMENT)

MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY	FIG. 17



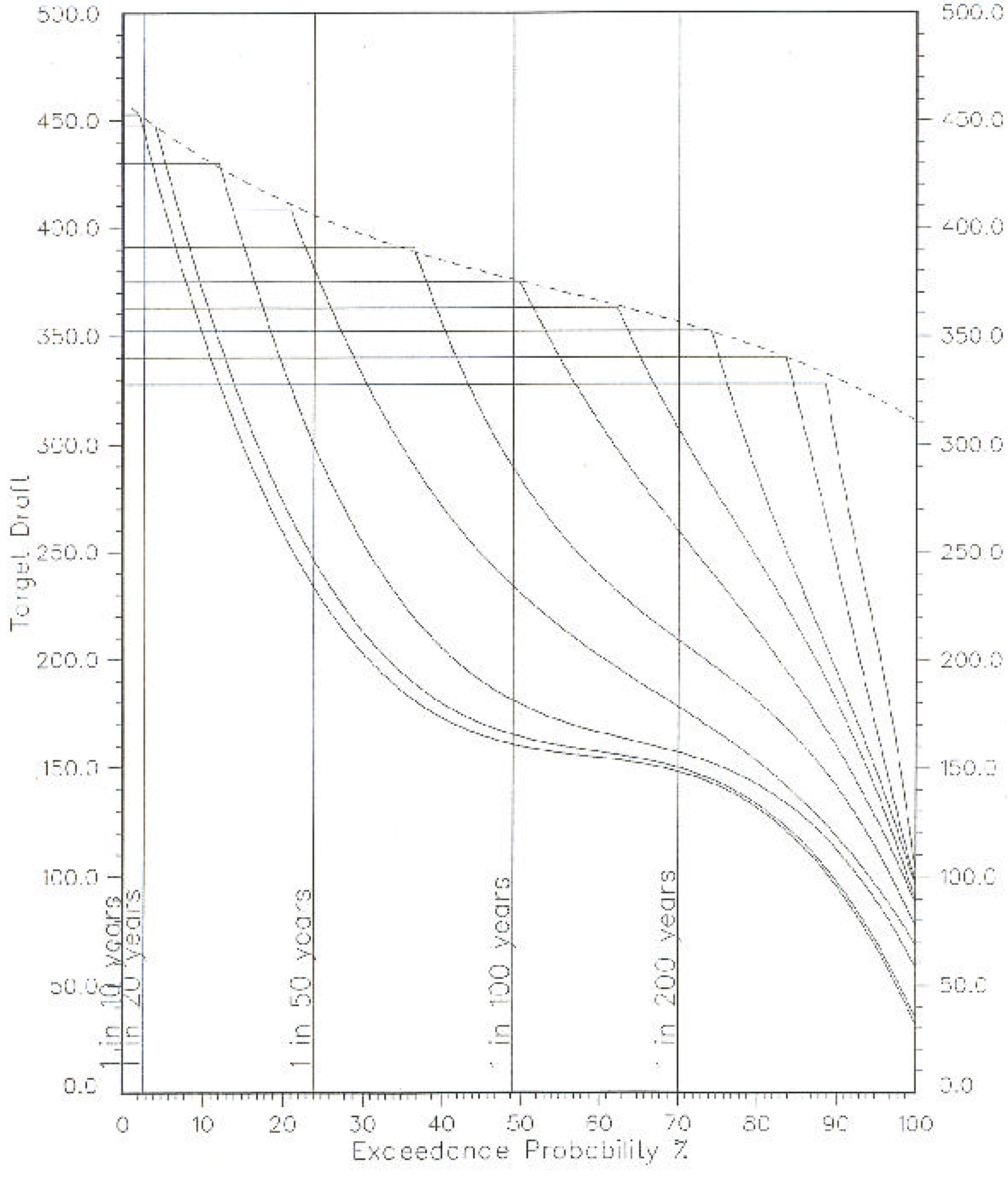
IMPENDLE 1.5 MAR LONG-TERM YIELD RELIABILITY CHARACTERISTICS (FUTURE DEVELOPMENT)

MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY	FIG. 18



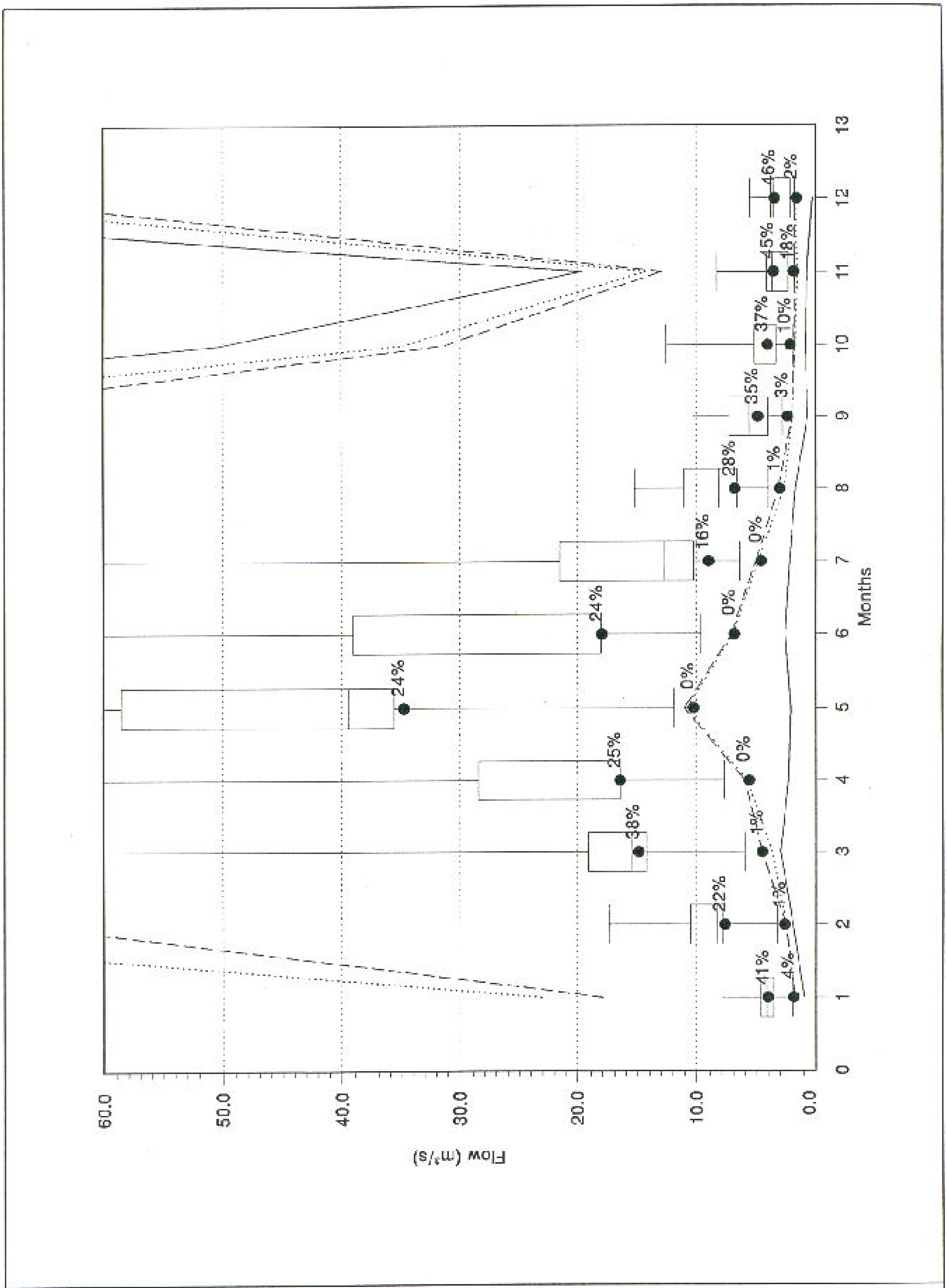
SMITHFIELD PHASE 2 LONG–TERM YIELD RELIABILITY CHARACTERISTICS (PRESENT DEVELOPMENT)

MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY	FIG. 19



SMITHFIELD PHASE 2 LONG-TERM YIELD RELIABILITY CHARACTERISTICS (FUTURE DEVELOPMENT)

MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY	FIG. 20



BOXPLOTS OF STOCHASTIC FLOWS AT IFR SITE 4
(FUTURE DEVELOPMENT)

MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY	FIG. 21