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DEPARTMENT OF WATER AFFAIRS
Directorate of Planning



VAAL RIVER SYSTEM ANALYSIS

Buffalo — Vaal subsystem analysis

BKS WATER RESOURCES ASSOCIATES
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VAAL RIVER SYSTEM ANALYSIS

BUFFALO-VAAL SUBSYSTEM ANALYSIS

EXECUTIVE SUMMARY

The Buffalo River flows south-eastwards from its origin on the Eastern Transvaal escarpment. A major tributary, the Ngagane River, joins the Buffalo River at Newcastle from where it continues to the confluence with the Tugela River. Two major water resource schemes were developed in the Buffalo basin. The Ngagane Government Water Scheme (NGWS) was constructed first to supply the demands of the Newcastle complex. Subsequently the Slang River Government Water Scheme (SRGWS) was constructed in one of the upper tributaries to supply water to the Majuba power station in the Vaal River basin and to augment the supply from the NGWS to Newcastle whenever necessitated by the growth in demand. Surplus water from the Slang River scheme, whenever available, will be transferred to the Grootdraai Dam in the Vaal basin.

The influence of the Slang River scheme on current and future abstractions from the Buffalo River for Newcastle, necessitates that the SRGWS and the NGWS be analysed together as one system, while the transfer of water to the Majuba power station and especially to the Grootdraai Dam constitutes it as part of the overall Vaal River system. The subsystem is thus named the Buffalo-Vaal subsystem.

The major components of the Buffalo-Vaal subsystem are situated in the Tugela basin and consist of two dams on tributaries of the Buffalo River. These are the Zaaihoek Dam situated on the Slang River near Volksrust, with a catchment area of 676 km², and the Chelmsford Dam situated on the Ngagane River with a catchment area of 830 km². Water is diverted from the Schurvepoort Weir on the Buffalo River to the Ngagane purification works. Water can also be pumped from the Roy Point Weir on the Ngagane River to the Ngagane purification works.

(ii)

The aim of the study is to investigate the yield - reliability characteristics of the subsystem with respect to the respective users, that is Eskom and Newcastle, and especially considering the transfer capabilities to the Vaal River. Yield analyses based on the historic inflow records only were first performed to establish the basic subsystem yield capabilities.

The historic inflow hydrology used in the analysis was derived from an evaluation of the net basin runoff at selected points on the rivers in the Tugela catchment area. Net basin runoff is equal to the naturalized streamflows minus the uncontrolled irrigation and afforestation abstractions within the catchment at the 1984 level of development. Stochastic inflow hydrology was in turn derived from a statistical representation of the naturalized streamflows, the stochastic net basin runoff being evaluated in a similar manner to the historical procedure.

The effects of the present and of a new operating policy on the historic yield characteristics of the subsystem were examined. By analysing the historic simulation results a historic critical hydrologic sequence was identified. The critical sequence is from April 1978 to October 1983. An optimization analysis was performed on the Buffalo-Vaal subsystem for the established critical hydrologic sequence with the new operating policy only, to determine whether the new operating strategy would have achieved the maximum firm yield from the subsystem, had one had full foreknowledge of future events. The optimal firm yield and reservoir drawdown patterns were compared with historic simulation results to confirm that an appropriate operating policy had been developed for the Buffalo-Vaal subsystem. From the results of both the optimization and simulation analyses it was found that no support to Newcastle is required from Zaaihoek Dam at the present level of demand, with the likelihood that it will not become necessary within the next five years.

(iii)

To maintain simplicity and parsimony, it was thus decided that the stochastic analysis and any further investigations be performed separately on the Zaaihoek and Chelmsford parts of the subsystem; with greater emphasis being placed on the Zaaihoek Dam and the transfer of water to the Vaal. The Zaaihoek Dam is therefore treated as the only active part of the Buffalo-Vaal subsystem from the point of view of the integrated Vaal River system. The full subsystem configuration will, however, again be required for any analyses covering the period when water supply from Chelmsford Dam needs to be supported from Zaaihoek Dam.

Long-term stochastic yield characteristics, comprising 41 64-year generated sequences, were analysed for the Chelmsford and Zaaihoek Dams respectively. Short term characteristic curves for operational decisions, based upon 201 5-year generated sequences, however, were only required for the Zaaihoek Dam as the currently active part of the integrated Vaal River system.

Summarized results from the analyses are presented in Tables A and B below.

TABLE A: RESULTS OF HISTORIC AND LONG-TERM STOCHASTIC ANALYSIS

DAM	FIRM YIELD FOR INDICATED RECURRENCE INTERVAL ($10^6 \text{ m}^3/\text{a}$)				HISTORIC YIELD ($10^6 \text{ m}^3/\text{a}$)	
	1:20	1:50	1:100	1:200	Firm	Total
Zaaihoek	64	58	52	48	47,2	54,0
Chelmsford	-	85	80	74	75,3	79,3

(iv)

TABLE B: RESULTS OF SHORT-TERM STOCHASTIC ANALYSIS (ZAAIHOEK DAM)

SYSTEM START VOLUME AS PERCENTAGE OF FULL SUPPLY CAPACITY	FIRM YIELD FOR INDICATED RECURRENCE INTERVAL ($10^6 \text{ m}^3/\text{a}$)			
	1:20 Yr	1:50 Yr	1:100 Yr	1:200 Yr
100 %	88,0	73,5	64,5	57,0
80 %	78,0	65,5	54,5	45,5
60 %	68,0	56,5	47,5	40,0
40 %	55,0	43,0	36,0	30,0
20 %	41,0	29,0	22,0	17,0
10 %	22,5	17,0	13,0	9,0

VAAL RIVER SYSTEMS ANALYSIS

BUFFALO-VAAL SUBSYSTEM ANALYSIS

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VAAL RIVER SYSTEM ANALYSIS

BUFFALO-VAAL SUBSYSTEM ANALYSIS

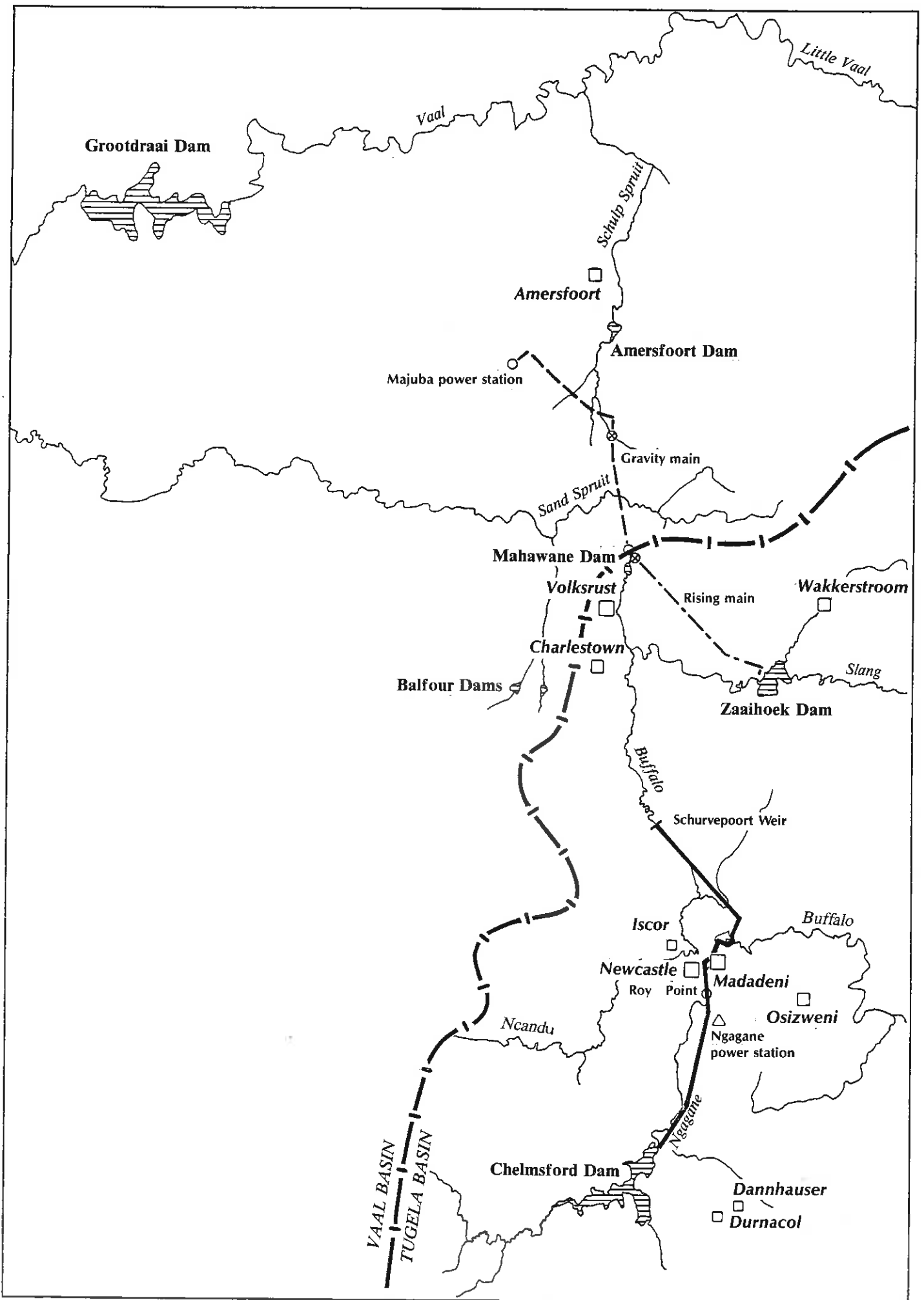
1. INTRODUCTION

The aim of the Vaal River System Analysis is to investigate the utilization of water resources in the Vaal River System. This investigation includes a number of subsystem analyses, of which the Buffalo-Vaal is one.

The Buffalo-Vaal subsystem consists of two interdependent Government Water Schemes, namely the Slang River Government Water Scheme (SRGWS) and the Ngagane River Government Water Scheme (NRGWS). The Slang River Government Water Scheme consists of the Zaaihoek Dam and its associated pipelines. The Ngagane River Government Water Scheme in turn consists of the Chelmsford Dam, Schurvepoort Weir and a river abstraction installation at Roy Point.

The geographical layout of the Buffalo-Vaal subsystem is given in Figure 1. The Slang River Government Water Scheme has been planned with the intention to supply water to the Majuba power station, the Ngagane River Government Water Scheme, to supplement the water supply to Volksrust and to provide compensation water for irrigation. Any surplus after these demands have been met is available for transfer to the Vaal River.

The purpose of this part of the study is to determine the yield-reliability characteristics of the Buffalo-Vaal subsystem for inclusion as part of the integrated Vaal River system; and to this end both historic and stochastic analyses are performed. The existing operating policy is reviewed and refined, with the final results based upon the revised strategy.



The yield analysis of the Buffalo-Vaal subsystem is evaluated in two phases. Firstly in terms of yield from the Zaaihoek Dam (Slang River Government Water Scheme), but including the total Buffalo-Vaal subsystem configuration and with operating rules reflecting the existing policy. Secondly, the Slang River GWS and the Ngagane River Government Water Scheme are separated and the yield from each system (scheme) is determined. In each instance the yield is modelled as a single demand point and the firm yield obtained from the analysis can therefore be allocated as required.

In the analysis of the existing operating policy the compensation flow is treated as a separate demand on the system to be supplied downstream of the confluence of the Buffalo and Ngagane Rivers. Uncontrolled irrigation and afforestation abstractions are subtracted directly from the naturalized streamflow. Municipalities reliant on the Buffalo-Vaal subsystem are treated as separate demand points, separate from the main yield channel.

Where the Zaaihoek Dam (SRGWS) is analysed separately from the whole Buffalo-Vaal subsystem, compensation flows are abstracted as a first priority and are not reflected as part of the yield.

Water not captured by the dams in the Buffalo-Vaal subsystem flows to the Indian Ocean via the Tugela River.

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2. SUBSYSTEM DATA

2.1 DESCRIPTION OF PHYSICAL SYSTEM

The Buffalo-Vaal subsystem consists of the Slang River Government Water Scheme (SRGWS) and the Ngagane River Government Water Scheme (NRGWS). The SRGWS comprises the Zaaihoek Dam on the Slang River, an upper tributary of the Buffalo River; and a pumping station and pipelines across the watershed to the Majuba power station and the Vaal River. The NRGWS consists of the Chelmsford Dam on the Ngagane River, a major tributary of the Buffalo River, a diversion at Schurvepoort Weir on the Buffalo River, a pump intake on the Ngagane River at Roy Point and a system of pumping stations and pipelines to transfer water from the abstraction points to the respective demand centres. The geographical layout of the Buffalo-Vaal subsystem is given in Figure 1.

From the Zaaihoek Dam, water designated for irrigation and to supplement the NRGWS and for irrigation will be released into the Slang River. The water for Majuba, Volksrust and for transfer to the Vaal River will be pumped over the basin-divide upstream of the Mahawane Dam. Water for Volksrust, when required, can be released upstream of the Mahawane Dam or supplied directly into the purification works from the pipeline. From the basin-divide the water will flow via a gravity main to Majuba and the water to be transferred to the Vaal River will be released into a tributary to the Schulpsspruit upstream of the Amersfoort Dam. Water thus transferred will pass through the Amersfoort Dam before it flows into the Rietspruit and then into the Vaal River upstream of the Grootdraai Dam.

The main source of water supply for the NRGWS is the Chelmsford Dam on the Ngagane River. Raw water is released via two pipelines for Eskom's Ngagane power station, other smaller users and for the Ngagane purification works. Raw

water is also supplied via another pipeline to Dannhauser, Durnacoll and farmers along the route.

Releases to the Ngagane River are made for ISCOR, Utrecht, Dundee - Glencoe, Nqutu and for compensation water.

The Ngagane purification works supply potable water to Newcastle, Madadeni and Osizweni. The raw water supply from the Chelmsford Dam to the purification works is supplemented by pumping from the Ngagane River at Roy Point and by a gravity feed from Schurvepoort Weir on the Buffalo River.

Potable water can also be supplied to Newcastle from the Boschhoek purification works on the Ncandu River.

2.1.1 Dams and Weirs

The elevation, storage volume and surface area relationships for the Chelmsford and Zaaihoek Dams were obtained from report P C000/00/4385 "Description of physical systems and operating rules" and are shown in Table 1. A summary of the data is given in Table 2.

The capacity of the dams is expressed as a percentage of the mean annual runoff (MAR) in the last row of the table to give an indication of the efficiency of the dam in capturing the basin runoff.

2.1.2 Pipelines

Details of the pumping capabilities of the Buffalo-Vaal subsystem were obtained from report P C000/00/4385 "Description of physical system and operating rules". The pumping capacities and capacity constraints of the connections in the subsystem are given in Table 3. Refer to Figure 2 for the configuration and channel references.

TABLE 1: ELEVATION, STORAGE VOLUME AND SURFACE AREA RELATIONSHIPS FOR DAMS IN THE BUFFALO-VAAL SUBSYSTEM

Tugela River Basin	
CHELMSFORD DAM	
Elevation (m)	1 226,52 1 236,22 1 238,11 1 239,47 1 240,57 1 241,52 1 232,37 1 243,15 1 234,86 1 245,11
Capacity (10 ⁶ m ³)	0,00 19,92 39,77 59,70 79,61 99,50 119,45 139,50 159,36 199,10
Area (ha)	5,30 847,60 1 264,90 1 660,90 1 960,50 2 227,20 2 463,30 2 683,50 2 918,80 3 443,00
ZAAIHOEK DAM	
Elevation	1 687,00 1 690,00 1 695,00 1 700,00 1 705,00 1 710,00 1 715,00 1 720,00 1 725,00 1 730,00
Capacity (10 ⁶ m ³)	0,00 0,05 1,04 7,07 18,92 36,20 60,52 95,13 141,54 199,25
Area (ha)	0,00 4,00 59,00 180,00 288,00 406,00 578,00 810,00 1 041,00 1 269,00

SOURCE: Report No P C000/00/4385, "Description of physical system and operating Rules."

TABLE 2: PHYSICAL DETAILS OF DAMS IN THE BUFFALO-VAAL SUBSYSTEM

DESCRIPTION	ZAAIHOEK DAM	CHELMSFORD DAM
Full supply level (m)	1 730,00 *	1 245,11 *
Dead storage level (m)	1 700,00 *	1 230,63 *
Volume at FSL ($10^6 m^3$)	199,26 *	199,10 *
Volume at DSL ($10^6 m^3$)	7,00 **	0,61 *
Surface area at FSL (km^2)	12,69 *	34,43 *
Capacity as % MAR	226 %	180 %

SOURCE: * Report No. PC000/00/4385, "Description of physical system and operating rules", Page B-5

** Report No. PV300/02/0285, "Uitbreiding van Slangrivier-Staatswaterskema: oorplasing van water na die Vaalrivier", Page 19 Table 8

TABLE 3: CHANNEL AND PIPELINE CAPACITIES IN THE BUFFALO-VAAL SUBSYSTEM

CHAN. NO	FROM	TO	CAPACITY LIMIT		TYPE	COMMENT
			UPPER (m ³ /s)	LOWER (m ³ /s)		
61	Zaaihoek	Yield	3,000	0,327	P	
62	Zaaihoek	Schurvepoort	N/A	0,000	G	Natural channel
63	Chelmsford	Roy Point	N/A	0,000	G	Natural channel
64	Schurvepoort	Confluence	N/A	0,000	G	Natural channel
65	Roy Point	Confluence	N/A	0,000	G	Natural channel
66	Confluence	Compensation	0,514	0,514	G	
67	Zaaihoek	Volkstrust	0,000	0,000	P	No demand at present
68	Zaaihoek	Schurvepoort	0,000	0,000	R	Volkstrust return flow
69	Schurvepoort	Ngagane P/W	0,300	0,000	G	Pipeline limitation
70	Chelmsford	Ngagane P/W	0,860	0,000	G	Pipeline limitation
71	Roy Point	Ngagane P/W	0,610	0,000	P	Pumping limitation
72	Ngagane P/W	Newcastle	0,526	0,526	P	Pumping and demand
73	Ngagane P/W	Confluence	0,275	0,275	R	Newcastle return flow
74	Chelmsford	Dannhauser	0,018	0,018	P	Demand
75	Roy Point	Iscor	0,270	0,270	P	Demand
76	Roy Point	Confluence	0,040	0,040	R	Iscor return flow
77	Mines	Chelmsford	0,015	0,015	R	Dewatering limit

SOURCE: Report No P C000/00/4385 "Description of Physical system and operating rules."

2.2 HYDROLOGICAL DATA

2.2.1 Naturalized Inflows

The naturalized streamflows at the Schurvepoort Weir, Roy Point Pumpstation and the Zaaihoek and Chelmsford dams were obtained from report no P C000/00/5586, "Hydrology of Tugela Basin". The recorded streamflows of the gauges at each site are compared to gauges upstream and downstream to confirm the consistency of the recorded values. When the record at a particular gauge is shorter than the 64 years required for the analysis, the gauge record is patched against suitable streamflow and rainfall gauges using the procedure outlined in report no P C000/00/4285 "Analysis and Patching of hydrological data". When the record at a particular gauge is longer than the 64 years required, it is reduced to the 64 year period used in the analysis. This approach is adopted to keep the results from the analysis consistent.

The streamflows at the different sites are for incremental catchment areas. The net basin runoff for the historic analysis is obtained by subtracting the afforestation and irrigation abstractions of the upstream catchments from the naturalized streamflows at the appropriate site. The naturalized streamflows used in this analysis are given in Appendix A, subsections A.6 to A.9. The catchment areas and incremental MAR at each node considered in the analysis are given in Table 4.

TABLE 4: CATCHMENT DETAILS FOR NATURALIZED INFLOWS IN THE BUFFALO-VAAL SUBSYSTEM

INFLOW STATION	GAUGE NO	MEAN ANNUAL RUNOFF ($10^6\text{m}^3/\text{a}$)	INCREMENTAL CATCHMENT AREA (km^2)
Zaaihoek Dam	V3M05	89,73	676
Chelmsford Dam	V3R01	110,86	830
Schurvepoort Weir	V3M02	129,98	842
Roy Point Pumpstation	-	28,27	212

2.2.2 Rainfall

The rainfall on the surface area of the dams is obtained by multiplying the monthly rainfall values expressed as a percentage of the MAP (presented in report no P C000/00/5586 "Hydrology of the Tugela Basin") by the mean annual precipitation at the site of the dam. The rainfall files used in the analysis are given in Appendix A, subsections A.10 to A.13.

2.2.3 Evaporation

The monthly gross evaporation values used in this analysis were obtained from report no P C000/00/5986 "Evaporation from reservoirs in the Vaal river system project area".

2.2.4 Stochastic Streamflows

The Stochastic Streamflow Generating model as discussed in report P C000/00/5186 "Stochastic modelling of streamflow" is used to generate the stochastic hydrology for the analysis. The stochastic streamflows are generated for the incremental catchments.

An auto-regressive moving-average (ARMA) stochastic streamflow model is used to generate annual streamflows. A number of specified gauges are used in the determination of the reference hydrological year for disaggregation of the annual values into monthly values. The method of stochastic streamflow generation and disaggregation is discussed in report P C000/00/5186, "Stochastic Modelling of Streamflow". The irrigation and afforestation abstractions for each reference year are subtracted from the stochastically generated streamflows to derive stochastic net basin runoff values. The monthly rainfall corresponding to the reference

hydrological year for streamflow disaggregation, is used to calculate net evaporation from the reservoirs.

2.3 WATER DEMANDS

2.3.1 Irrigation

The area within the Buffalo-Vaal subsystem which was under irrigation at 1984 levels of development was obtained from estimates made in report P C000/00/5586 "Hydrology of the Tugela Basin". This area was used to obtain an estimate for the irrigation abstractions in the subsystem using the following methodology. The irrigation requirement of the type of crops grown in the Tugela catchment was determined on a monthly basis. Irrigation requirement was assumed to be the difference between the evapotranspiration and the effective rainfall. The effective rainfall was considered to be 60 percent of the actual rainfall, except in months with a total rainfall of less than 15 mm, in which case the effective rainfall was considered equal to the total rainfall. The irrigation demands were then taken as being the product of the irrigation requirement and the area irrigated during the specific year. An irrigation efficiency of 80 percent and a return flow of 10 percent was assumed. Irrigation demand for the full period from September 1984 was assumed to be constant at the level required for the area under irrigation in September 1984.

The files of the uncontrolled irrigation abstractions used in the analysis are included in Appendix A, sub section A.1 to A.4, for reference. A summary of the mean annual values is given in Table 5.

TABLE 5: MEAN ANNUAL VALUE OF UNCONTROLLED ABSTRACTIONS FROM THE BUFFALO-VAAL SUBSYSTEM

NODE	IRRIGATION ($10^6\text{m}^3/\text{a}$)	AFFORESTATION ($10^6\text{m}^3/\text{a}$)
Zaaihoek Dam	1,75	0,00
Chelmsford Dam	2,17	0,00
Schurvepoort Weir	3,97	0,78
Roy Point	0,56	0,00

TABLE 6: RETURN FLOWS IN BUFFALO-VAAL SUBSYSTEM

CHAN. NO	RETURN FLOW DESCRIPTION	RETURN FLOW ($10^6\text{m}^3/\text{a}$)	
		SUB-TOTAL	TOTAL
77	DANNHAUSER Mine Dewatering	0,48	0,48
76	ISCOR		1,25
73	NEWCASTLE Newcastle Madadeni & Osizweni	4,28 4,38	8,66
			10,39 =====

SOURCE: Report No P C000/00/4886, "Historical and future water demands and return flows".

A demand of $42 \times 10^6 \text{m}^3/\text{a}$, to be supplied from the Chelmsford Dam was used in the analysis. More details of the Buffalo-Vaal subsystem demands can be obtained from report No. P C000/000/4886 "Historical and Future water demands and Return Flows". Table 6 gives a summary of the return flows influencing the operation of the subsystem, while Table 7 gives a summary of the water demands in the Buffalo-Vaal subsystem.

The annual demands as set out in Table 7 were assumed to be uniformly distributed throughout the year. This implies that in each month approximately one-twelfth of the total annual demand has to be satisfied.

TABLE 7: WATER DEMAND FROM THE BUFFALO-VAAL SUBSYSTEM

CHAN. NO	DEMAND DESCRIPTION	DEMAND ($10^6\text{m}^3/\text{a}$)	
		SUB-TOTAL	TOTAL
	<u>ZAAIHOEK</u>		
61	Target draft Majuba Wakkerstroom (1985)	10,12(30) 0,18	10,35(30,23)
67	Volkstrust (1985)	0,00	
	<u>CHELMSFORD</u>		
74	DANNHAUSER Durnacol-dam -upstream Dannhauser (1985) Farms Return flow	0,27 0,48 0,27 0,03 -0,48	0,57
72	NEWCASTLE Newcastle, Madadeni and Osizweni (1985) Ngagane Power Station Chemical industries	17,81 5,60 1,85	25,26
75	ISCOR Iscor Newcastle (1985) Durnacol Dannhauser (1985)	8,30 1,20 0,22 0,25	9,97
66	COMPENSATION Utrecht (1985) Dundee-Glencoe (DWA permit) Nqutu (1985) Irrigation (WP-M-83) River losses	0,00 5,11 1,12 8,29 1,71	16,23
			62,38

SOURCE: Report No P C000/00/4886, "Historical and Future water demands and return flows"

NOTE: The demand consists of return flows and consumptive use.

2.3.2 Afforestation

The area of afforestation at the 1984 level of development was derived from report no P C000/00/5586 "Hydrology of the Tugela Basin", from records of the Department of Environmental Affairs and from the report "Surface Water Resources of South Africa" (HRU 1981). The area of afforestation obtained in this manner was used in the Pitman (1973) model to obtain the abstractions due to afforestation. The Pitman model was run for the catchment, initially including the area under afforestation and then without the afforestation area. The difference between the streamflows resulting from these two runs was then taken as the afforestation abstraction for use in the subsystem analysis.

The historic afforestation abstractions at the 1984 level of development were calculated for a period of 64 years (1920-1983). The basin yield determined by this analysis is therefore in addition to all afforestation abstractions.

The files of afforestation abstractions used in the analysis are reproduced in Appendix A, subsection A.5 and summarised in Table 4. From the table it can be seen that Schurvepoort Weir is the only site upstream of which any significant afforestation abstractions occur.

2.3.3 Compensation flows

Compensation flows require careful consideration when the subsystem is considered in its various configurations. These include the combined system and the Zaaihoek Dam and the Chelmsford Dam treated separately.

During the course of the study the SRGWS and the NRGWS were found to be independent of one another at current demand levels (refer paragraph 3.8). Greater emphasis was

subsequently placed on the analyses of the Zaaihoek Dam (SRGWS), the only part of the Buffalo-Vaal subsystem contributing to the Vaal System. Compensation flows to be released from Zaaihoek Dam were therefore specifically addressed during the study.

The following compensation flow below the Zaaihoek Dam was used in the final yield analysis.

WPF - 85 $4,8 \times 10^6 \text{ m}^3/\text{annum}$
 Court Order: Volksrust Turbines $4\ 260 \text{ m}^3/\text{day}$.

This is $6,36 \times 10^6 \text{ m}^3/\text{annum}$ or $0,201 \text{ m}^3/\text{sec}$.

When analysing the total Buffalo-Vaal subsystem, however, compensation releases of $22\ 700 \text{ m}^3/\text{day}$ ($0,262 \text{ m}^3/\text{s}$) was allowed for as specified in W.P. M 71.

2.4 DESCRIPTION OF EXISTING OPERATING RULE

The first part of the study deals with the existing operating policy for the Buffalo-Vaal subsystem as described in report PC 000/00/4385, "Description of Physical System and Operating Rules", and summarised below. As the SRGWS was still under construction at the time of writing of this report, this operating rule had never been implemented but rather reflected the planned operating rule for the subsystem (a revised operating policy was subsequently developed and also forms the basis for the final results - refer paragraphs 4.3 and 4.4).

- (a) Due to its strategic importance, Majuba power station has to be supplied with water as a first priority, regardless of the state of storage in the Zaaihoek Dam.
- (b) The restriction criteria for municipal users and irrigation abstractions from the Buffalo and Slang Rivers are based on the combined storage of the Zaaihoek and Chelmsford Dams. The criteria are shown in Table 8.

TABLE 8: RESTRICTION CRITERIA FOR SLANG RIVER SYSTEM

COMBINED STORAGE IN CHELMSFORD AND ZAAIHOEK DAMS	PERCENTAGE OF FULL QUOTA ALLOWED TO ABSTRACT	
	MUNICIPAL USERS	IRRIGATION
ABOVE 19 %	100 %	100 %
19 - 15 %	90 %	50 %
15 - 12 %	55 %	35 %
LESS THAN 12 %	35 %	NO RELEASES

Note: Releases from the dams are only made to supplement the natural flow in the rivers in order to allow abstraction at the above percentages of the quota.

- (c) The flow in the river is stabilized to allow the abstraction of the full capacity of the Ngagane River GWS (Buffalo River diversion) of $800\,000\text{ m}^3/\text{month}$ ($0,30\text{ m}^3/\text{s}$) regardless of the storage of Zaaihoek Dam.
- (d) Water will only be transferred to the Vaal Catchment when storage at the Zaaihoek Dam is in excess of 33 % of full capacity.

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3. ANALYSIS METHODOLOGY

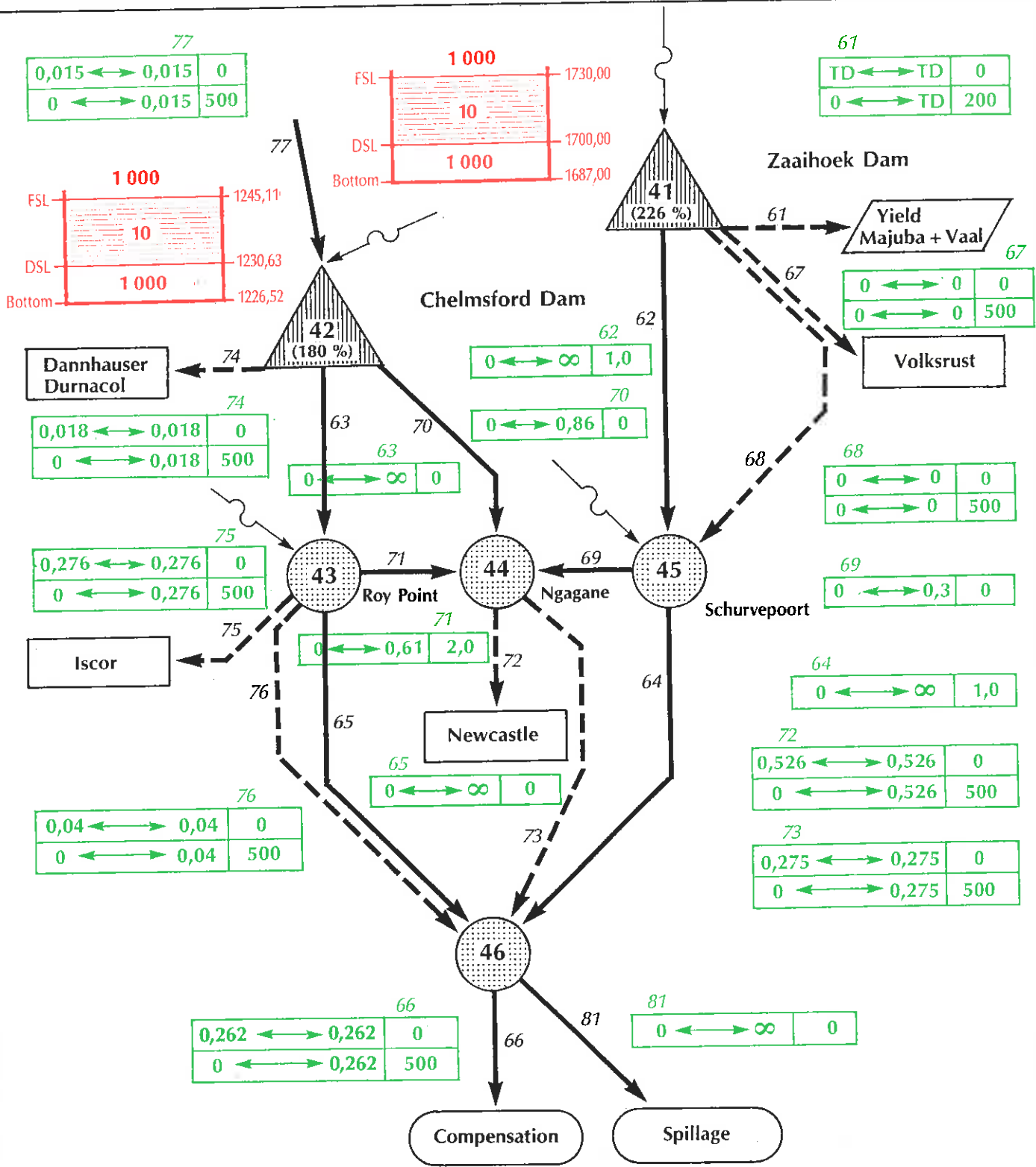
The study of the Buffalo subsystem follows the basic analysis procedure outlined in the Vaal River System Analysis report P C000/00/4185, "Modelling Strategy and Study Analysis Work Programme."

The procedure basically consists of a simulation and optimization analysis using the existing operating policy and historic data, to determine the optimal operating policy. A detailed historic and stochastic simulation analysis was conducted using the optimal operating policy to establish the probabilistic behaviour of the subsystem.

Network schematics of the Buffalo-Vaal, subsystem were developed for the existing subsystem. The schematic representation (with associated channel and node numbers) as illustrated in Figure 2 was used by the simulation algorithm to analyse the yield of the Buffalo-Vaal subsystem. The existing operating policy and a new operating policy were investigated using the simulation model.

The network schematic as illustrated in Figure 3 was used by the optimization algorithm to investigate the optimal system behaviour. The network schematics depicted in Figures 4 and 5 were used to investigate the yield from the Zaaihoek and Chelmsford Dams as independent systems.

Simulation analyses of the Buffalo-Vaal subsystem over 64 years of historic hydrology (1920 - 1983) were performed to evaluate the historic yield characteristics of the three configurations of the Buffalo-Vaal subsystem. The hydrological year used in the simulation analysis commences on May 1st. From the initial simulation analysis, a critical hydrologic sequence was identified. The critical

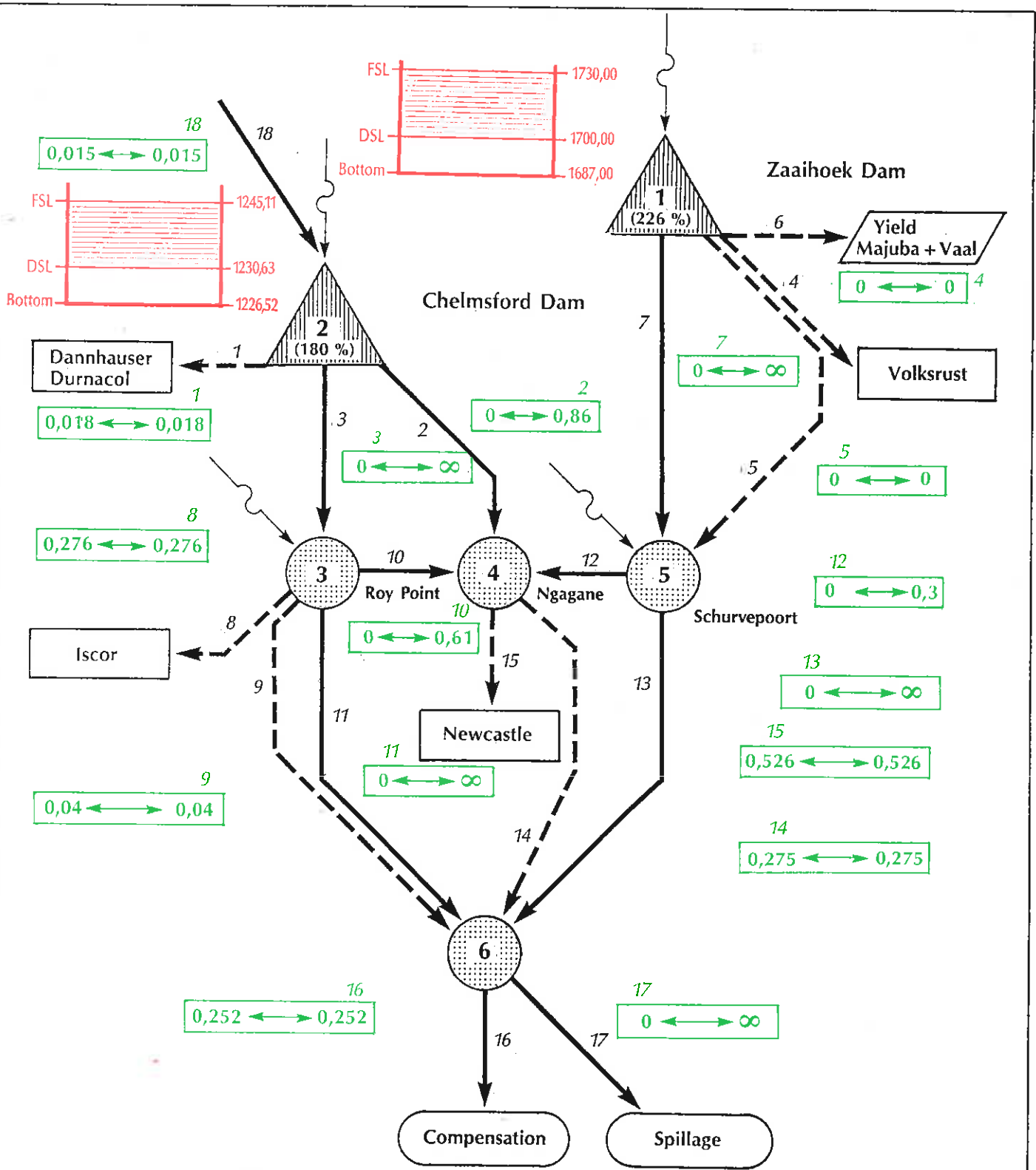


Storage	Penalty	Elevation
FSL	1 000	1303,00
Working storage		
DSL	1 000	1287,00
Bottom		1279,00

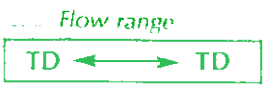
Flow range	Penalty
TD ↔ TD	0
0 ↔ TD	250

- 61 Channel reach and number
- 62 Pumping line or canal
- Natural inflow
- Basin divide
- Node
- Storage node (reservoir)

- Controlled demand
- Losses from subsystem
- Subsystem yield
- Subsystem outflow/inflow
- (215 %) Node capacity as % of MAR

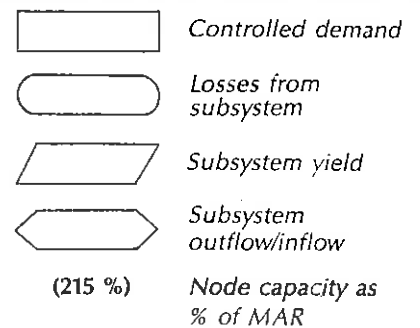
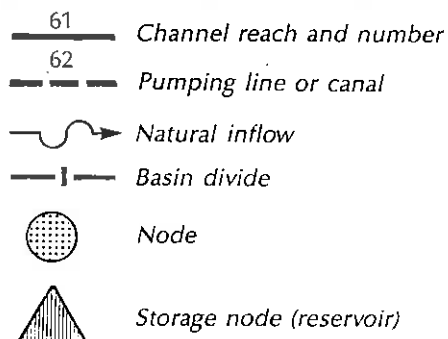
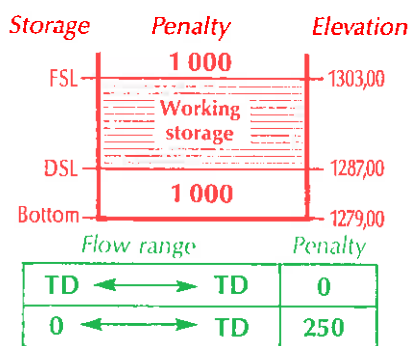
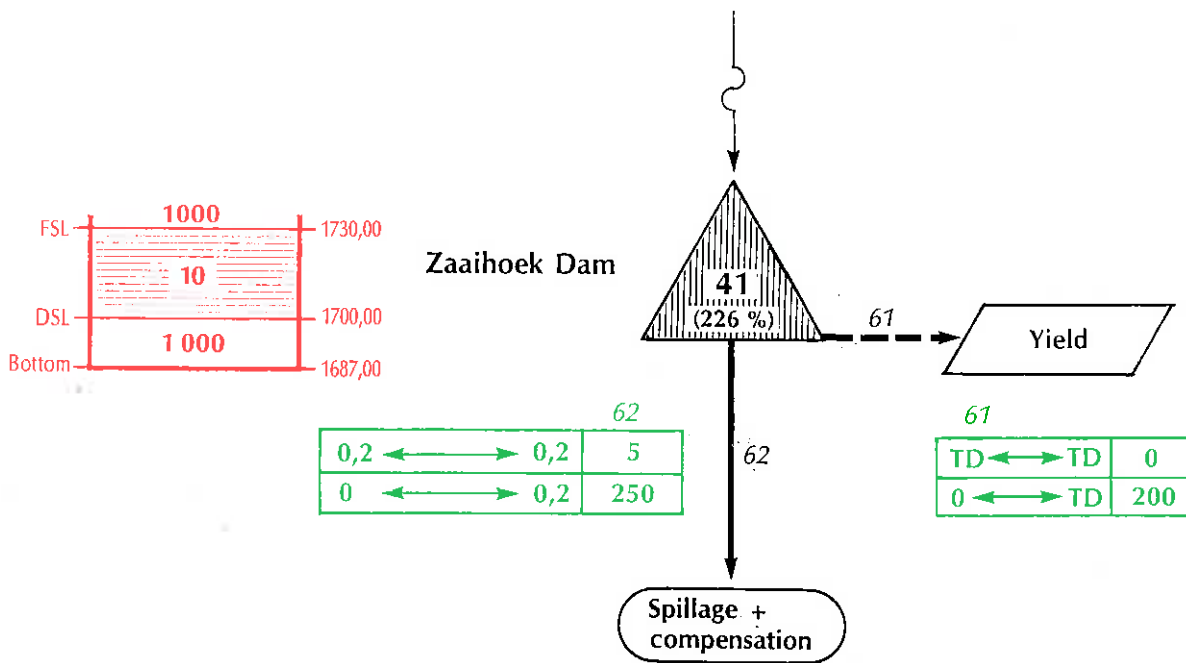


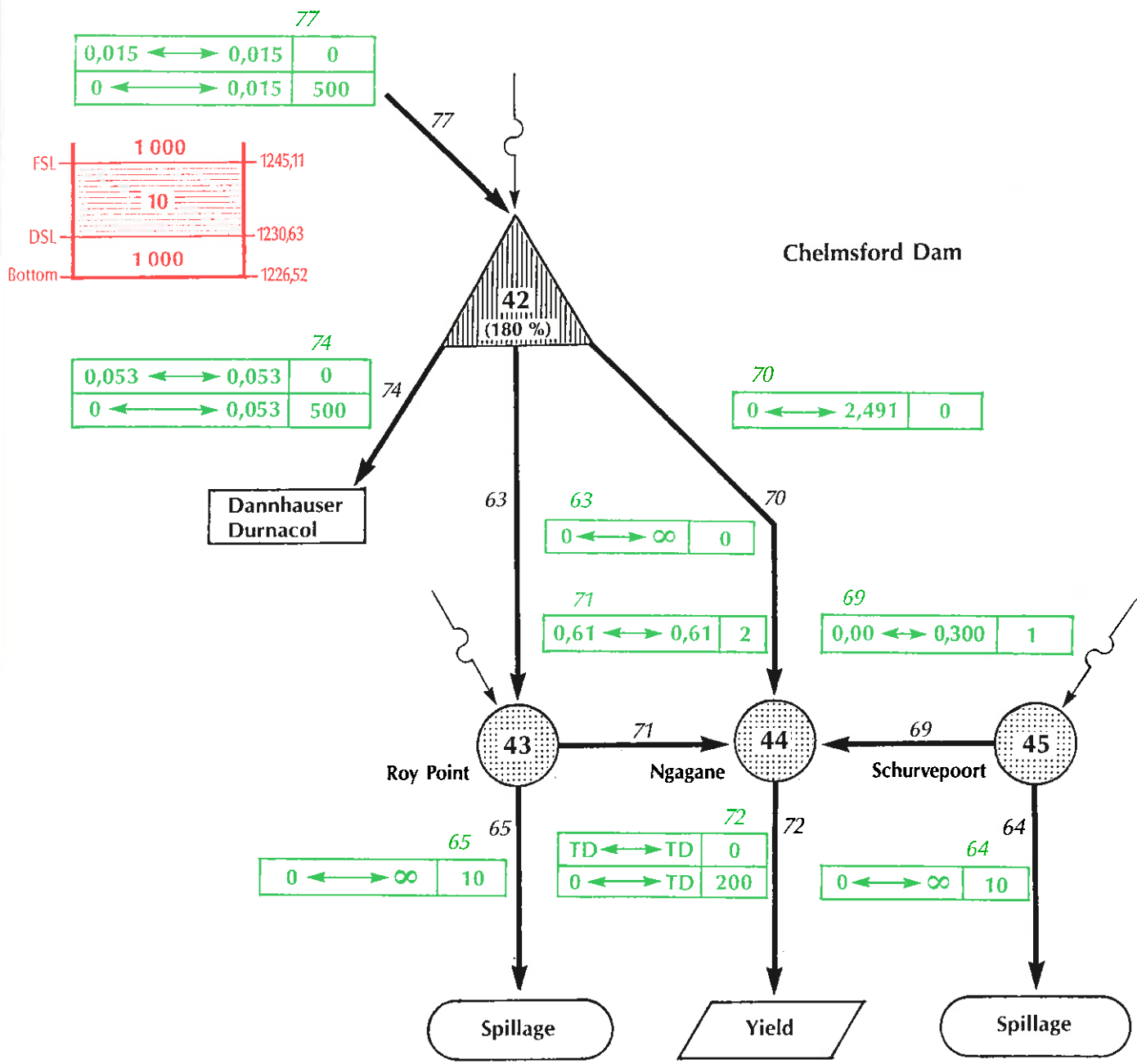
Storage Elevation



- 61 Channel reach and number
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- (215 %) Node capacity as % of MAR





Storage	Penalty	Elevation
FSL	1 000	1303,00
Working storage		
DSL		1287,00
Bottom	1 000	1279,00

Flow range	Penalty
TD ↔ TD	0
0 ↔ TD	250

- 61 Channel reach and number
- 62 Pumping line or canal
- Natural inflow
- Basin divide
- Node
- Storage node (reservoir)
- Controlled demand
- Losses from subsystem
- Subsystem yield
- Subsystem outflow/inflow
- (215 %) Node capacity as % of MAR

hydrologic sequence represents the period in history when the Buffalo-Vaal subsystem would have experienced its worst yield when subjected to the full demands of the users at the 1985 demand level. The critical historic hydrologic sequence was determined to be the period from April 1978 to November 1983.

The operating policy proposed for the Buffalo-Vaal subsystem in the "Eerste aanvullende verslag oor die voorgestelde Slangrivier Staatswaterskema" and reported in Report No P C000/00/4385 "Description of physical system and operating rules" was evaluated to obtain a comparative drawdown trajectory of the reservoirs in the subsystem. An alternative operating policy was investigated where the reduction in water supply during severe drawdown conditions inherent in the proposed DWA operating policy were removed in order to establish the unrestricted yield characteristics of the Buffalo-Vaal subsystem.

The critical hydrologic sequence identified by the simulation model was analysed using the dynamic programming model to evaluate the optimal reservoir drawdown strategy and optimal firm yield from that sequence. The optimal reservoir drawdown pattern and optimal firm yield were examined to determine if an improvement in the operating policies previously evaluated by the simulation model were possible.

The drawdown patterns were very similar and reflected a single reservoir type of operation. After obtaining confirmation of the independence of the two reservoirs (at current demand levels) by looking for releases at the Zaaihoek Dam to supplement the Chelmsford Dam, the analysis was continued separately on each reservoir to obtain the optimal yield from each dam.

After determining the best operating policy for the historic yield analysis, the simulation model was used in combination

with the stochastic streamflow generator (report P C000/00/5186 "Stochastic modelling of streamflow") to perform a stochastic yield analysis for that operating policy. Long-term stochastic analyses covering a period of 64 years were performed for both the Chelmsford and Zaaihoek Dams. Short-term analyses spanning 5 years of projected hydrology were performed with respect to the Zaaihoek Dam only. Forty-one 64-year sequences and two hundred and one 5-year sequences were analysed. Different reservoir levels were assumed for the start of the analyses of the short-term stochastic series.

3.1 SIMULATION MODEL

The simulation model used in the analysis of the subsystem is known as the Acres Reservoir Simulation Program (ARSP). This computer program simulates the behaviour of the reservoir system by making use of the continuity equation for flow of water through a reservoir and a special linear programming formulation. The latter requires the system to be represented by means of a network consisting of nodes and channels. Junctions and control points, such as reservoirs, are represented as nodes, while natural or man-made flow paths connecting nodes, are referred to as channels.

Each channel is represented in the computer model as either a flow channel or a demand channel. A flow channel can have its full flow carrying capacity divided into a number of discrete ranges. Each range has user-specified bounds, and a penalty to reflect the relative desirability of having flow in that range. Demand channels, on the other hand, have user-prescribed penalties associated with not meeting the imposed demand. In the case of reservoirs, discrete intervals of reservoir storage, known as zones, are defined. Each storage zone has a specified upper and lower boundary and a user-specified penalty, that represents the relative cost of water stored in the zone.

Representing reservoir zones, demands, and channel flow ranges in this manner permits the study of trade-offs in a water resource system subject to different operating policies. An operating policy reflects the operating strategy employed to optimize benefits within the water resource system, and is defined by the channel and storage zone penalties.

The total penalty to the system is the sum of all channel and storage zone drawdown penalties. The network solution algorithm determines the flow-routing resulting in the minimum total transfer cost for a given time step.

3.2 SUBSYSTEM REPRESENTATION

The schematic representation of the Buffalo-Vaal subsystem used in the simulation analysis of the existing operating policy is given in Figure 2. The schematic presentation used in the simulation analysis of the yield from the Zaaihoek and Chelmsford Dams as separate subsystems is given in Figures 4 and 5.

The main difference between the representations for the simulation and optimization analysis is in the numbering of the nodes and the channels. In the remainder of the report reference will only be made to the channel numbers used in the simulation analysis. In the division of the Buffalo-Vaal subsystem into the Zaaihoek and Chelmsford Dam partial subsystems, the channel numbers were preserved as far as possible.

The resultant yield channel (after satisfying specified demands) of the total subsystem is through the pipeline from

the Zaaihoek Dam to the Majuba powerstation. This pipeline is represented by channel 61.

The demands from Dannhauser, Iscor, Newcastle and Volksrust are represented by channels 74, 75, 72 and 67 respectively while the return flows from Iscor, Newcastle and Volksrust are represented by channels 76, 73 and 68. The return flow from Dannhauser is represented by channel 77 which also represents the mine dewatering flows from Durnacol. Demands downstream of the confluence of the Buffalo and Ngagane rivers are represented by channel 66.

The spillage from the Chelmsford and Zaaihoek Dam flows down channels 63 and 62 respectively. Spillage from Roy Point and Schurvepoort flows down channels 65 and 64 respectively. Spillage from the system is represented by channel 81.

3.3 ABSTRACTION CAPACITY AT SCHURVEPOORT WEIR

The abstraction capacity of the diversion weir at Schurvepoort was investigated to determine if its maximum capacity of $0,3 \text{ m}^3/\text{s}$, on a monthly basis, was possible.

The daily flows for each month during the critical period of May 1978 to November 1983 were screened and the number of days with average daily streamflows less than $0,3 \text{ m}^3/\text{s}$ was obtained. A total monthly streamflow in the diversion works was determined by taking $0,3 \text{ m}^3/\text{s}$ for the days with an average daily flow of $0,3 \text{ m}^3/\text{s}$ and the actual average daily flow for the days where the streamflow was less than $0,3 \text{ m}^3/\text{s}$.

An efficiency factor was determined for each month by taking the average daily draw-off as a fraction of the maximum daily draw-off for each month. The average over the period analysed was then taken to determine a mean for each month.

The factor determined in this manner was inserted into the program to define an actual monthly maximum allowable flow through the diversion works.

3.4 EXISTING OPERATING POLICY ANALYSIS

The operating policy for the Slang River Scheme as described in report P C000/00/4385 "Description of Physical System and Operating Rules" was simulated by means of the subsystem simulation model.

Additional irrigation channels were defined to implement the irrigation restriction downstream of the reservoirs. Irrigation upstream of the reservoirs is handled as described in Section 2.2.1.

The reservoir and channel capacities as described in Section 2.1.2 were used to complete the definition of the operating policy.

3.5 SUBSYSTEM OPTIMIZATION ANALYSIS

An optimization analysis was performed on the historic critical hydrologic sequence as determined from the preliminary simulation analysis. The sequence consisted of 7 years of historic hydrology (Oct. 1977 to Sept. 1983).

The 7 year period was analysed using 28 three-monthly time periods. The initial conditions of all reservoirs were assumed to be full at the start of the historic critical hydrologic sequence. The period analysed was extended beyond the critical period so that start conditions and end conditions did not affect the optimal operation of the system during the critical period.

The program determines the optimal yield during the critical hydrologic sequence as well as the reservoir drawdown

pattern required to achieve this optimal yield. The optimal yield is defined as the maximum yield that can be supplied without failure during the critical period.

The continuity equation used by the optimization program may be stated as follows:

$$S_t - S_{t-1} = Q_{net} + Q_{in} - Q_{out} + (Rain - Evap)Area$$

where S_t = storage volume at end of time period 't'.
 Q_{net} = the naturalized inflow minus uncontrolled irrigation usage and afforestation losses.
 Q_{in} = Sum of flows in all inflow routes.
 Q_{out} = Sum of flows in all outflow routes.
 Area = average reservoir surface area during time period 't'.
 Rain = rainfall on the reservoir during time period 't'.
 Evap = gross evaporation during time period 't'.

3.6 BASIC OPERATING POLICY

The following basic operating policy was established to examine various reservoir operating strategies.

A basic operating policy is achieved by defining the relative priority on reservoir drawdown among the two reservoirs and defining priorities in transfer routes within the system. The priority on reservoir drawdown is defined using storage zone penalties as shown in Figure 3. The priority on transfer routes is defined by route path penalties as shown in Figure 3. The total cost to the system is the cost of storage zone drawdown plus the cost of deficit flows in the inter-node channels. The solution algorithm solves for the flow routing which produces the minimum total system cost.

3.6.1 Operating Rule Curve Analysis

The priority on reservoir drawdown for the basic operating policy is illustrated in Table 8.

TABLE 8: RESERVOIR DRAWDOWN PRIORITY - BASIC OPERATING POLICY

	CHELMSFORD DAM	ZAAIHOEK DAM
ZONE A		
Zone Penalty	1	2
Percent Storage Range	100 % - 100 %	100 % - 100 %
ZONE B		
Zone Penalty	10	20
Percent Storage Range	0 % - 100 %	0 % - 100 %

The most desirable water level for all reservoirs is the 100 percent full supply level. At this level, the maximum amount of water is available to meet the target demands. When the target demand is greater than the net basin runoff the reservoir will be drawn down to meet the target demand.

Reservoir drawdown will occur in the storage zone with the lowest zone penalty, to meet the target demand as long as a flow capacity constraint is not encountered and as long as water storage is available in that reservoir zone. If either constraint is detected, then reservoir drawdown will proceed to the storage zone with the next lowest zone penalty.

The zone penalties also represent the relative desirability of water storage among the dams and their respective zones. For example if water was available in the Chelmsford Dam, Zone B, Zone penalty = 10; and Zaaihoek Dam, Zone B, zone penalty = 20 is below 100 percent full and compensation releases continue to be supplied, water will be released from the Chelmsford Dam rather than from the Zaaihoek Dam until:

1. a flow constraint is encountered.
2. compensation releases are satisfied.
3. Chelmsford Dam zone B is empty.

3.6.2 Transfer Costs

Transfer costs are used to define the preferred paths for routing water. Flow will be routed through the paths which result in the smallest increase in total system cost.

If there are two routes from the same reservoir to the same demand point the following procedure is adopted. If one route results in a physical cost, for example pumping, being incurred and the second involves no actual cost, then a higher transfer cost is assigned to the route involving pumping. The simulation model will route the water along the path with the lowest transfer cost until a capacity limitation is reached. If the demand is still not satisfied additional water will be routed along the path with the higher transfer cost until the demand is satisfied or a flow capacity constraint is encountered.

3.7 SUBSYSTEM SIMULATION ANALYSIS

The yield analysis simulation model was used to analyse the yield characteristics of the Buffalo-Vaal subsystem. This model is described in the Vaal River System Analysis report PC000/00/4185, "Modelling Strategy and Study Analysis Work Programme" and will be documented in detail in a forthcoming model documentation report.

The initial yield analysis focussed on the Buffalo-Vaal subsystem historic yield characteristics. For this analysis, the 64 years of historic hydrology for the period 1920 to 1983 were used as the inflow hydrology. A monthly time period analysis for a range of target demands was performed using the following continuity equation:

$$S_t - S_{t-1} = Q_{\text{net}} + Q_{\text{in}} - Q_{\text{out}} + (\text{Rain} - \text{Evap}) \text{ Area}$$

where all symbols are as previously defined in Section 4.4 except:

Area = reservoir surface area at start of time period 't'.

The historic yield characteristics of the Buffalo-Vaal subsystem were evaluated using the operating rule curve as discussed in Section 3.4. The firm yield characteristics of the operating policy were also compared with the optimal firm yield obtained from the optimization analysis. The operating policy was adjusted to obtain as close to optimal performance as possible.

3.8 DIVISION OF SUBSYSTEM

Both the optimization analysis and the simulation analysis indicated that the Zaaihoek and Chelmsford Dams can act independently to supply the respective water demands at the 1985 demand level.

The subsystem simulation analysis was repeated for the separate Zaaihoek Dam and Chelmsford Dam partial subsystems, and the operating rule for each of them was determined.

Using the selected operating policy (the policy which resulted in the best yield characteristics), the probabilistic yield characteristics of Zaaihoek Dam were examined. Both long-term and short-term stochastic yield analyses were performed using the yield analysis simulation model.

The analyses were performed over a range of target drafts, also examining the effect of different reservoir starting volumes on the short-term stochastic yield characteristics.

3.9 RELIABILITY ANALYSIS

Curves representing the probability of firm yield as a function of target draft were derived from the results of the stochastic yield analyses. The curves are derived by fitting a least squares curve through the data points which represent the reliability of supply at a given yield. The curve fitting was done for both the long term and the short-term stochastic analyses.

The curves are representative of the yield reliability relationships discussed in the Vaal River System Analysis report no P C000/00/4185, "Modelling Strategy and Study Analysis Work Programme".

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4. RESULTS OF SUBSYSTEM ANALYSIS

4.1 INTRODUCTION

During the course of the comprehensive analysis of the Buffalo-Vaal subsystem the focus of the study shifted between a number of issues and sub-issues.

The major objective of the study was to determine the yield-reliability relationship with respect to surplus water that can be transferred from the Buffalo subsystem to the Vaal system.

Secondary objectives included the determination of the degree of interdependence of the two dams in the Buffalo system, namely the Zaaihoek Dam and the Chelmsford Dam; an examination of the abstraction capacity at the Schurvepoort Weir and examination of the characteristics and behaviour of the subsystem resulting from the existing operating policy.

The results of the subsystem yield analyses on the Buffalo-Vaal subsystem are presented in five major categories:

- (i) analysis of the abstraction capacity at the Schurvepoort Weir;
- (ii) the analysis of the existing operating rule for the subsystem;
- (iii) subsystem yield analysis including justification for division of the subsystem;
- (iv) yield analysis for the Zaaihoek Dam; and
- (v) yield analysis for the Chelmsford Dam.

4.2 DIVERSION CAPACITY OF SCHURVEPOORT WEIR

Daily streamflow records for the Schurvepoort weir were analysed to determine the proportion of flow passing the weir that can affectively be diverted to Newcastle. The period analysed stretches from October 1977 to September 1983, covering the historic critical hydrological period as obtained from initial simulation runs. Efficiency factors to be applied to monthly streamflow values were thereby determined.

The efficiency factor for the weir was defined as:

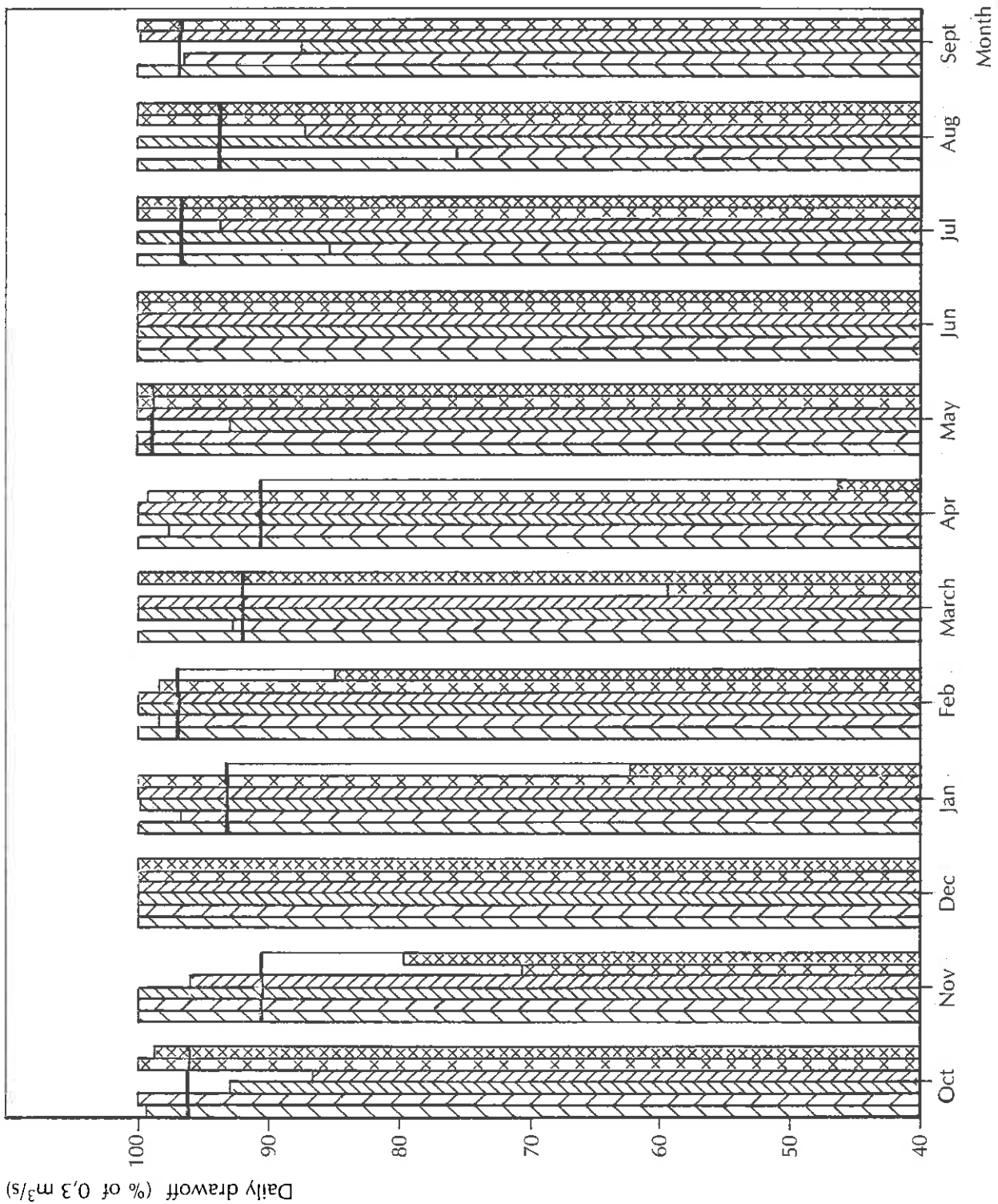
$$\text{eff.} = \frac{\text{average daily drawoff}}{\text{max possible daily drawoff}} \times 100 \quad (1)$$

The maximum possible daily drawoff was taken as $0,3 \text{ m}^3/\text{s}$ during days when the average daily stream flow was greater than $0,3 \text{ m}^3/\text{s}$. In the instances where the average daily streamflow in the Buffalo River was less than $0,3 \text{ m}^3/\text{s}$, the maximum possible daily drawoff was taken to be equal to the average daily streamflow for that day. It is therefore possible to obtain a monthly efficiency of 100 % when all daily flows are less than $0,3 \text{ m}^3/\text{s}$ for that month.

The average monthly efficiency rates were evaluated as described in equation (2).

$$\text{eff. Oct} = \frac{\text{eff Oct}(1) + \text{eff Oct}(2) + \dots + \text{eff Oct}(n)}{n} \quad (2)$$

It should be noted that this is the expected scenario during critical low streamflow periods. During periods with a base streamflow in excess of $0,3 \text{ m}^3/\text{s}$ the efficiency of the weir will be 100 %. The analysis, however, concentrates on critical low flow periods and these efficiency factors are therefore added to the input data for the simulation analysis.



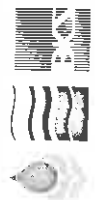
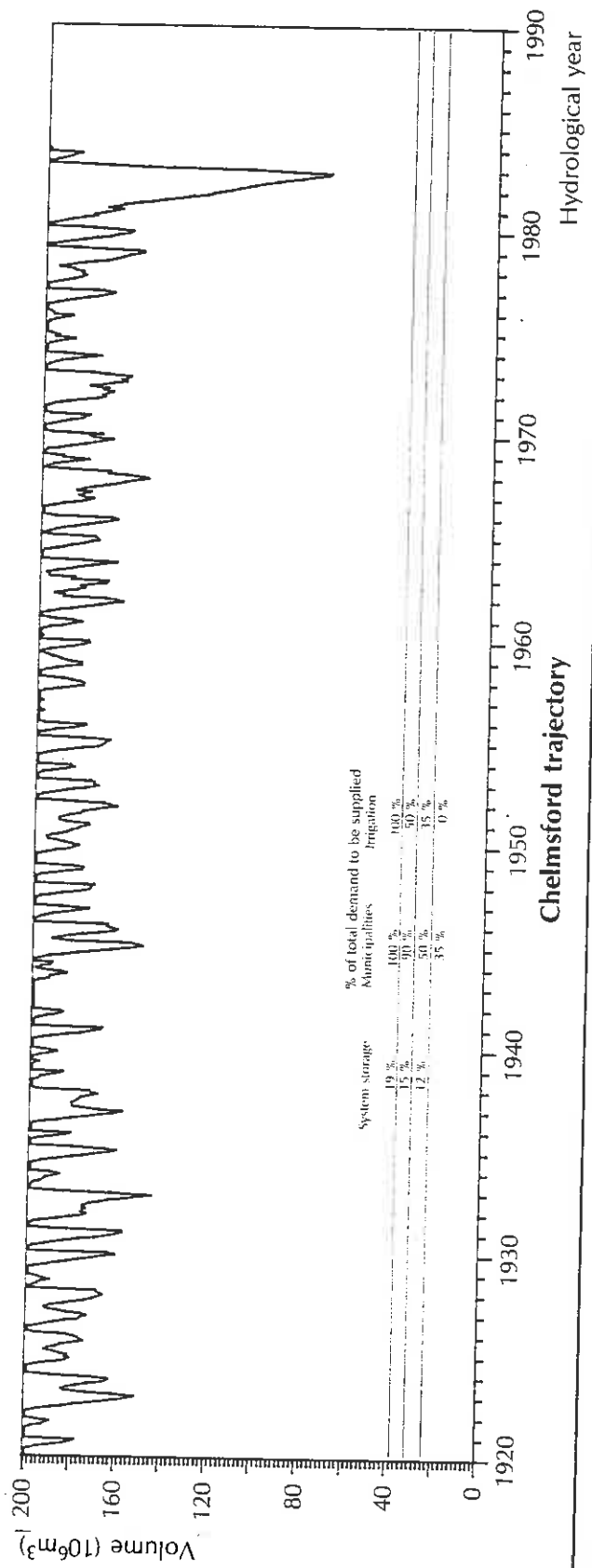
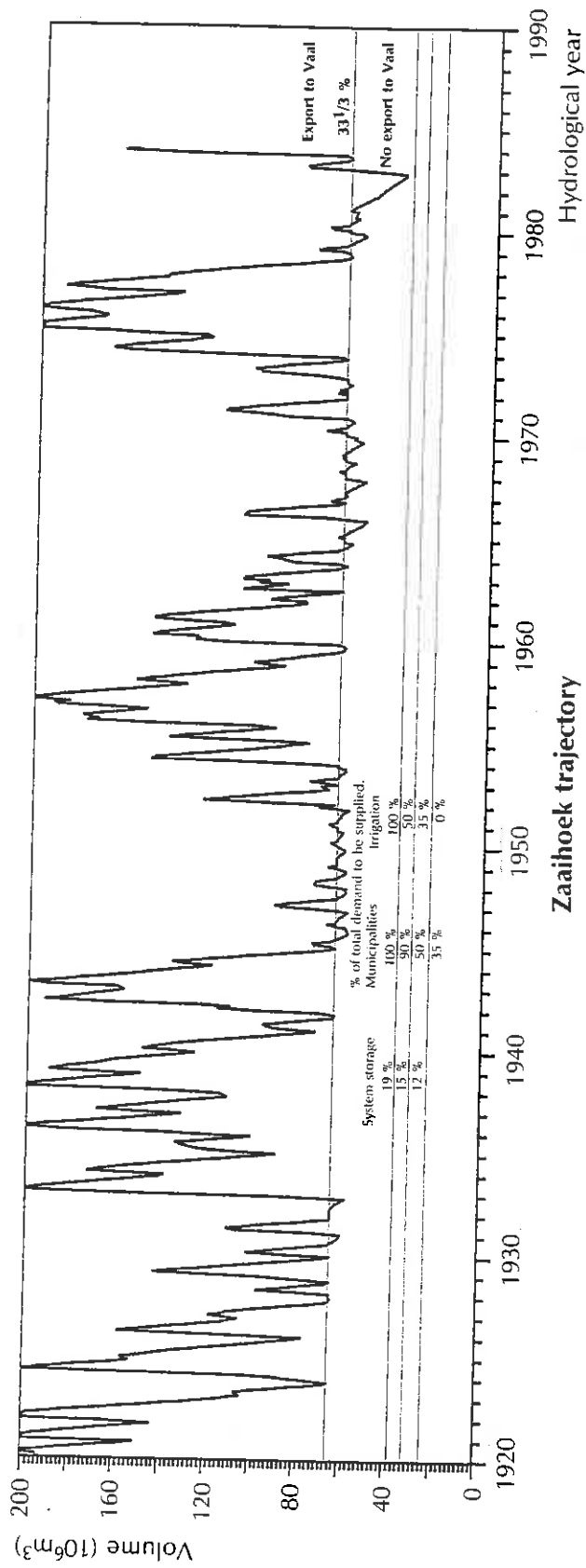
The weir is very efficient during periods of low streamflow, and the potential exists to extract more water from the weir, since the maximum daily demand (current diversion capacity) is very small compared to the mean annual inflow from the upstream catchment.

4.3 ANALYSIS OF EXISTING OPERATING POLICY

A historic yield analysis was performed on the Buffalo-Vaal subsystem using the subsystem yield simulation model with the existing operating policy. The simulation yield analysis investigates the drawdown trajectories of the dams in the Buffalo-Vaal subsystem when subjected to the 1985 demand levels with restrictions imposed according to the proposed DWA. operating policy. The yield analysis uses the net basin runoff obtained from historic hydrology.

The definition of the existing operating policy does not allow an analysis of the firm yield to be conducted, but is rather aimed at evaluating the validity and effectiveness of this operating strategy. At the current (1985) levels of municipal demand, however, no support of the NRCWS is required from the Zaaihoek Dam, leaving the results of this part of the analysis as rather inconclusive.

Figure 7 indicates that the restriction placed on the transfer of water to the Vaal from Zaaihoek results in significant conservation of water and ensures a continuous supply of water to Majuba from Zaaihoek throughout the drought sequence. Nothing is achieved by the restrictions placed on municipal users, because they do not in fact become effective. The 1983 critical sequence for Chelmsford does not result in any restrictions because of its surplus storage.



Since the primary aim of the subsystem analysis is to obtain the yield characteristics of the subsystem with respect to the influence thereof on the transfer of water to the Vaal system, the existing operating policy was not analysed further.

4.4 COMBINED SUBSYSTEM YIELD ANALYSIS

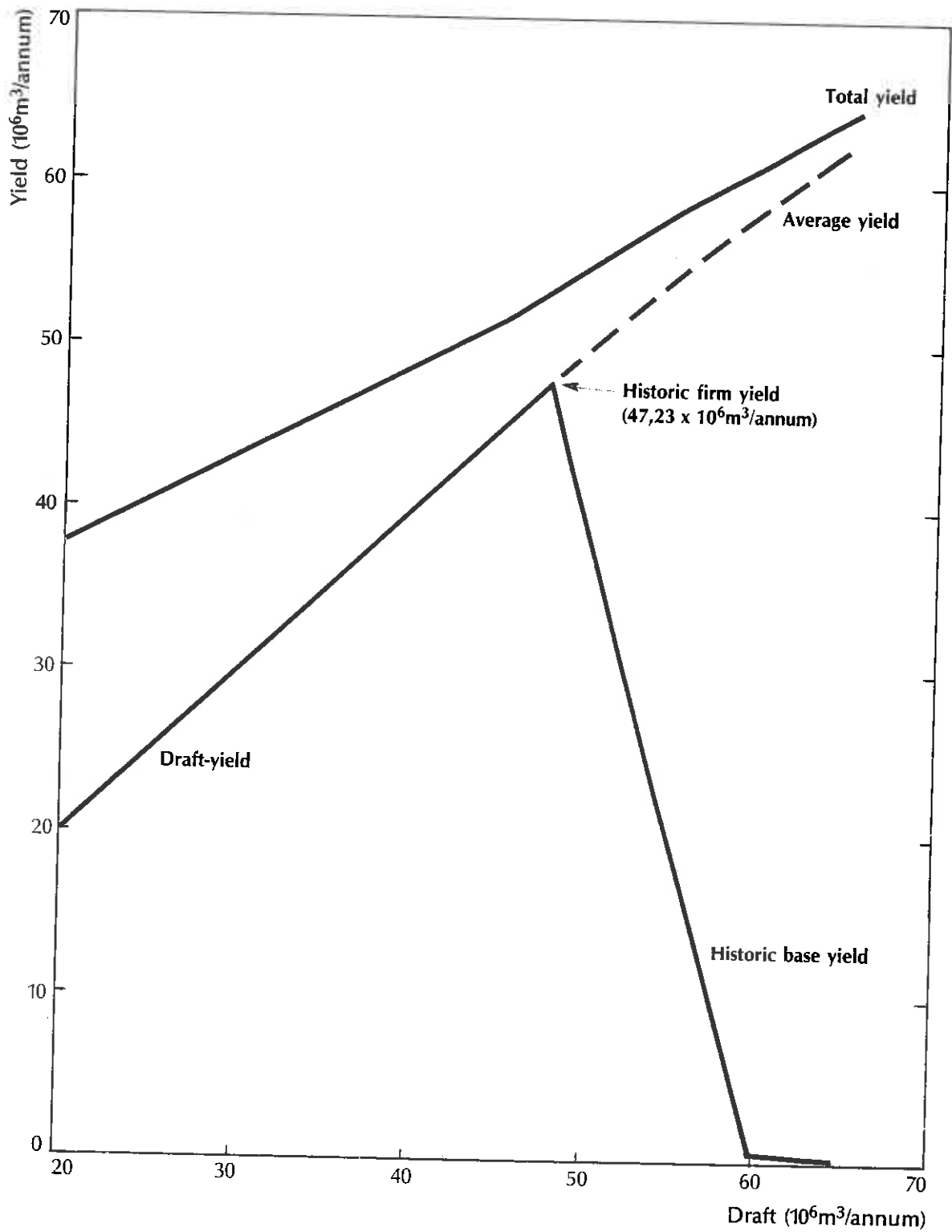
An operating policy defining the relative priorities for the supply from the different sources of the combined subsystem, namely the Zaaihoek Dam and Chelmsford Dam, was adopted as an initial operating policy. The Newcastle complex is supplied from Schurvepoort, Roy Point, Chelmsford and supplemented from the Zaaihoek Dam when this is required.

This policy was tested using both the simulation model and the optimization model and the results were compared to determine which policy best emulated the desired behaviour of the system in the simulation analysis. The results from both models indicate that the Chelmsford and Zaaihoek Dams act as independent reservoirs at the 1985 demand levels and that no support is required from Zaaihoek to Chelmsford. This will only hold true over the short to medium term as long as Chelmsford can fully supply all the demands from Newcastle. Once these demands exceed the yield-reliability capabilities of Chelmsford Dam, the total Buffalo-Vaal subsystem again becomes one interdependent unit.

4.4.1 Historic Yield Analysis

A historic yield analysis was performed on the Buffalo-Vaal subsystem using the subsystem yield simulation model. The simulation yield analysis investigates the firm yield and the average annual yield of the Buffalo-Vaal subsystem over a range of annual target drafts. The results of the historic yield analysis are illustrated in Figure 8.

MAR (Zaaihoek Dam) = $89,7 \times 10^6 \text{ m}^3 / \text{annum}$



A historic firm yield of $47,2 \times 10^6 \text{ m}^3$ per annum for the Buffalo-Vaal subsystem was obtained, this being the resultant yield after specified demands and compensation releases have been satisfied (refer to paragraph 3.2 and Figure 2). The annual total yield at a target draft of $47,2 \times 10^6 \text{ m}^3$ per annum is $54,0 \times 10^6 \text{ m}^3$ per annum. The total yield includes water supply above the target draft when the subsystem is in a spillage mode.

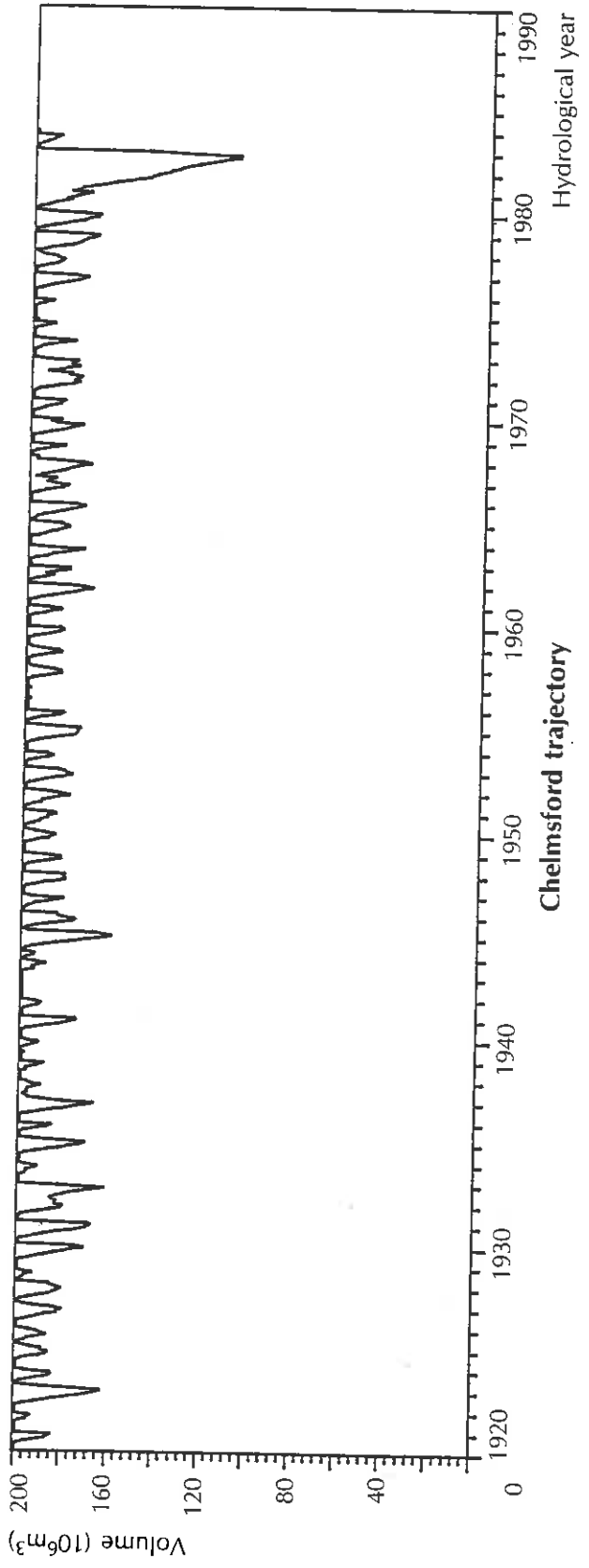
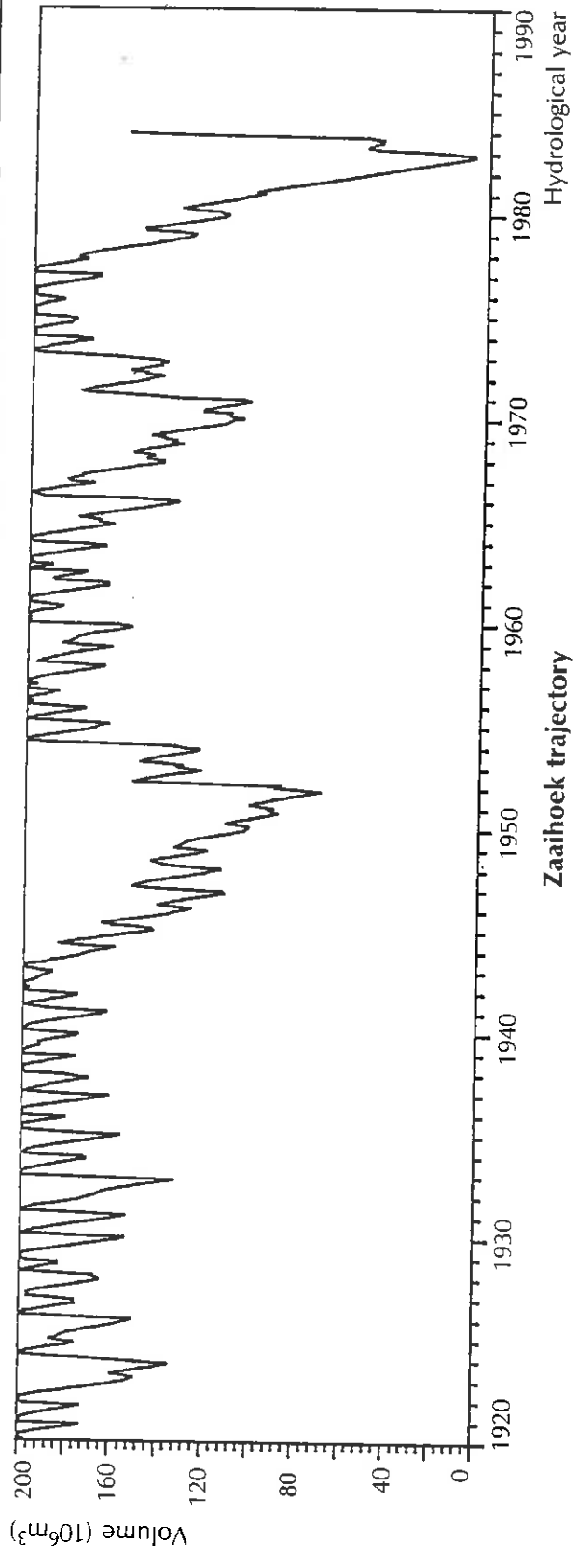
Figure 9 gives the volume of the reservoirs during the analysis of the historic hydrology subject to a target draft of $47,2 \times 10^6 \text{ m}^3$ per annum. It can be seen that the 1983 hydrological year gives the lowest reservoir drawdown for both the Zaaihoek and Chelmsford Dams. Zaaihoek fails during the 1983 hydrological year while Chelmsford is above 50 % of its capacity in the same year.

4.4.2 Optimization analysis

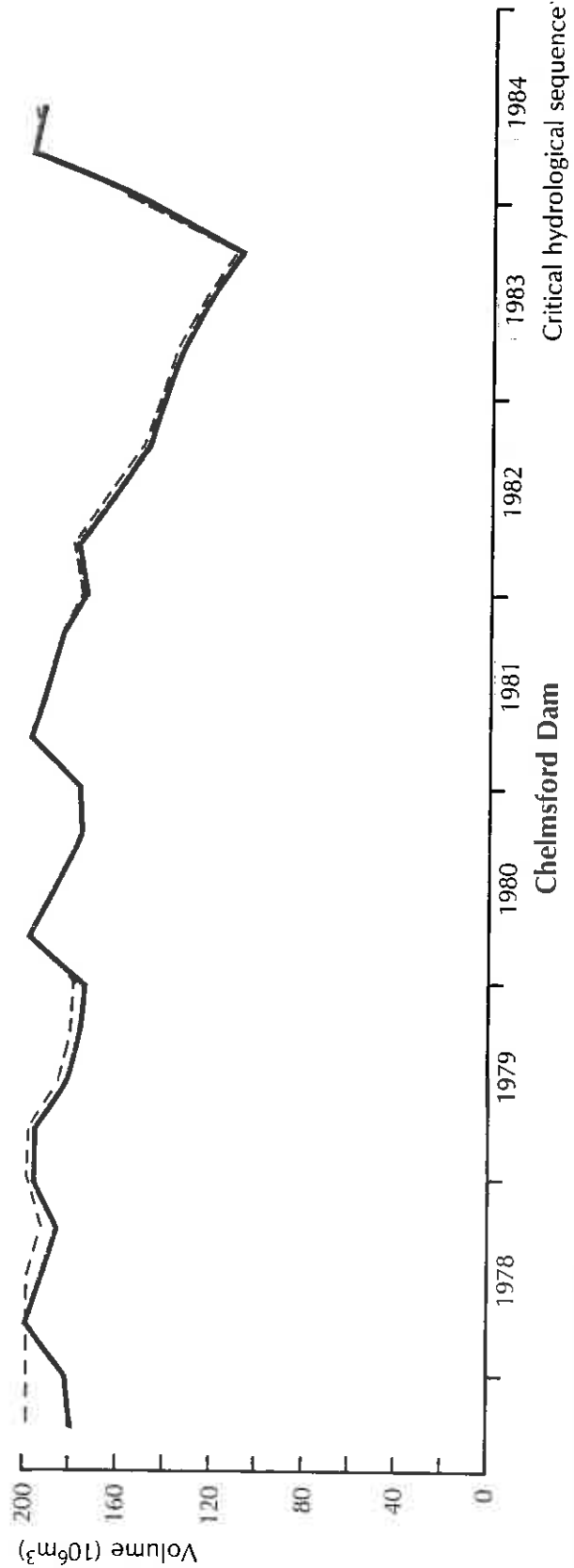
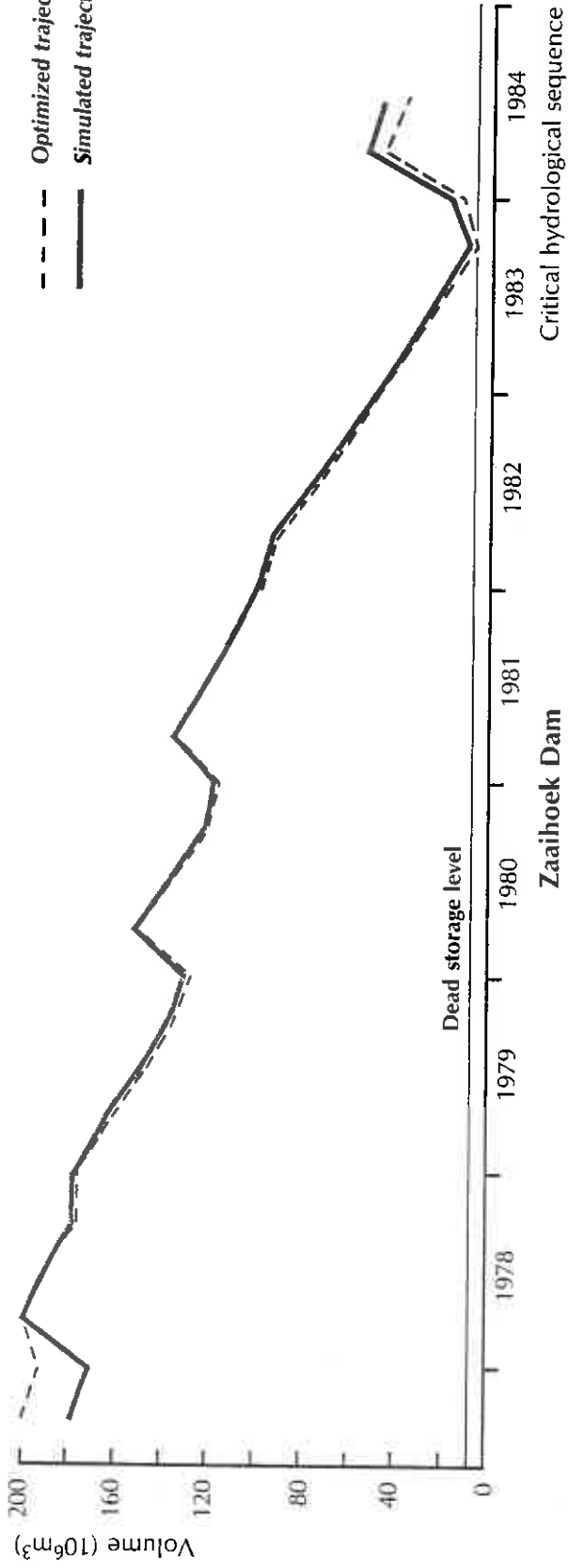
A dynamic programming optimization analysis was performed on the Buffalo-Vaal subsystem. The optimization yield analysis evaluates the optimal firm yield and reservoir drawdown patterns for the selected hydrologic sequences.

A critical historic hydrologic sequence was selected from preliminary simulation results. The hydrologic period from 1977 to 1983 was analysed using the optimization yield analysis model.

A comparison of the optimization results with the simulation results using the selected operating strategy is presented in Figure 10. The figure compares the reservoir drawdown trajectories of the optimal and simulated results over the critical hydrologic sequence. The simulation trajectories presented are for the operating strategy discussed in the previous section.



- - - Optimized trajectory
 — Simulated trajectory



The optimal firm yield was evaluated as $48,4 \times 10^6 \text{ m}^3$ per year (for the 1983 critical hydrological sequence) again subject to certain specified demands such as for Newcastle.

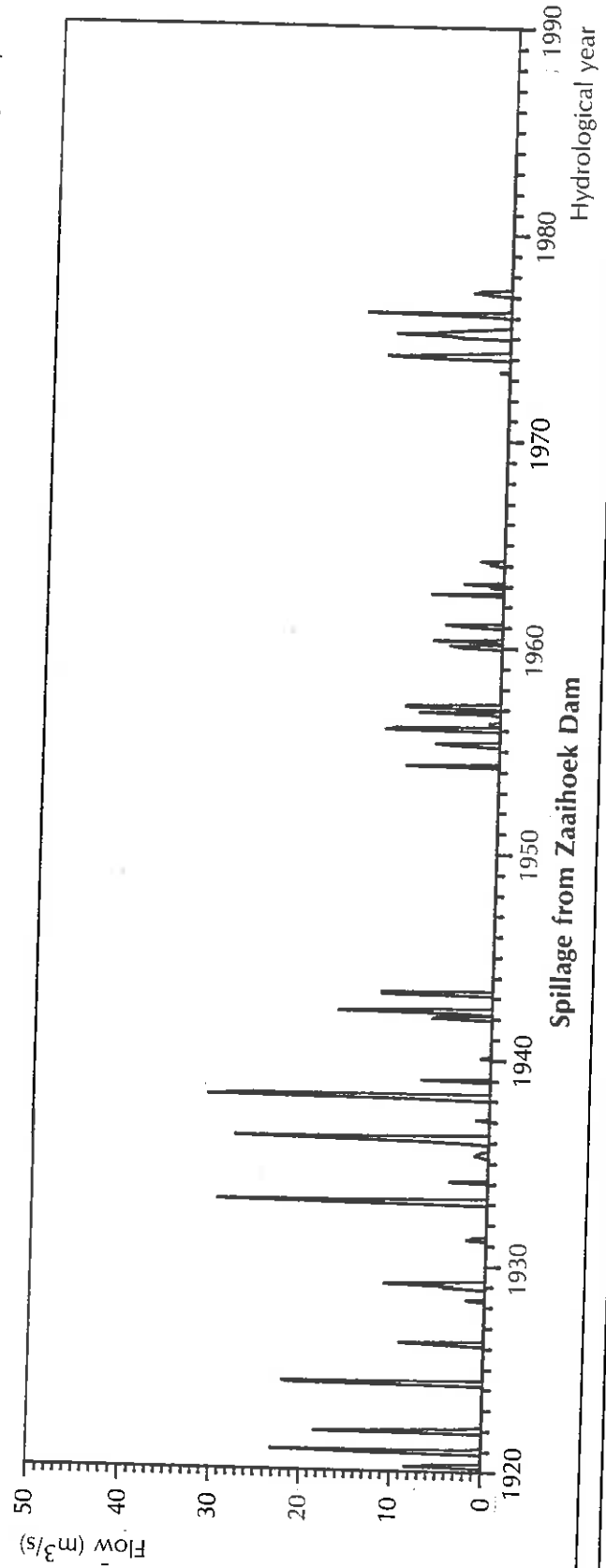
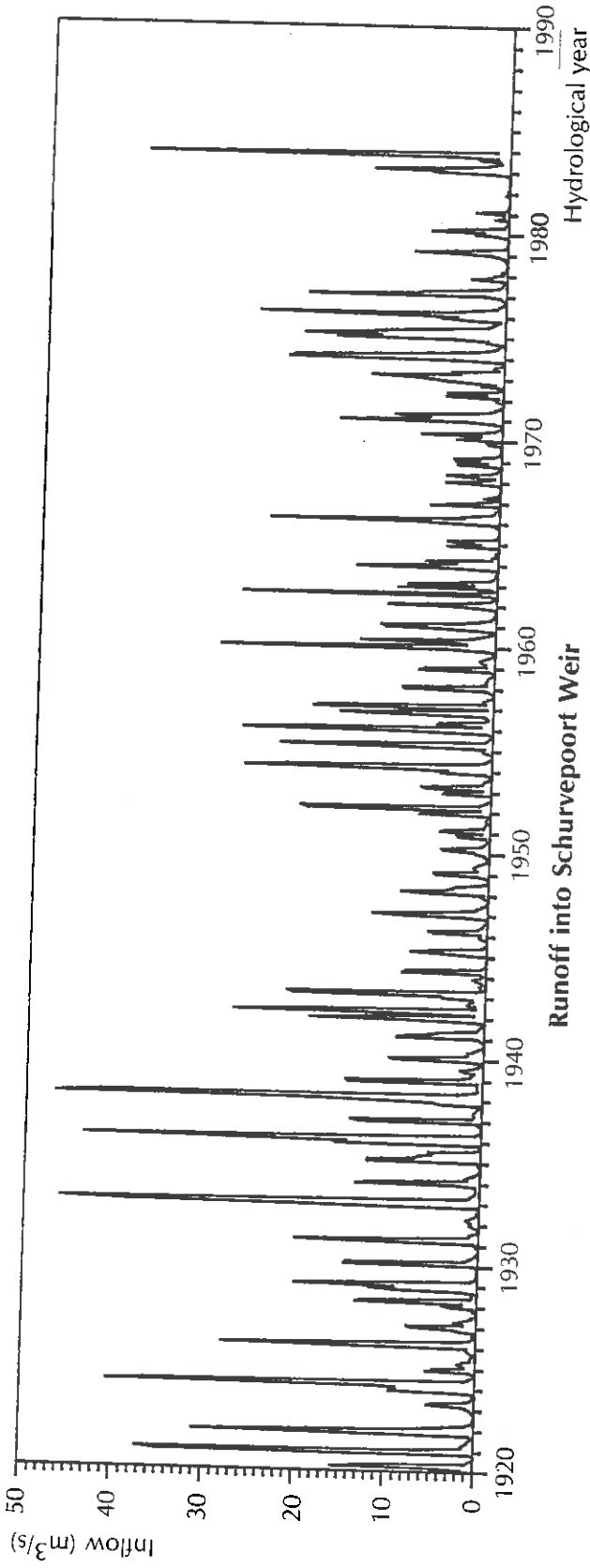
The comparison of the drawdown patterns of the two reservoirs illustrates that the optimal drawdown pattern is essentially the same as the simulated drawdown pattern for the selected operating strategy. The small differences that occur between the trajectories can be attributed to the fact that the dynamic programming analysis uses three month time periods whereas the simulation analysis uses one month time periods. The trajectories follow the drawdown pattern expected from a single reservoir operation for both Chelmsford and Zaaihoek Dams.

4.4.3 Division of Subsystem

Figure 11 illustrates the natural inflow into the Schurvepoort Weir and spillage from the Zaaihoek Dam, which indicates that the Newcastle complex draws no support from the Zaaihoek Dam. The trajectories obtained from the optimization analysis presented in Figure 10 confirm the single reservoir operation of the subsystem.

The preliminary analyses indicate that Chelmsford can be dedicated to the supply of the Newcastle complex thus allowing Zaaihoek to be dedicated to the supply of Majuba power station and Volksrust. As already described, this strategy is subject to change due to growth in demand at Newcastle.

The results of Zaaihoek Dam analysed on its own are shown in Section 4.5 and those for Chelmsford which was analysed in lesser detail are shown in Section 4.6. The emphasis is placed on the Zaaihoek Dam since it is the only part of the subsystem that can be used to transfer water to the Vaal System. The importance of the Chelmsford Dam in the



subsystem arises from the fact that Zaaihoek might have to be used to supplement Chelmsford in the future, thereby reducing the amounts that can be transferred to the Vaal System. This may only occur in about five years time.

4.5 ZAAIHOEK DAM YIELD ANALYSIS

Due to the current independence of the Zaaihoek and Chelmsford Dams and because Chelmsford does not yet require any support from Zaaihoek, it is possible to eliminate Chelmsford from the active system. All the results given in this section relate to Zaaihoek Dam only and are synonymous with those of the active part of the Buffalo-Vaal system.

4.5.1 Historic Yield Analysis

A historic yield analysis was performed on the Zaaihoek Dam using the subsystem yield simulation model. The simulation yield analysis investigates the firm yield and the average annual yield over a range of annual target drafts.

Because of the definition of the yield channel (as in Figures 2 and 4 and paragraph 3.2), the historic firm yield for the Zaaihoek Dam is the same as for the complete Buffalo-Vaal subsystem at $47,2 \times 10^6 \text{ m}^3$ per annum. The annual total yield at a target draft of $47,2 \times 10^6 \text{ m}^3$ per annum is $54,0 \times 10^6 \text{ m}^3$ per annum. The total yield includes supply above the target draft when the subsystem is in a spillage mode.

The yield of $47,2 \times 10^6 \text{ m}^3/\text{annum}$ (plus $6,36 \times 10^6 \text{ m}^3$ compensation flow) obtained for the Zaaihoek Dam in this analysis can be compared to the net firm yield of $61,4 \times 10^6 \text{ m}^3/\text{annum}$ published in WP E-86. The yield in the white paper was however, obtained from a MAR of $125 \times 10^6 \text{ m}^3$ compared to the MAR of $89,7 \times 10^6 \text{ m}^3$ used in this study.

Figure 12 shows the historic yield characteristics for the Zaaihoek Dam, and is the same as Figure 8.

4.5.2 Stochastic Yield Characteristics

A stochastic yield analysis was performed on the Zaaihoek Dam using the subsystem yield simulation model. This simulation analysis investigates the stochastic nature of the firm yield and annual average yield of the Zaaihoek Dam. Both long-term and short-term projection periods of 64 years and 5 years respectively were investigated. The inflow hydrology was derived using the stochastic streamflow generator.

4.5.2.1 Long-Term Stochastic Yield Analysis

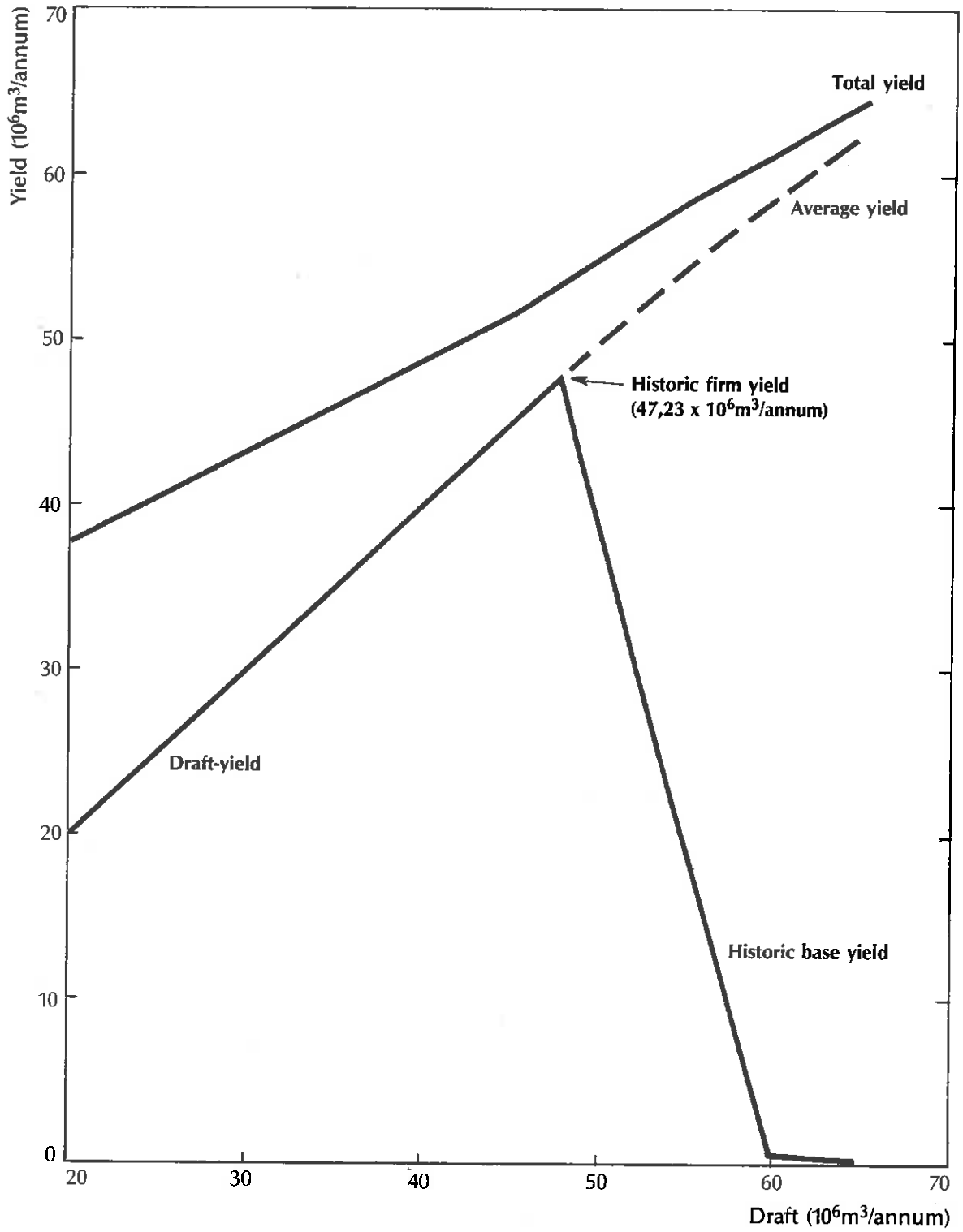
The results of the long-term stochastic yield analysis for five target drafts are presented in Figure 13 and Table 9.

Figure 14 shows a family of deterministically generated long-term yield-reliability curves. Refer to Appendix C for details of the coefficients of the equations of these curves.

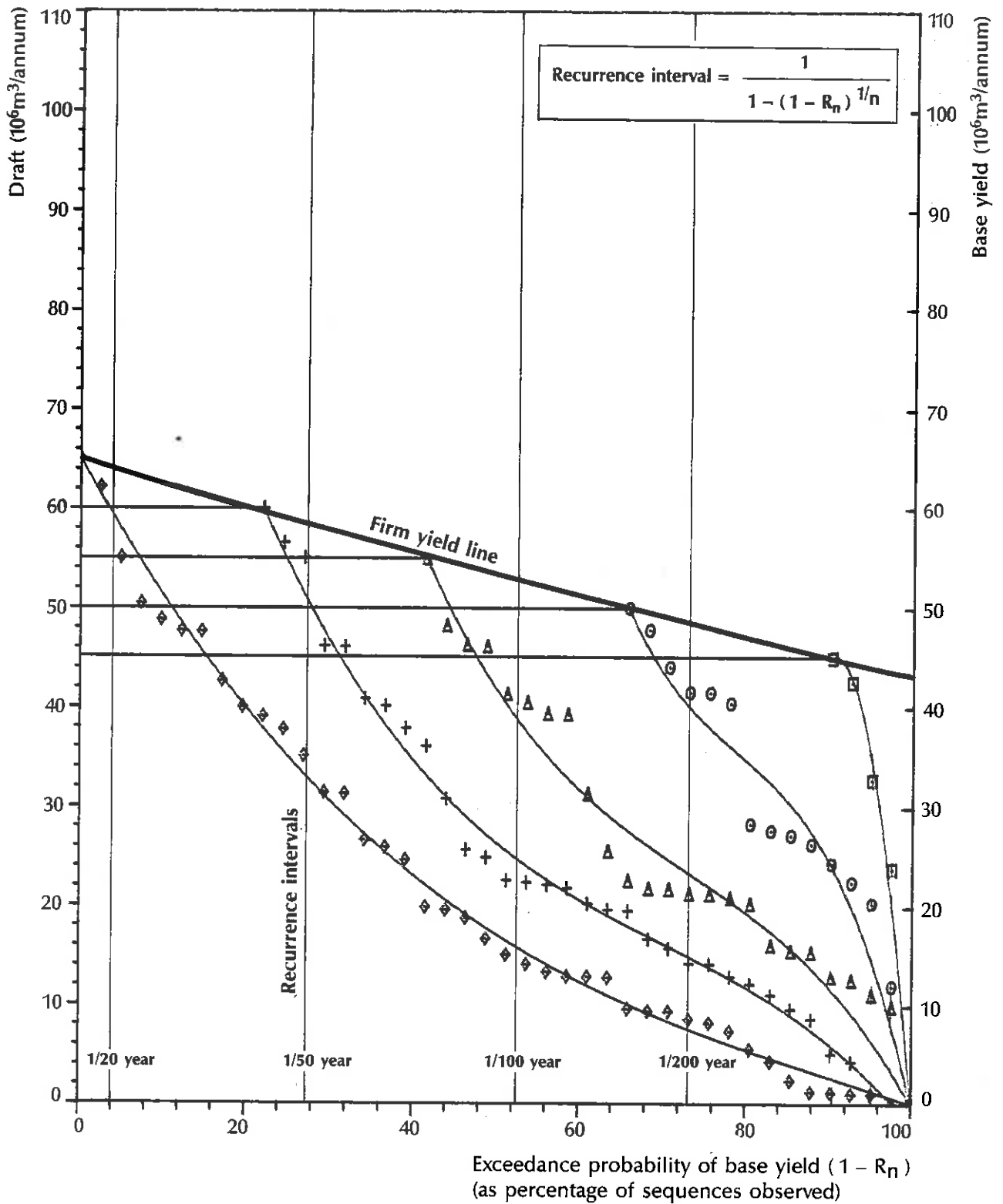
TABLE 9: RESULTS OF LONG-TERM STOCHASTIC YIELD ANALYSIS FOR THE ZAAIHOEK DAM

FIRM YIELD FOR INDICATED RECURRENCE INTERVAL ($10^6 \text{ m}^3/\text{annum}$)				
1:20 yr	1:50 yr	1:100 yr	1:200 yr	Historic
64,0	58,0	52,0	48,0	47,2

MAR (Zaaihoek Dam) = $89,7 \times 10^6 \text{ m}^3 / \text{annum}$



Reliability of base yield derived from
41 64-year generated sequences



Reliability of base yield derived from
41 64-year generated sequences

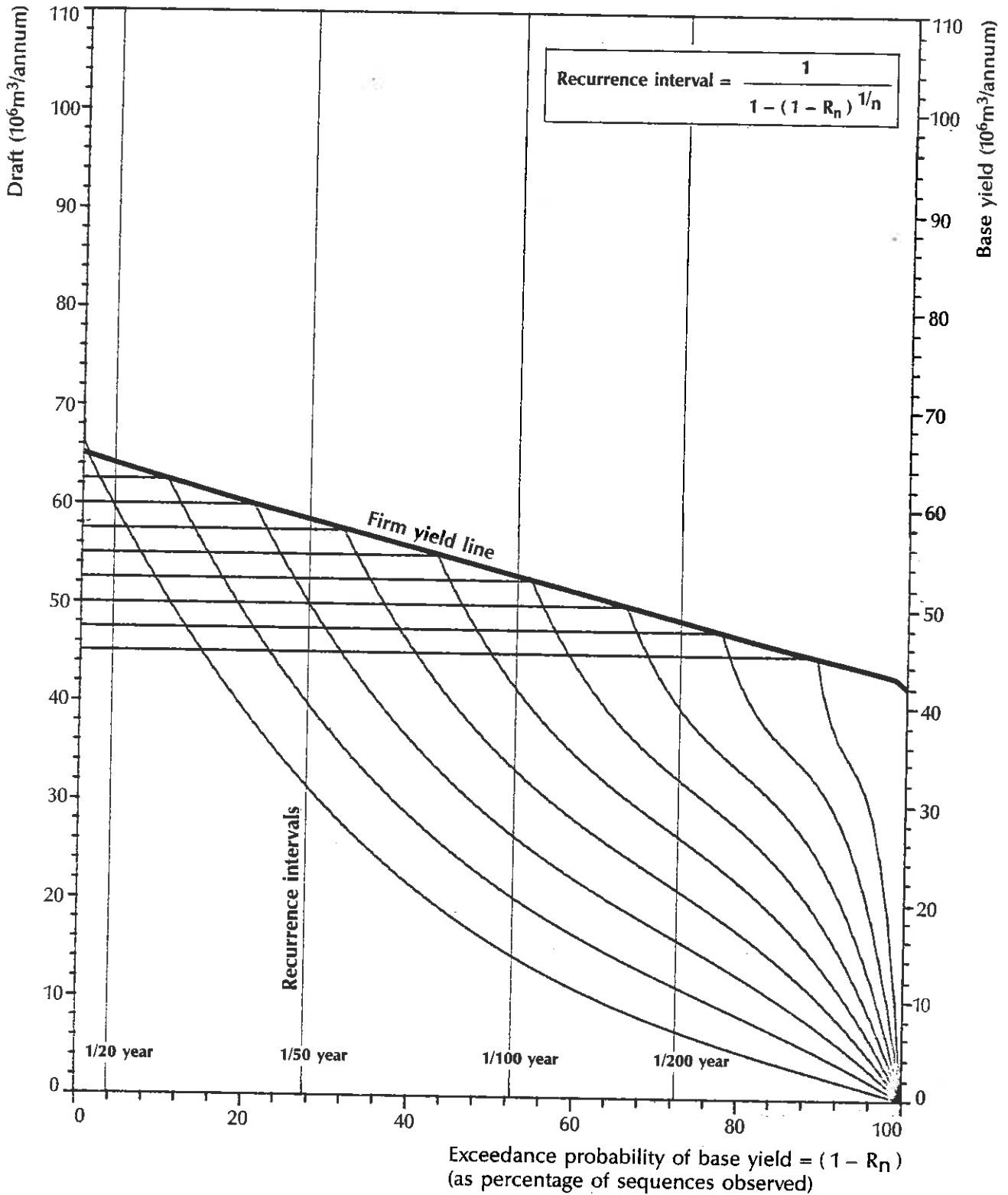
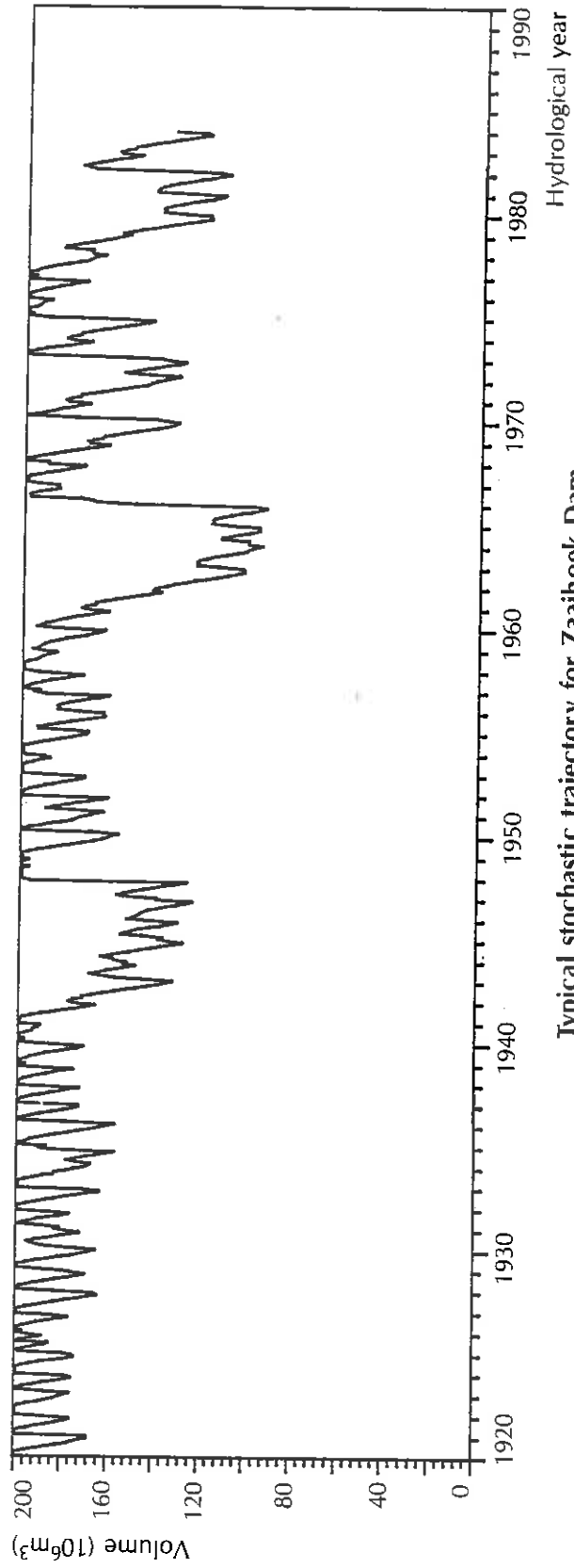
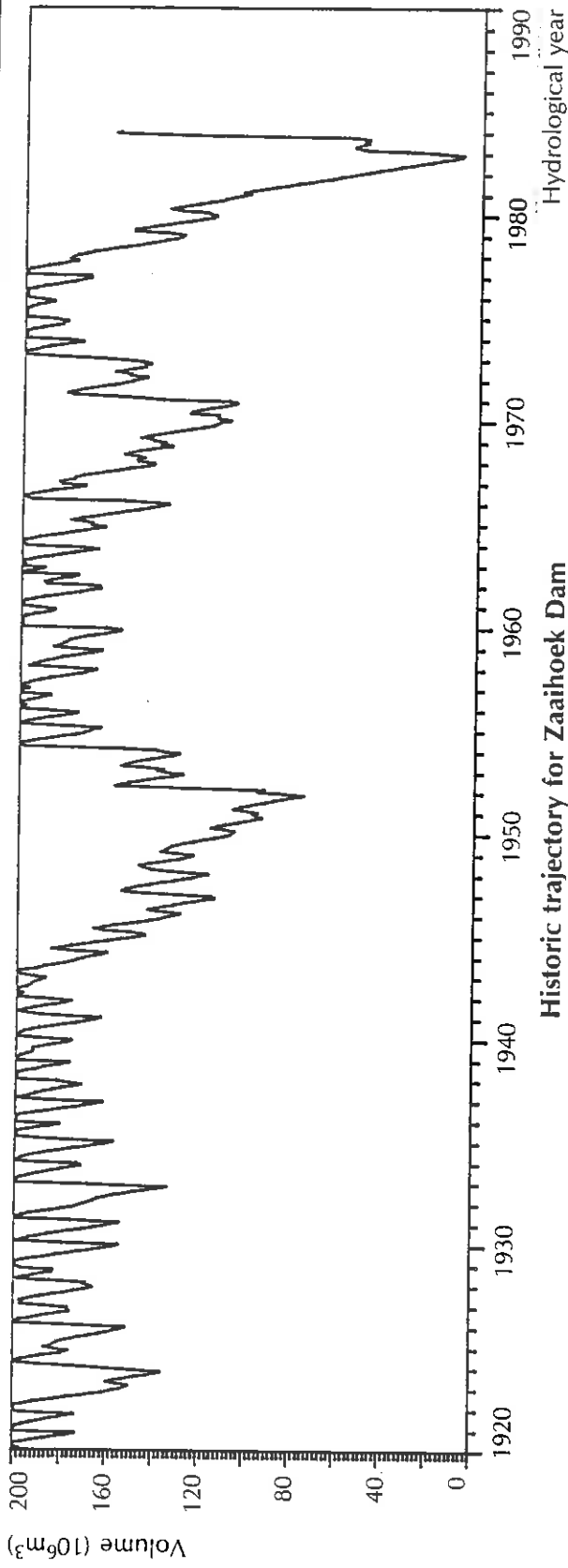
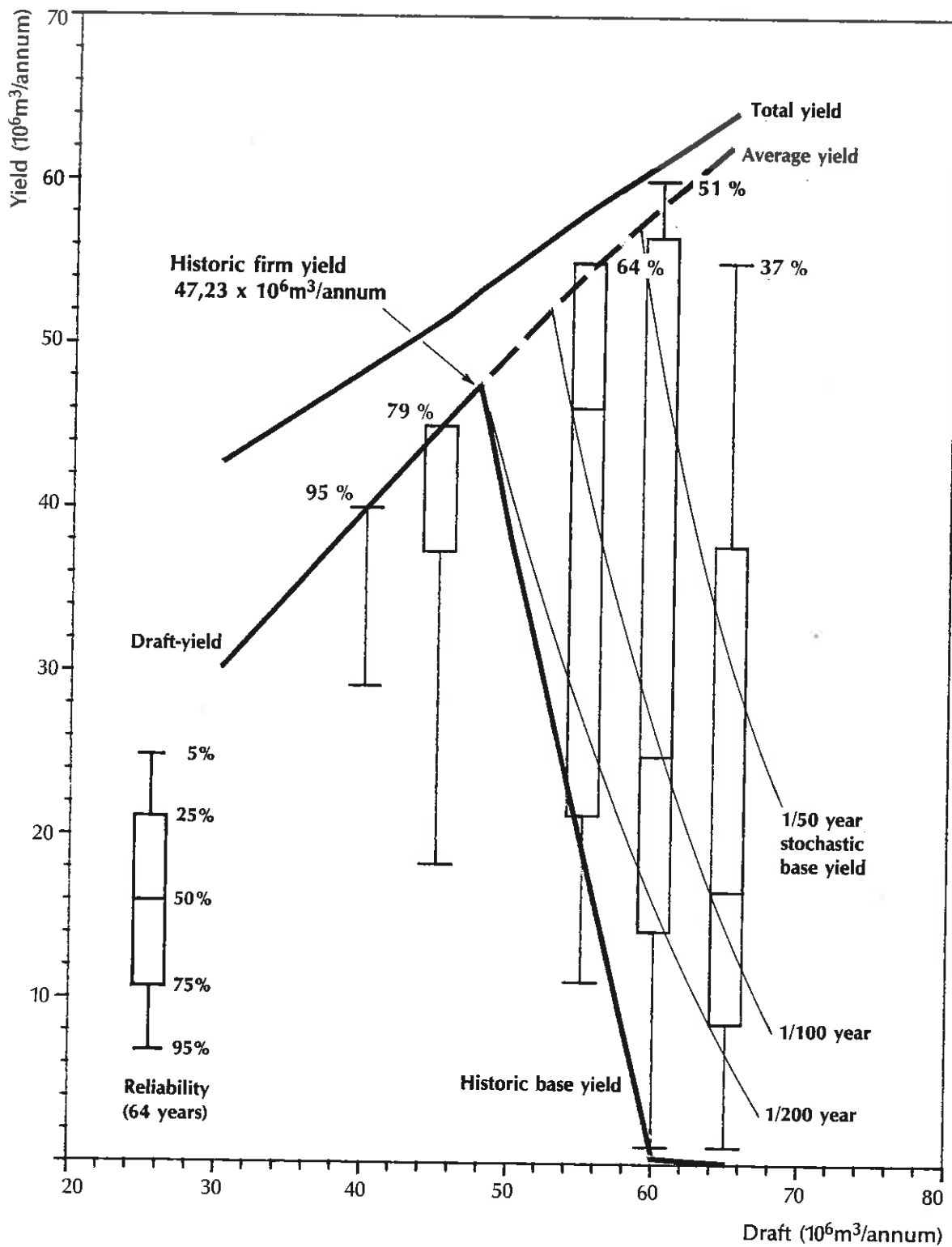


Figure 15 gives a comparison of the reservoir trajectories resulting from the historical natural streamflow and a typical stochastically generated streamflow record. It can be seen that the stochastic sequence results in a reservoir trajectory that has the same pattern as that of the historic trajectory.

Figure 16 shows a comparison of the stochastic yield analysis with that of the historic analysis for Zaaihoek Dam.





4.5.2.2 Short-Term Stochastic Yield Analysis

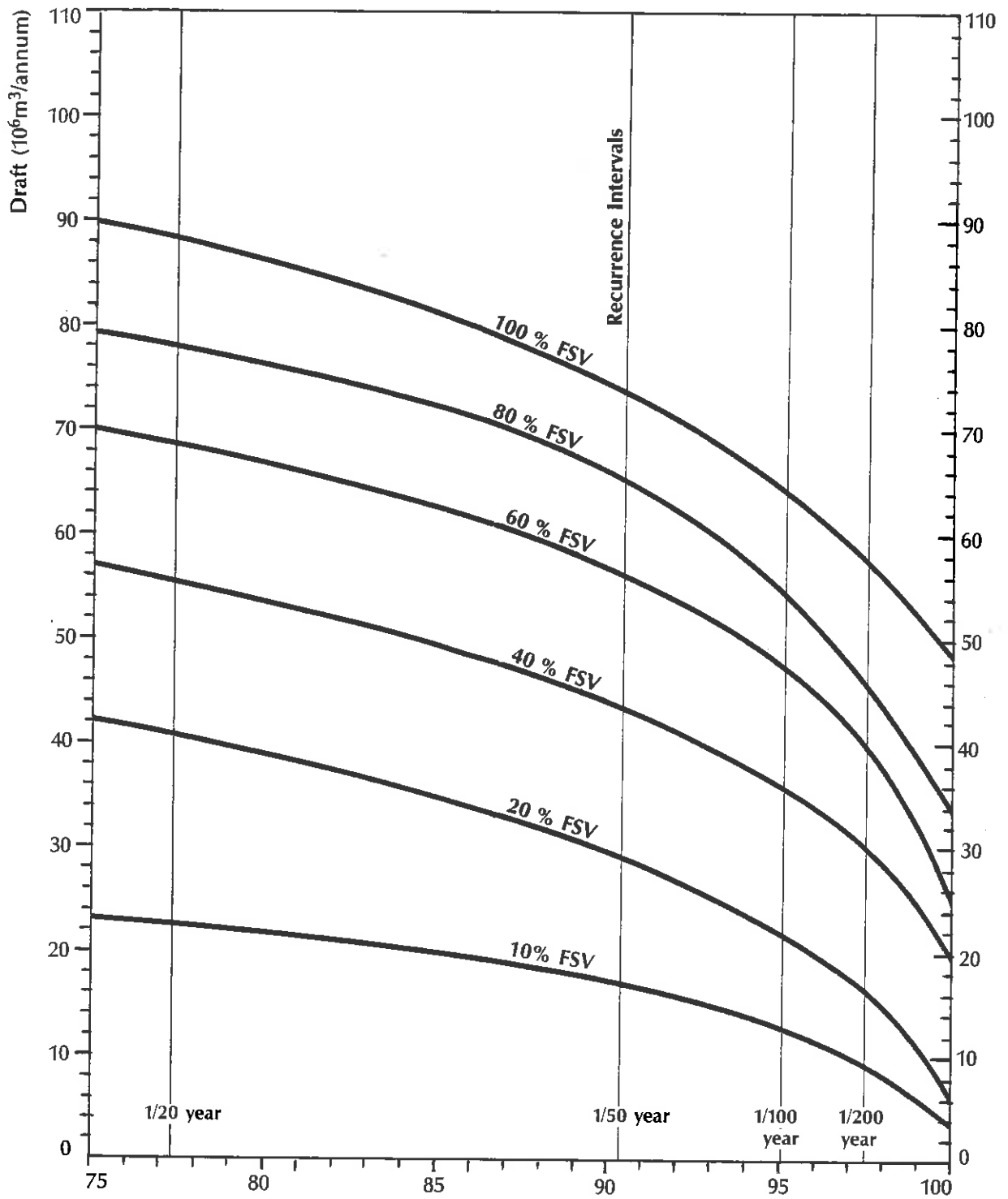
The results of the short-term stochastic yield analysis are presented in Figures 17 - 23. The Zaaihoek Dam partial subsystem was analysed for system start volumes of 100 %, 80 %, 60 %, 40 %, 20 % and 10 % of full supply capacity. The figures illustrate the family of curves for each system start volume.

The salient results from the family of curves are presented in Table 10. The coefficients of the curves used to generate the short-term stochastic family of curves, for each system start condition, are presented in Appendix C, C3.

TABLE 10: RESULTS OF SHORT-TERM STOCHASTIC ANALYSIS

SYSTEM START VOLUME AS PERCENTAGE OF FULL SUPPLY CAPACITY	FIRM YIELD FOR INDICATED RECURRENCE INTERVAL ($10^6\text{m}^3/\text{annum}$)			
	1:20 yr	1:50 yr	1:100 yr	1:200 yr
100 %	88,0	73,5	64,5	57,0
80 %	78,0	65,5	54,5	45,5
60 %	68,0	56,5	47,5	40,0
40 %	55,0	43,	36,0	30,0
20 %	41,0	29,0	22,0	17,0
10 %	22,5	17,0	13,0	9,0

Reliability of firm yield derived from
201 5-year generated sequences

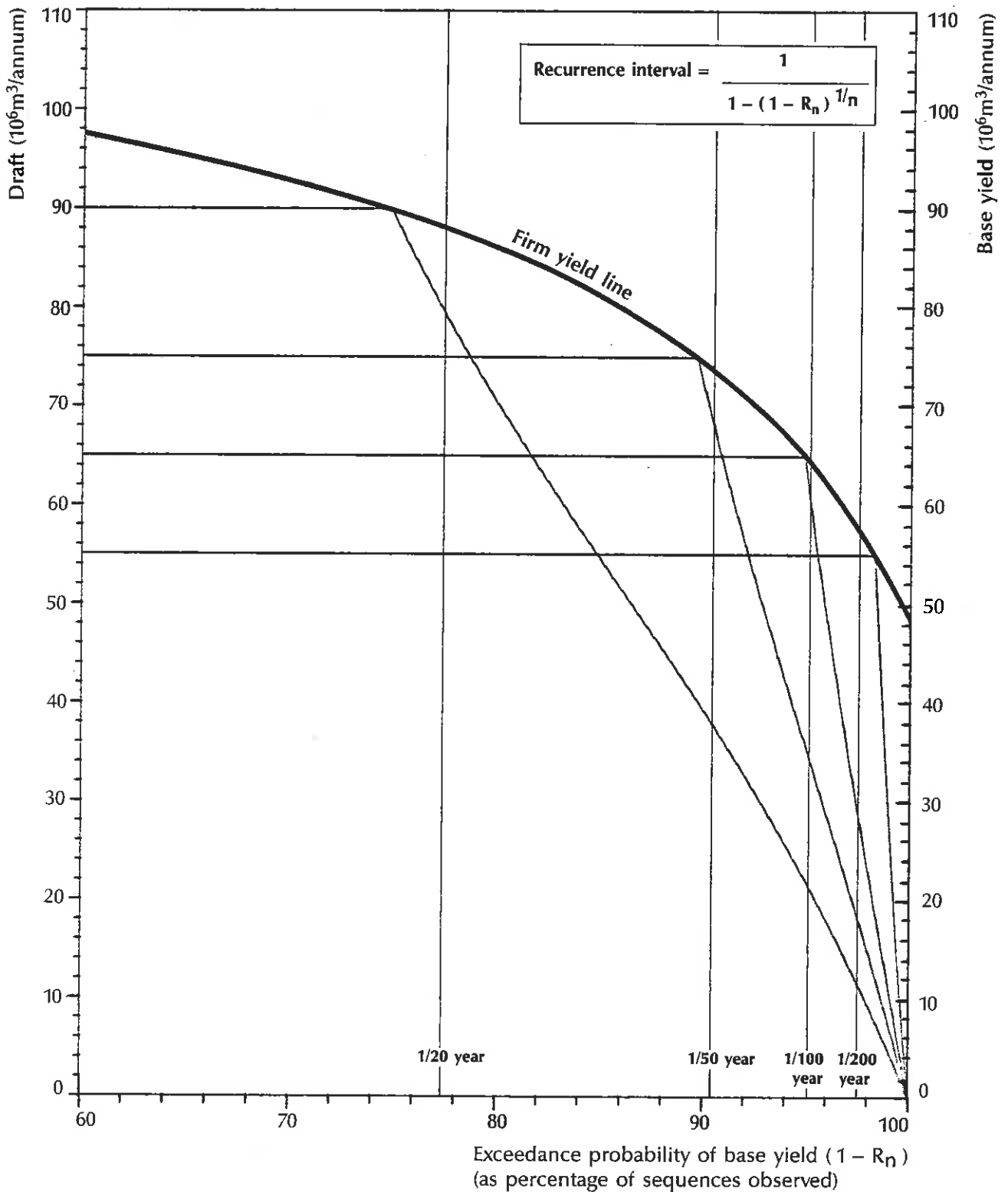


Note:
The curves represent the firm yield lines
for a system start at the full supply volume
percentages indicated

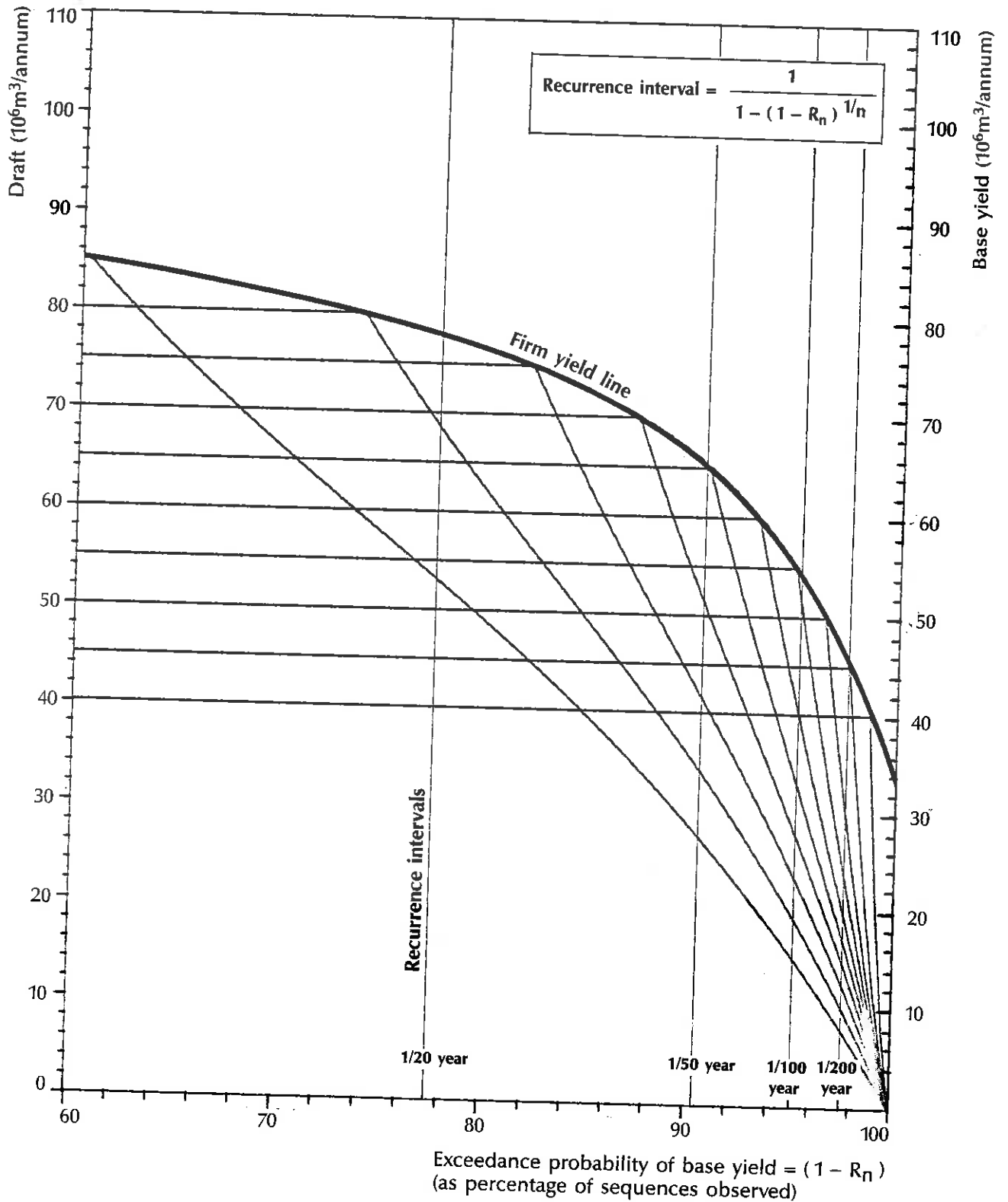
Exceedance probability of base yield
(as percentage of sequences observed)



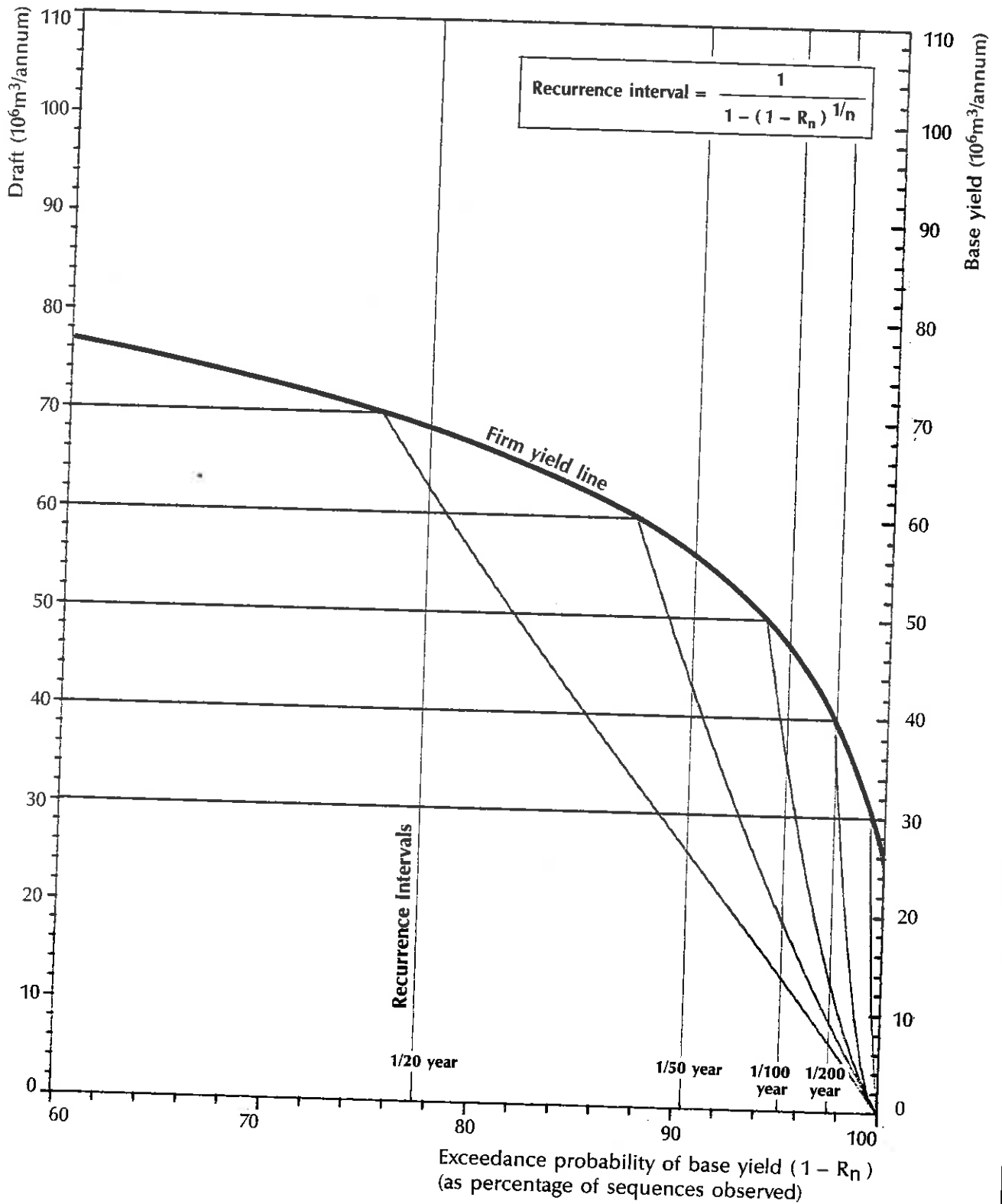
Reliability of base yield derived from
201 5-year generated sequences



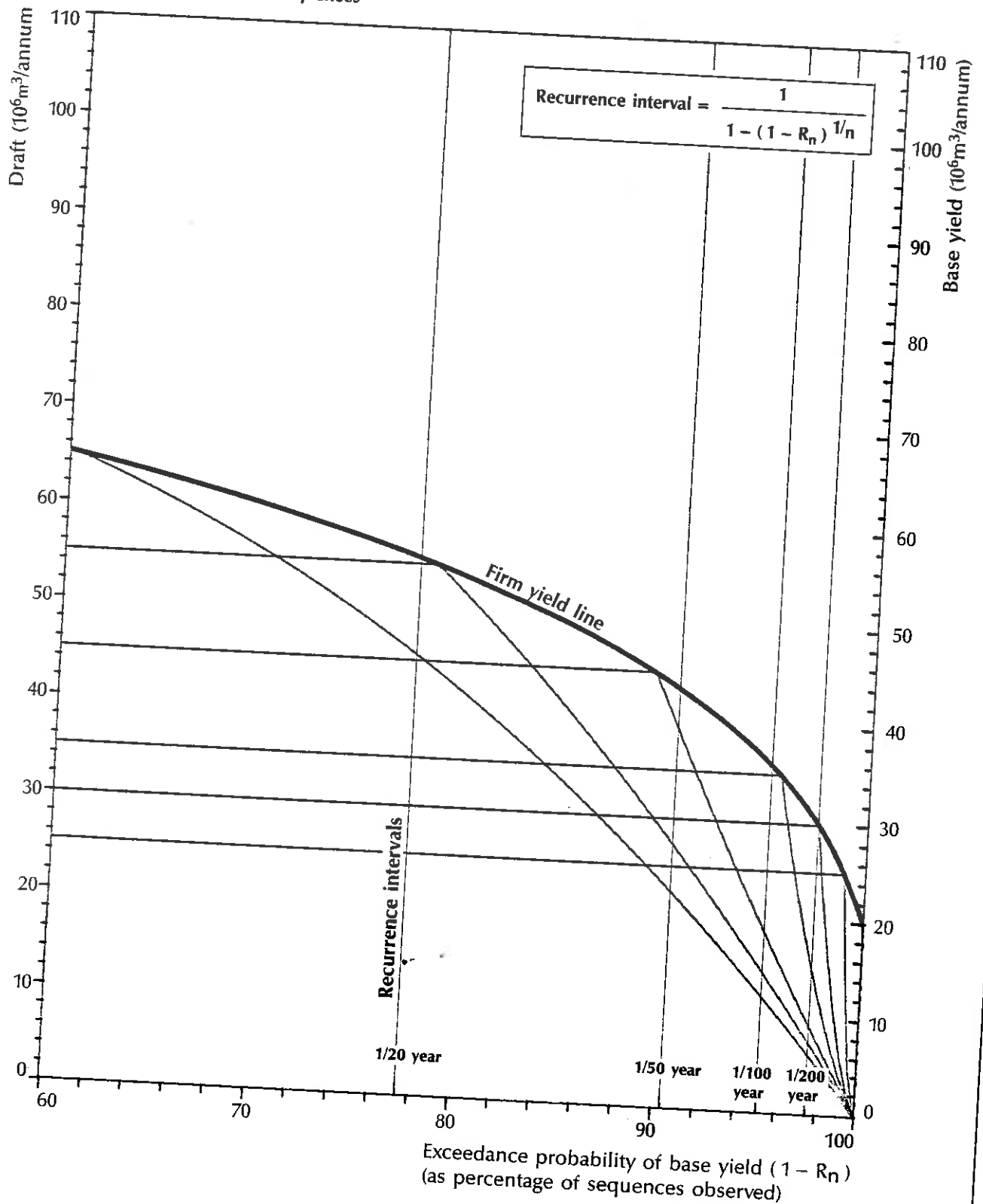
Reliability of base yield derived from
201 5-year generated sequences



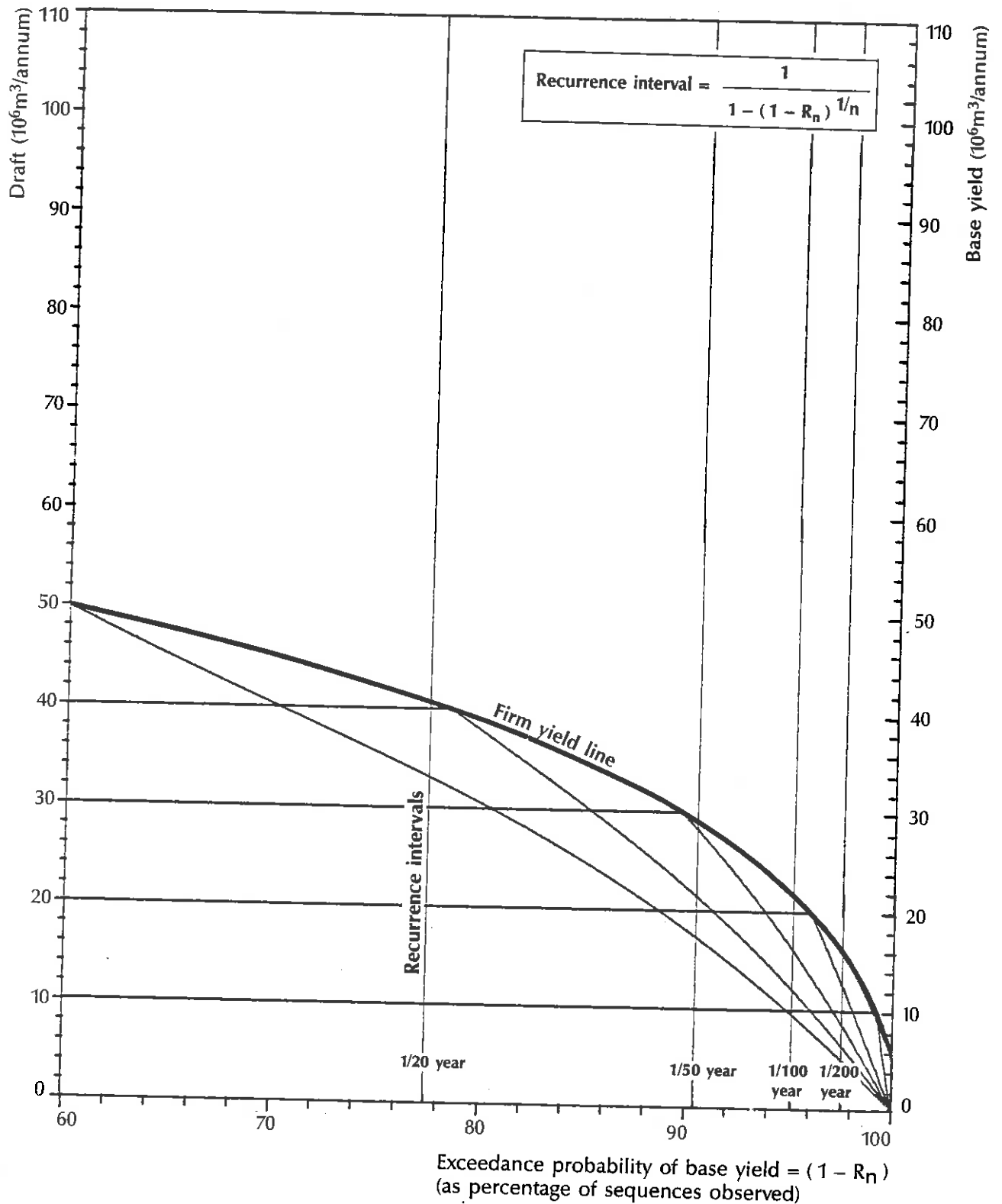
Reliability of base yield derived from
201 5-year generated sequences



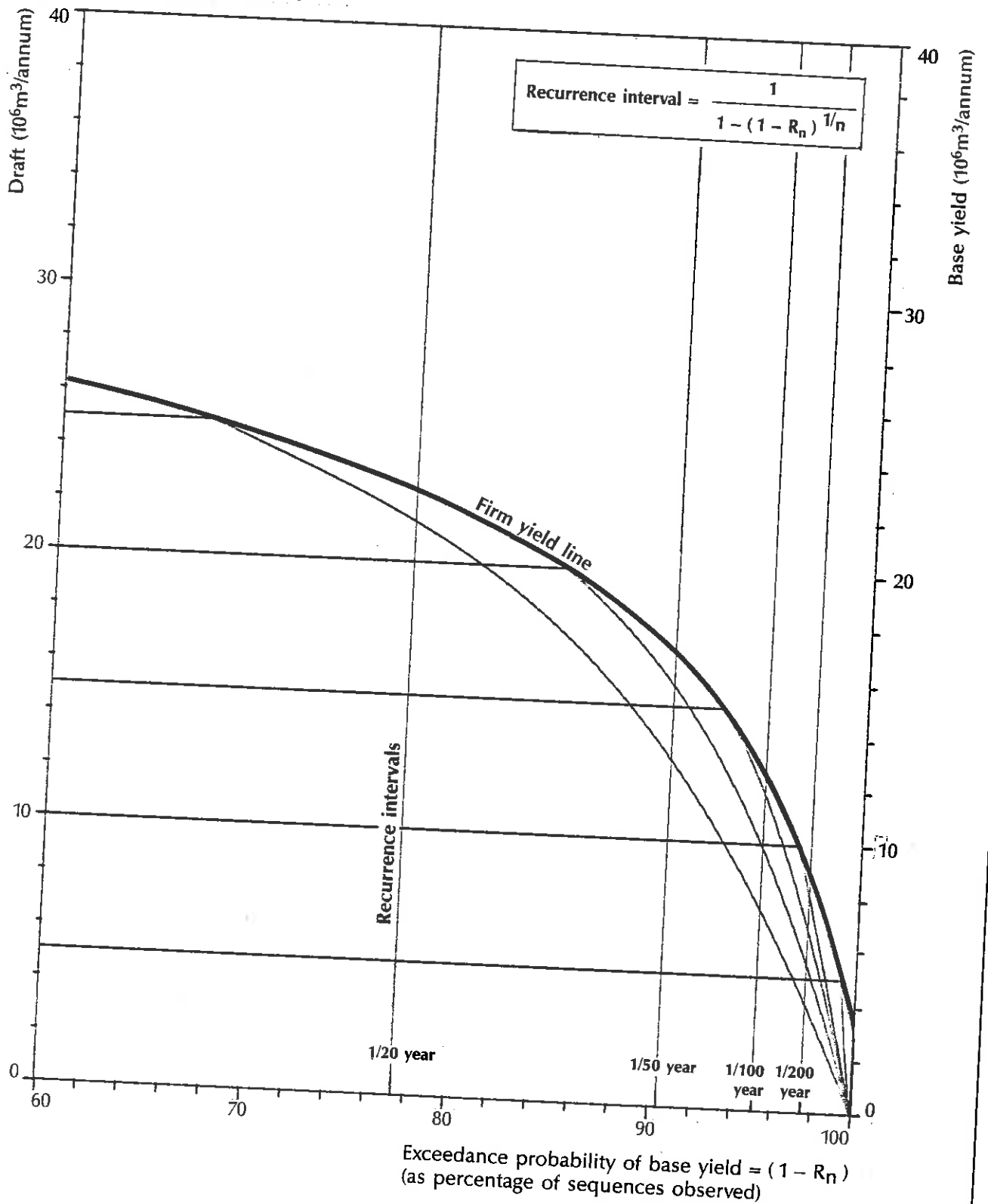
Reliability of base yield derived from
201 5-year generated sequences



Reliability of base yield derived from
201 5-year generated sequences



Reliability of base yield from
201 5-year generated sequences



4.6 CHELMSFORD DAM YIELD ANALYSIS

Interim results of the Buffalo-Vaal subsystem study have led to the Chelmsford Dam being identified as currently independent of the Zaaihoek Dam and its yield being allocated solely for use within the Newcastle Complex.

The purpose of further analysis of the Chelmsford subsystem is to determine its yield for long-term planning purposes. This information is required to determine the magnitude and timing of any support Chelmsford may require or, alternatively, give.

4.6.1 Historic Yield Analysis

A historic yield analysis was performed on the Chelmsford Dam using the subsystem yield simulation model with the adopted operating policy. The simulation yield analysis investigates the firm yield and the average annual yield of the Chelmsford Dam over a range of annual target draft. The results of the historic yield analysis are illustrated in Figure 24.

A historic firm yield of $75,3 \times 10^6 \text{ m}^3$ per annum for the simulation analysis was obtained. The total yield at a target draft of $75,3 \times 10^6 \text{ m}^3$ per annum is $79,3 \times 10^6 \text{ m}^3$ per annum. The total yield includes water supply above the target draft when the subsystem is in a spillage mode.

4.6.2 Stochastic Yield Analysis

A stochastic yield analysis was performed on the Chelmsford Dam using the subsystem yield simulation model. The simulation analysis investigates the stochastic nature of the firm and average yield of the Chelmsford Dam under the adopted operating policy. A simulation period of 64 years was investigated. The inflow hydrology was derived using the stochastic streamflow generator.

The results of the long-term stochastic yield analysis for three target drafts of $75,3 \times 10^6 \text{ m}^3$ per annum, $80 \times 10^6 \text{ m}^3$ per annum and $85 \times 10^6 \text{ m}^3$ per annum are presented in Figure 25 and Table 11.

TABLE 11: RESULTS OF LONG-TERM STOCHASTIC YIELD ANALYSIS FOR THE CHELMSFORD DAM

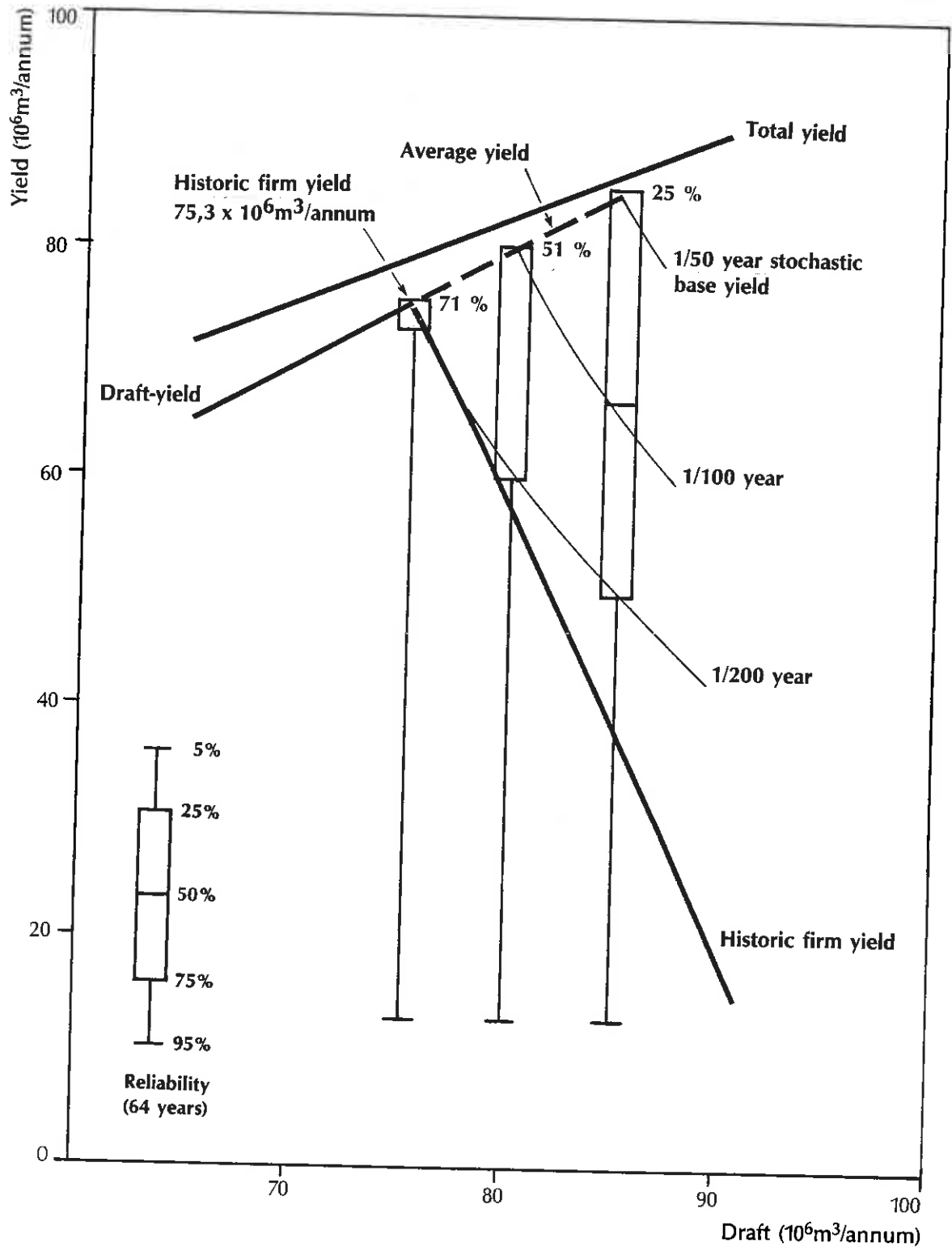
FIRM YIELD FOR INDICATED RECURRENCE INTERVAL ($10^6 \text{ m}^3/\text{annum}$)		
1:50 yr	1:100 yr	1:200 yr
84,9	79,5	74,3

A comparison of the stochastic yield analysis with the historic yield analysis can be made when a summary of the long term projection analysis is superimposed upon the historic yield analysis as illustrated in Figure 24. The stochastic yield analysis results are summarized in terms of a box plot of the stochastic yield characteristics highlighting the 5 percent, 25 percent, 50 percent, 75 percent and 95 percent long-term reliability of water supply. A box plot of the stochastic results for the firm yield only is presented. The stochastic variability or distribution of the firm yield is truncated at each target demand. The percent quoted at the truncated end of the box plot represents the long-term reliability at that target draft. The dashed line represent the stochastic firm yield at reliability levels of 1/50, 1/100 and 1/200 years of supply as the stochastic firm yield criteria.

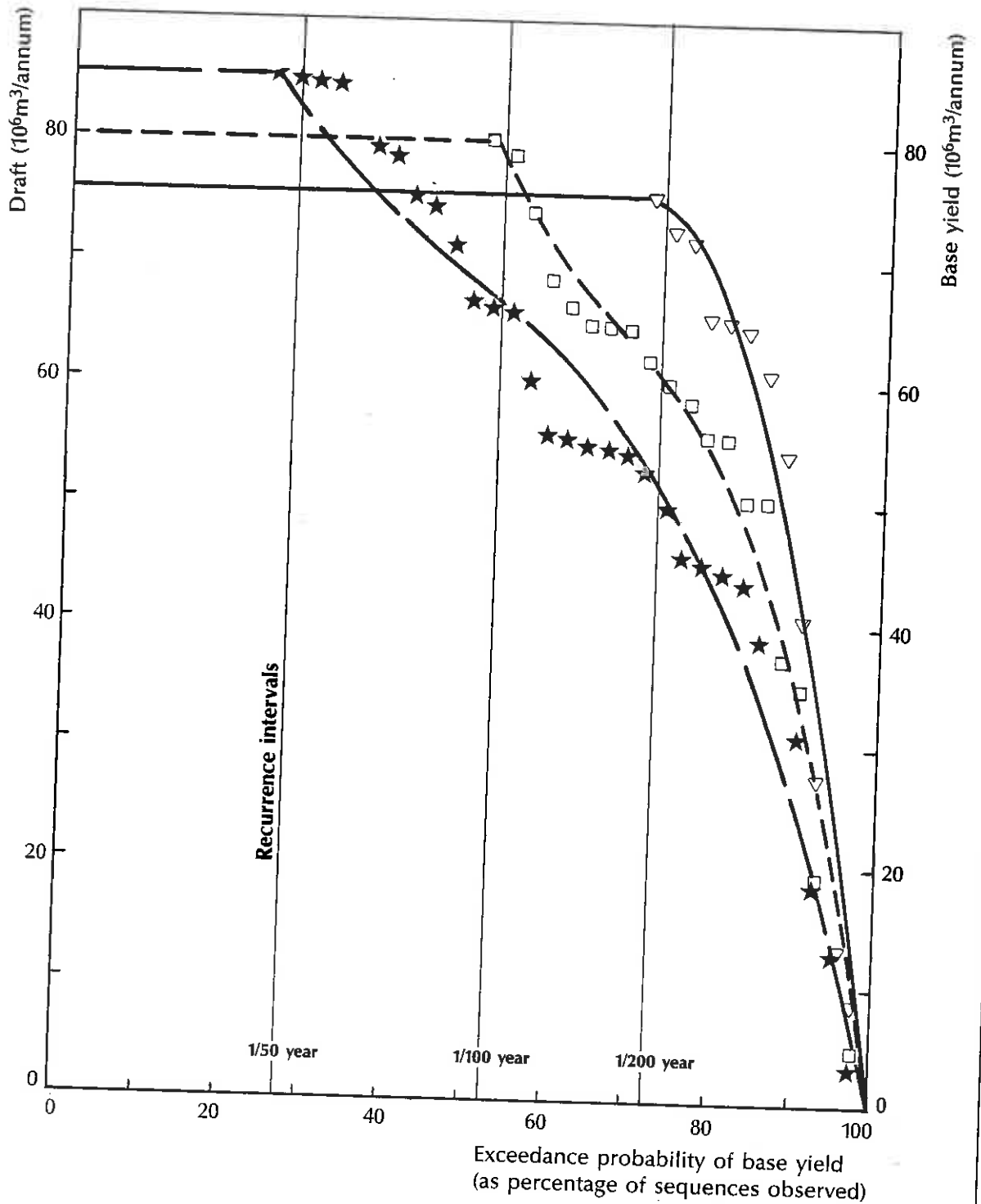
3042C/0954B

1989-06-26

MAR (Chelmsford Dam) = 110,86 m³ / annum



Reliability of base yield derived from
41 64-year generated sequences



5. STUDY FINDINGS

The study shows that the Zaaihoek Dam is currently independent of the Chelmsford Dam, but that this situation will change in future as the demand of Newcastle grows and Chelmsford becomes dependent on support from the Zaaihoek Dam. The Buffalo-Vaal subsystem can thus over the short to medium term be viewed as the Zaaihoek Dam and Chelmsford Dam partial subsystems.

The firm yield of the Zaaihoek Dam is far in excess of the demands of the Majuba power station, facilitating the remainder of the yield being applied to other users at different levels of assurance. With the installed pumping capacity from the Zaaihoek Dam to Majuba and the Vaal basin in excess of both the firm and average yields, even at very low reliabilities of supply, substantial quantities of water can over the medium term be transferred to the greater Vaal River System.

Chelmsford requires no support at 1985 levels of development and no rapid changes in this situation are foreseen as regards existing development trends in the Newcastle Complex.

5.1 SUMMARY OF RESULTS

5.1.1 Optimal Operating Rule Curve

The reservoirs in the Buffalo-Vaal subsystem can over the medium term be operated independently. The Chelmsford Dam can be used to supply the Newcastle Complex and the Zaaihoek Dam can be used to supply Majuba Power Station and to transfer the remainder of its firm yield to the Vaal System.

5.1.2 Historic Yield Characteristics

The historic firm yield for the Buffalo-Vaal subsystem is $47,2 \times 10^6 \text{ m}^3$ per annum. Due to the common definition of the yield channel for the Buffalo-Vaal subsystem and the Zaaihoek Dam partial subsystem, this also corresponds to the historic firm yield for the Zaaihoek Dam. The total yield at a target draft of $47,2 \times 10^6 \text{ m}^3$ per annum is $54,0 \times 10^6 \text{ m}^3$ per annum in both cases.

The historic firm yield for the Chelmsford Dam is $75,3 \times 10^6 \text{ m}^3$ per annum. The total yield at a target draft of $75,3 \times 10^6 \text{ m}^3$ per annum is $79,3 \times 10^6 \text{ m}^3$ per annum.

5.1.3 Critical Hydrologic Sequence

1. The critical historic hydrologic sequence runs from April 1978 to October 1983.
2. The length of the typical historical drought sequence of the Buffalo-Vaal subsystem is 5 to 6 years.

5.1.4 Stochastic Yield Characteristics

The results of the long-term stochastic analysis are presented in tabular form below (Table 12). Due to the common definition of the yield channel for the analysis of the total Buffalo-Vaal subsystem and for the Zaaihoek Dam partial subsystem, the yields for both Zaaihoek Dam and Chelmsford Dam are listed for greater clarity. The historic firm yields are also given for comparative purposes.

TABLE 12: RESULTS OF HISTORIC AND LONG-TERM STOCHASTIC ANALYSES

DAM	FIRM YIELD FOR INDICATED RECURRENCE INTERVAL ($10^6 \text{ m}^3/\text{a}$)				HISTORIC YIELD ($10^6 \text{ m}^3/\text{a}$)	
	1:20	1:50	1:100	1:200	Firm	Total
Zaaihoek	64	58	52	48	47,2	54,0
Chelmsford	-	85	80	74	75,3	79,3

Short term characteristic curves for real-time operational decisions were only developed for the Zaaihoek Dam partial subsystem as the currently active part contributing to the integrated Vaal River System.

The results of the short-term stochastic analyses for Zaaihoek Dam are presented in Table 13.

TABLE 13: RESULTS OF SHORT-TERM STOCHASTIC ANALYSES

SYSTEM START VOLUME AS PERCENTAGE OF FULL SUPPLY CAPACITY	FIRM YIELD FOR INDICATED RECURRENCE INTERVAL ($10^6 \text{ m}^3/\text{annum}$)			
	1:20 yr	1:50 yr	1:100 yr	1:200 yr
100 %	88,0	73,5	64,5	57,0
80 %	78,0	65,5	54,5	45,5
60 %	68,0	56,5	47,5	40,0
40 %	55,0	43,0	36,0	30,0
20 %	41,0	29,0	22,0	17,0
10 %	22,5	17,0	13,0	9,0

5.1.4 Long and Short-Term Yield Reliability Characteristics

The probabilistic yield-reliability characteristics illustrated in Figure 14 and Figures 18 to 23 were derived from least-squares curves which were fitted to the results of the stochastic analyses.

The purpose of this fitting procedure is to arrive at a set of equations which describe the yield-reliability characteristics in a deterministic fashion and thus eliminate the need to perform excessive time consuming stochastic simulation analyses. These families of curves, describing both the long and short-term yield-reliability characteristics, can be generated using coefficient data which is set out in Appendix C.

The procedures used are outlined in reports P C000/00/6886, "Yield Analysis - Terms and Procedures" P C000/00/6986, "Study Procedure Manual, Volume 1" and are summarised in Appendix C, C-1.

5.2 General Conclusions

1. The short-term reliability of the Zaaihoek partial subsystem declines rapidly with increasing yield.
2. The Chelmsford Dam currently requires no support from Zaaihoek Dam.
3. The long-term yield-reliability characteristics of Zaaihoek indicate that it should be able to yield within a range from 45 to $65 \times 10^6 \text{ m}^3$ per annum, depending on the required reliability of supply.

APPENDIX A

INPUT DATA TABLES

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1. Irrigation Abstractions (1984) above Zaaihoek Dam	A - 1
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IRRIGATION ABSTRACTION UPSTREAM OF ZAAIHOEKDAM BASED ON 1984 LEVEL (10**6 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1920/21	0.00	0.13	0.19	0.26	0.09	0.00	0.09	0.03	0.11	0.13	0.39	0.32	1.89	1.89
1921/22	0.03	0.00	0.07	0.19	0.06	0.10	0.12	0.07	0.07	0.18	0.24	0.27	1.40	3.29
1922/23	0.00	0.01	0.21	0.28	0.19	0.23	0.10	0.13	0.08	0.13	0.37	0.37	2.10	5.39
1923/24	0.13	0.11	0.27	0.14	0.26	0.02	0.05	0.07	0.11	0.18	0.36	0.16	1.87	7.26
1924/25	0.06	0.00	0.34	0.00	0.26	0.00	0.06	0.08	0.07	0.15	0.39	0.18	1.59	9.85
1925/26	0.07	0.01	0.24	0.29	0.21	0.13	0.13	0.05	0.00	0.18	0.39	0.11	1.82	10.67
1926/27	0.15	0.12	0.17	0.10	0.13	0.05	0.05	0.13	0.12	0.06	0.39	0.32	1.80	12.47
1927/28	0.00	0.23	0.00	0.18	0.10	0.01	0.07	0.11	0.12	0.13	0.35	0.20	1.50	14.07
1928/29	0.11	0.03	0.14	0.16	0.24	0.15	0.07	0.09	0.01	0.13	0.37	0.09	1.64	15.71
1929/30	0.00	0.22	0.14	0.00	0.21	0.25	0.03	0.13	0.12	0.11	0.33	0.33	1.81	17.52
1930/31	0.22	0.12	0.23	0.22	0.00	0.01	0.07	0.13	0.12	0.06	0.39	0.37	2.13	19.65
1931/32	0.09	0.06	0.14	0.31	0.00	0.01	0.07	0.04	0.06	0.17	0.39	0.33	1.89	21.54
1932/33	0.13	0.00	0.00	0.16	0.24	0.06	0.06	0.07	0.10	0.08	0.27	0.34	1.35	23.43
1933/34	0.11	0.02	0.19	0.00	0.19	0.04	0.11	0.08	0.09	0.17	0.38	0.33	1.35	24.78
1934/35	0.11	0.24	0.00	0.16	0.26	0.01	0.10	0.00	0.11	0.17	0.39	0.31	1.63	26.46
1935/36	0.10	0.00	0.27	0.00	0.00	0.19	0.09	0.13	0.12	0.18	0.39	0.25	1.89	28.35
1936/37	0.08	0.28	0.00	0.16	0.00	0.33	0.11	0.11	0.03	0.12	0.34	0.32	1.72	30.07
1937/38	0.00	0.16	0.01	0.07	0.33	0.03	0.10	0.06	0.12	0.05	0.30	0.30	1.88	31.95
1938/39	0.11	0.00	0.19	0.17	0.19	0.08	0.05	0.00	0.00	0.18	0.38	0.27	1.20	33.15
1939/40	0.17	0.02	0.06	0.16	0.15	0.05	0.03	0.13	0.12	0.18	0.39	0.32	1.62	34.77
1940/41	0.09	0.15	0.13	0.06	0.22	0.01	0.09	0.07	0.05	0.18	0.34	0.24	1.78	36.55
1941/42	0.05	0.01	0.04	0.24	0.21	0.01	0.00	0.06	0.11	0.00	0.24	0.24	1.63	38.18
1942/43	0.05	0.15	0.03	0.11	0.00	0.07	0.14	0.12	0.00	0.18	0.24	0.30	1.27	39.45
1943/44	0.05	0.18	0.39	0.23	0.00	0.23	0.11	0.11	0.12	0.18	0.39	0.16	1.46	40.91
1944/45	0.06	0.24	0.41	0.06	0.17	0.03	0.12	0.10	0.12	0.18	0.38	0.35	2.34	43.25
1945/46	0.25	0.14	0.29	0.21	0.15	0.10	0.06	0.13	0.08	0.18	0.38	0.34	2.40	45.65
1946/47	0.06	0.14	0.29	0.21	0.15	0.10	0.06	0.13	0.08	0.18	0.37	0.34	2.03	47.68
1947/48	0.12	0.04	0.08	0.11	0.28	0.03	0.09	0.09	0.12	0.18	0.39	0.24	1.77	49.45
1948/49	0.14	0.06	0.37	0.04	0.14	0.08	0.00	0.09	0.10	0.18	0.39	0.28	1.67	51.32
1949/50	0.08	0.04	0.08	0.23	0.27	0.03	0.04	0.06	0.09	0.17	0.31	0.32	1.72	53.04
1950/51	0.09	0.30	0.12	0.16	0.10	0.14	0.09	0.06	0.10	0.16	0.22	0.31	1.62	54.66
1951/52	0.00	0.16	0.24	0.08	0.35	0.09	0.05	0.10	0.12	0.04	0.39	0.35	1.99	56.65
1952/53	0.16	0.00	0.24	0.29	0.00	0.06	0.05	0.08	0.11	0.18	0.34	0.32	1.83	58.48
1953/54	0.16	0.01	0.24	0.20	0.07	0.06	0.07	0.06	0.09	0.17	0.38	0.22	1.73	60.21
1954/55	0.07	0.02	0.35	0.00	0.00	0.02	0.07	0.09	0.11	0.17	0.37	0.34	1.61	61.82
1955/56	0.06	0.07	0.14	0.32	0.01	0.00	0.11	0.05	0.12	0.15	0.39	0.27	1.69	63.51
1956/57	0.03	0.04	0.00	0.21	0.18	0.01	0.04	0.09	0.07	0.03	0.28	0.02	1.00	64.51
1957/58	0.04	0.24	0.18	0.00	0.33	0.14	0.00	0.09	0.12	0.18	0.39	0.20	1.95	66.46
1958/59	0.09	0.08	0.02	0.22	0.23	0.05	0.09	0.11	0.11	0.16	0.37	0.26	1.72	68.18
1959/60	0.07	0.01	0.20	0.26	0.12	0.05	0.00	0.11	0.12	0.17	0.32	0.26	1.69	69.87
1960/61	0.07	0.01	0.00	0.28	0.20	0.02	0.00	0.05	0.05	0.18	0.39	0.15	1.40	71.27
1961/62	0.09	0.03	0.10	0.08	0.23	0.11	0.07	0.09	0.10	0.18	0.35	0.27	1.70	72.97
1962/63	0.14	0.01	0.16	0.00	0.40	0.06	0.08	0.13	0.09	0.00	0.39	0.36	1.70	74.67
1963/64	0.08	0.01	0.40	0.00	0.33	0.16	0.05	0.13	0.09	0.18	0.35	0.31	2.10	76.77
1964/65	0.00	0.12	0.17	0.03	0.26	0.18	0.07	0.12	0.09	0.14	0.34	0.31	1.79	78.56
1965/66	0.10	0.04	0.25	0.20	0.16	0.14	0.10	0.08	0.09	0.18	0.34	0.22	2.00	80.56
1966/67	0.07	0.25	0.03	0.00	0.38	0.01	0.05	0.11	0.12	0.18	0.36	0.32	1.57	82.13
1967/68	0.08	0.02	0.15	0.22	0.38	0.01	0.10	0.12	0.11	0.17	0.29	0.35	2.00	84.13
1968/69	0.18	0.01	0.15	0.14	0.29	0.01	0.03	0.06	0.11	0.15	0.29	0.25	1.78	85.91

IRRIGATION ABSTRACTION UPSTREAM OF ZAAIHOEKDAM BASED ON 1984 LEVEL (10**6 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1969/70	0.03	0.14	0.09	0.20	0.20	0.20	0.09	0.09	0.07	0.14	0.32	0.29	1.86	87.77
1970/71	0.04	0.14	0.30	0.07	0.31	0.13	0.00	0.06	0.11	0.17	0.33	0.28	1.94	39.71
1971/72	0.05	0.02	0.10	0.04	0.12	0.04	0.09	0.07	0.11	0.18	0.38	0.36	1.56	91.27
1972/73	0.13	0.03	0.30	0.14	0.03	0.05	0.00	0.12	0.12	0.17	0.21	0.19	1.49	92.76
1973/74	0.09	0.04	0.17	0.09	0.16	0.08	0.03	0.08	0.07	0.12	0.36	0.33	1.62	94.39
1974/75	0.14	0.01	0.00	0.03	0.05	0.07	0.07	0.09	0.12	0.17	0.39	0.17	1.32	95.70
1975/76	0.11	0.05	0.12	0.14	0.17	0.02	0.03	0.05	0.12	0.18	0.38	0.33	1.70	97.40
1976/77	0.05	0.11	0.04	0.03	0.22	0.04	0.10	0.13	0.12	0.18	0.36	0.24	1.62	99.02
1977/78	0.07	0.08	0.13	0.00	0.09	0.12	0.06	0.10	0.12	0.18	0.30	0.21	1.51	100.53
1978/79	0.02	0.09	0.22	0.31	0.34	0.18	0.07	0.12	0.10	0.09	0.22	0.19	1.95	102.48
1979/80	0.13	0.12	0.19	0.02	0.01	0.25	0.10	0.12	0.11	0.18	0.37	0.24	1.84	104.32
1980/81	0.16	0.01	0.19	0.07	0.04	0.03	0.08	0.08	0.08	0.15	0.32	0.23	1.44	105.76
1981/82	0.10	0.18	0.25	0.06	0.43	0.15	0.11	0.12	0.11	0.14	0.39	0.32	2.37	108.13
1982/83	0.06	0.28	0.28	0.27	0.41	0.06	0.08	0.05	0.08	0.13	0.30	0.35	2.35	110.48
1983/84	0.02	0.03	0.03	0.00	0.25	0.02	0.09	0.13	0.05	0.06	0.22	0.32	1.22	111.70
AVERAGE	0.09	0.09	0.15	0.13	0.18	0.08	0.07	0.09	0.09	0.14	0.35	0.27	1.75	
% TOTAL	4.97	5.11	9.29	7.65	10.40	4.46	3.84	5.13	5.22	8.29	19.95	15.68	100.00	

MEAN(LOG) = 0.236100 STD. DEV. = 0.072463 MEAN ANNUAL VALUE = 1.75

IRRIGATION ABSTRACTION UPSTREAM OF SCHURVEPOORT WEIR BASED ON 1984 LEVEL (10**6 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1920/21	0.00	0.27	0.45	0.41	0.26	0.00	0.17	0.17	0.25	0.40	0.88	0.55	3.92	3.92
1921/22	0.18	0.00	0.22	0.49	0.42	0.21	0.15	0.16	0.17	0.39	0.55	0.66	3.60	7.52
1922/23	0.00	0.01	0.23	0.27	0.45	0.56	0.23	0.30	0.21	0.34	0.83	0.83	4.27	11.79
1923/24	0.30	0.38	0.53	0.27	0.43	0.04	0.13	0.17	0.26	0.40	0.79	0.42	4.17	15.96
1924/25	0.22	0.02	0.43	0.10	0.29	0.00	0.13	0.15	0.20	0.34	0.85	0.43	3.22	19.18
1925/26	0.21	0.05	0.33	0.23	0.44	0.07	0.24	0.17	0.02	0.40	0.86	0.27	3.81	22.99
1926/27	0.35	0.26	0.39	0.02	0.01	0.07	0.19	0.29	0.26	0.12	0.87	0.74	3.57	26.56
1927/28	0.04	0.49	0.04	0.35	0.53	0.02	0.17	0.16	0.26	0.40	0.77	0.53	3.83	30.39
1928/29	0.37	0.06	0.19	0.32	0.60	0.00	0.20	0.24	0.02	0.30	0.82	0.18	3.68	34.07
1929/30	0.06	0.09	0.20	0.00	0.70	0.46	0.20	0.30	0.25	0.26	0.79	0.75	4.06	38.13
1930/31	0.47	0.56	0.26	0.00	0.44	0.27	0.10	0.30	0.26	0.23	0.88	0.81	4.58	42.71
1931/32	0.45	0.30	0.65	0.52	0.00	0.03	0.17	0.09	0.16	0.38	0.86	0.72	4.36	47.07
1932/33	0.21	0.23	0.38	0.73	0.14	0.22	0.17	0.16	0.18	0.27	0.88	0.72	4.43	51.50
1933/34	0.30	0.00	0.00	0.00	0.51	0.14	0.15	0.16	0.23	0.20	0.62	0.75	3.06	54.56
1934/35	0.25	0.06	0.08	0.42	0.42	0.08	0.23	0.20	0.22	0.39	0.85	0.74	3.94	58.50
1935/36	0.23	0.55	0.50	0.00	0.54	0.02	0.24	0.00	0.25	0.39	0.88	0.70	4.36	62.86
1936/37	0.21	0.00	0.65	0.00	0.00	0.45	0.22	0.30	0.26	0.40	0.88	0.59	3.97	66.83
1937/38	0.21	0.64	0.00	0.40	0.74	0.27	0.02	0.26	0.06	0.28	0.76	0.71	4.35	71.18
1938/39	0.01	0.36	0.06	0.11	0.00	0.07	0.25	0.13	0.26	0.12	0.70	0.66	2.73	73.91
1939/40	0.29	0.00	0.33	0.35	0.54	0.20	0.05	0.30	0.26	0.40	0.85	0.54	3.76	77.67
1940/41	0.41	0.06	0.13	0.32	0.42	0.09	0.15	0.00	0.01	0.40	0.87	0.73	4.04	81.71
1941/42	0.26	0.38	0.34	0.09	0.44	0.04	0.20	0.16	0.10	0.40	0.78	0.52	3.71	85.42
1942/43	0.12	0.04	0.05	0.47	0.48	0.00	0.00	0.14	0.25	0.00	0.48	0.70	2.74	88.16
1943/44	0.11	0.37	0.11	0.35	0.00	0.18	0.32	0.28	0.00	0.40	0.88	0.35	3.43	91.59
1944/45	0.13	0.43	0.84	0.56	0.45	0.01	0.24	0.22	0.26	0.40	0.86	0.79	5.19	96.78
1945/46	0.57	0.60	0.85	0.13	0.30	0.04	0.28	0.23	0.26	0.40	0.87	0.77	5.30	102.08
1946/47	0.14	0.31	0.65	0.46	0.15	0.17	0.14	0.30	0.16	0.26	0.85	0.75	4.34	106.42
1947/48	0.30	0.05	0.13	0.19	0.61	0.07	0.21	0.19	0.26	0.40	0.89	0.53	3.87	110.29
1948/49	0.29	0.21	0.82	0.07	0.27	0.15	0.00	0.22	0.23	0.40	0.87	0.63	4.16	114.45
1949/50	0.17	0.12	0.21	0.38	0.56	0.06	0.05	0.14	0.21	0.39	0.69	0.75	3.73	118.18
1950/51	0.22	0.31	0.27	0.48	0.21	0.25	0.17	0.15	0.23	0.32	0.49	0.73	3.83	122.01
1951/52	0.05	0.66	0.28	0.20	0.81	0.26	0.13	0.25	0.26	0.09	0.87	0.77	4.63	126.64
1952/53	0.42	0.01	0.53	0.49	0.00	0.18	0.11	0.21	0.25	0.40	0.78	0.75	4.13	130.77
1953/54	0.38	0.02	0.61	0.45	0.14	0.10	0.15	0.13	0.19	0.38	0.87	0.49	3.91	134.68
1954/55	0.17	0.06	0.77	0.03	0.00	0.05	0.17	0.21	0.25	0.39	0.85	0.76	3.71	138.39
1955/56	0.15	0.19	0.42	0.74	0.03	0.00	0.22	0.11	0.26	0.35	0.87	0.62	3.96	142.35
1956/57	0.09	0.03	0.00	0.42	0.49	0.03	0.12	0.22	0.15	0.05	0.65	0.06	2.31	144.66
1957/58	0.10	0.55	0.50	0.00	0.75	0.25	0.00	0.28	0.26	0.38	0.88	0.50	4.46	149.12
1958/59	0.21	0.17	0.10	0.57	0.57	0.15	0.19	0.09	0.26	0.36	0.85	0.61	4.12	153.24
1959/60	0.15	0.02	0.49	0.62	0.34	0.13	0.01	0.22	0.26	0.38	0.71	0.63	3.96	157.20
1960/61	0.18	0.04	0.00	0.70	0.55	0.04	0.00	0.12	0.12	0.40	0.87	0.37	3.39	160.59
1961/62	0.23	0.08	0.23	0.18	0.51	0.30	0.16	0.23	0.24	0.40	0.78	0.51	3.95	164.54
1962/63	0.33	0.02	0.38	0.00	0.89	0.14	0.18	0.22	0.00	0.00	0.88	0.81	3.85	168.39
1963/64	0.17	0.03	0.90	0.00	0.72	0.36	0.14	0.30	0.19	0.40	0.80	0.69	4.70	173.09
1964/65	0.00	0.31	0.42	0.16	0.58	0.44	0.16	0.27	0.11	0.33	0.75	0.71	4.24	177.33
1965/66	0.21	0.08	0.65	0.43	0.44	0.58	0.23	0.22	0.22	0.40	0.77	0.52	4.76	182.09
1966/67	0.18	0.56	0.10	0.00	0.05	0.34	0.08	0.24	0.26	0.28	0.82	0.73	3.64	185.73
1967/68	0.19	0.07	0.40	0.52	0.88	0.03	0.24	0.27	0.26	0.39	0.66	0.78	4.69	190.42
1968/69	0.41	0.05	0.41	0.31	0.68	0.02	0.36	0.15	0.24	0.34	0.38	0.60	4.15	194.57

IRRIGATION ABSTRACTION UPSTREAM OF SCHURVEPOORT WEIR BASED ON 1984 LEVEL (10**6 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1969/70	0.08	0.36	0.24	0.48	0.47	0.45	0.21	0.20	0.15	0.30	0.69	0.66	4.29	198.85
1970/71	0.10	0.31	0.73	0.17	0.67	0.19	0.00	0.13	0.25	0.38	0.80	0.64	4.37	203.23
1971/72	0.14	0.07	0.25	0.11	0.31	0.08	0.21	0.15	0.25	0.40	0.83	0.81	3.62	206.85
1972/73	0.30	0.09	0.68	0.35	0.09	0.12	0.02	0.27	0.26	0.39	0.45	0.45	3.47	210.32
1973/74	0.21	0.11	0.41	0.22	0.37	0.17	0.06	0.18	0.17	0.28	0.83	0.72	3.73	214.05
1974/75	0.32	0.02	0.06	0.08	0.17	0.21	0.15	0.20	0.26	0.39	0.37	0.39	3.13	217.18
1975/76	0.25	0.11	0.27	0.34	0.40	0.05	0.07	0.12	0.26	0.40	0.86	0.73	3.86	221.04
1976/77	0.12	0.29	0.13	0.10	0.54	0.12	0.22	0.30	0.26	0.40	0.81	0.54	3.93	224.87
1977/78	0.18	0.20	0.35	0.00	0.25	0.23	0.15	0.25	0.25	0.39	0.66	0.50	3.49	228.36
1978/79	0.08	0.25	0.53	0.74	0.75	0.38	0.17	0.26	0.22	0.22	0.48	0.44	4.52	232.88
1979/80	0.28	0.32	0.44	0.03	0.05	0.57	0.22	0.28	0.26	0.40	0.83	0.54	4.22	237.10
1980/81	0.34	0.02	0.37	0.19	0.12	0.12	0.19	0.20	0.17	0.35	0.71	0.51	3.29	240.39
1981/82	0.28	0.33	0.58	0.14	0.98	0.34	0.24	0.23	0.25	0.32	0.88	0.75	5.32	245.71
1982/83	0.11	0.62	0.69	0.61	0.91	0.18	0.18	0.12	0.18	0.31	0.69	0.80	5.40	251.11
1983/84	0.05	0.07	0.09	0.00	0.57	0.05	0.19	0.27	0.11	0.15	0.50	0.72	2.77	253.88
AVERAGE	0.21	0.21	0.38	0.28	0.41	0.17	0.15	0.20	0.20	0.33	0.78	0.62	3.97	
% TOTAL	5.36	5.40	9.51	7.04	10.41	4.32	3.89	5.15	5.16	8.26	19.77	15.74	100.00	

MEAN(LOG) = 0.593109 STD. DEV. = 0.069837 MEAN ANNUAL VALUE = 3.97

IRRIGATION ABSTRACTION UPSTREAM OF CHELMSFORD DAM BASED ON 1984 LEVEL (10**6 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1920/21	0.01	0.24	0.30	0.30	0.16	0.01	0.10	0.11	0.14	0.22	0.48	0.18	2.25	2.25
1921/22	0.18	0.00	0.04	0.21	0.21	0.03	0.11	0.03	0.09	0.21	0.29	0.32	1.77	4.02
1922/23	0.03	0.01	0.13	0.03	0.27	0.30	0.13	0.14	0.08	0.17	0.46	0.45	2.20	6.22
1923/24	0.15	0.28	0.35	0.06	0.16	0.04	0.11	0.13	0.14	0.21	0.42	0.23	2.26	8.48
1924/25	0.11	0.03	0.12	0.19	0.10	0.00	0.04	0.11	0.12	0.19	0.47	0.23	1.77	10.25
1925/26	0.12	0.09	0.39	0.14	0.27	0.07	0.13	0.10	0.03	0.22	0.48	0.11	2.15	12.40
1926/27	0.13	0.13	0.19	0.11	0.10	0.02	0.13	0.16	0.14	0.12	0.44	0.44	2.11	14.51
1927/28	0.07	0.29	0.13	0.15	0.32	0.03	0.11	0.10	0.14	0.22	0.42	0.29	2.27	16.78
1928/29	0.12	0.28	0.19	0.25	0.37	0.00	0.13	0.13	0.02	0.11	0.45	0.10	2.15	18.93
1929/30	0.12	0.01	0.21	0.02	0.36	0.19	0.08	0.14	0.13	0.16	0.41	0.37	2.20	21.13
1930/31	0.19	0.34	0.08	0.00	0.23	0.17	0.10	0.15	0.14	0.16	0.48	0.45	2.50	23.63
1931/32	0.19	0.19	0.37	0.22	0.01	0.03	0.13	0.03	0.11	0.21	0.48	0.39	2.36	25.99
1932/33	0.21	0.16	0.15	0.43	0.34	0.06	0.08	0.15	0.11	0.14	0.48	0.44	2.76	28.75
1933/34	0.26	0.01	0.12	0.00	0.38	0.07	0.09	0.07	0.14	0.10	0.32	0.43	1.99	30.74
1934/35	0.11	0.04	0.02	0.24	0.16	0.03	0.07	0.11	0.09	0.22	0.46	0.37	1.92	32.66
1935/36	0.20	0.32	0.36	0.07	0.13	0.01	0.11	0.00	0.14	0.21	0.48	0.41	2.44	35.10
1936/37	0.11	0.00	0.43	0.00	0.05	0.19	0.10	0.16	0.14	0.22	0.46	0.36	2.24	37.34
1937/38	0.24	0.29	0.05	0.20	0.25	0.20	0.04	0.14	0.00	0.15	0.41	0.40	2.38	39.72
1938/39	0.03	0.26	0.04	0.14	0.02	0.03	0.16	0.05	0.13	0.08	0.43	0.37	1.74	41.46
1939/40	0.16	0.01	0.08	0.24	0.29	0.23	0.08	0.00	0.01	0.21	0.47	0.29	2.07	43.53
1940/41	0.18	0.04	0.08	0.16	0.13	0.05	0.00	0.16	0.14	0.20	0.47	0.39	1.99	45.52
1941/42	0.17	0.26	0.24	0.00	0.10	0.07	0.07	0.08	0.08	0.22	0.38	0.28	1.95	47.47
1942/43	0.08	0.00	0.08	0.01	0.34	0.01	0.00	0.07	0.14	0.01	0.48	0.41	1.30	48.77
1943/44	0.02	0.03	0.01	0.23	0.00	0.13	0.18	0.13	0.00	0.22	0.48	0.11	1.54	50.31
1944/45	0.06	0.28	0.41	0.40	0.29	0.01	0.10	0.13	0.13	0.22	0.47	0.41	2.91	53.22
1945/46	0.31	0.36	0.50	0.09	0.23	0.01	0.13	0.10	0.14	0.22	0.48	0.43	3.00	56.22
1946/47	0.07	0.05	0.35	0.34	0.00	0.05	0.07	0.16	0.04	0.16	0.47	0.39	2.15	58.37
1947/48	0.14	0.01	0.07	0.04	0.27	0.03	0.10	0.12	0.14	0.21	0.48	0.32	1.93	60.30
1948/49	0.08	0.20	0.35	0.00	0.09	0.05	0.00	0.15	0.14	0.22	0.48	0.34	2.10	62.40
1949/50	0.08	0.09	0.04	0.14	0.24	0.08	0.00	0.05	0.13	0.20	0.39	0.41	1.86	64.26
1950/51	0.10	0.24	0.13	0.26	0.20	0.09	0.07	0.11	0.13	0.15	0.30	0.40	2.18	66.44
1951/52	0.10	0.37	0.17	0.10	0.41	0.13	0.09	0.11	0.14	0.06	0.47	0.41	2.56	69.00
1952/53	0.22	0.02	0.30	0.07	0.01	0.10	0.06	0.15	0.12	0.22	0.32	0.40	1.99	70.99
1953/54	0.22	0.05	0.34	0.23	0.00	0.03	0.12	0.06	0.08	0.22	0.48	0.26	2.09	73.08
1954/55	0.07	0.01	0.37	0.01	0.01	0.10	0.10	0.11	0.13	0.22	0.47	0.41	2.01	75.09
1955/56	0.09	0.19	0.30	0.37	0.08	0.00	0.13	0.05	0.14	0.22	0.48	0.33	2.38	77.47
1956/57	0.10	0.01	0.00	0.15	0.23	0.01	0.03	0.14	0.09	0.00	0.35	0.00	1.11	78.58
1957/58	0.03	0.30	0.37	0.03	0.18	0.02	0.00	0.16	0.14	0.21	0.48	0.31	2.23	80.81
1958/59	0.08	0.14	0.15	0.28	0.10	0.11	0.08	0.06	0.14	0.16	0.47	0.38	2.15	82.96
1959/60	0.06	0.05	0.25	0.30	0.20	0.15	0.01	0.12	0.14	0.21	0.38	0.38	2.25	85.21
1960/61	0.11	0.13	0.00	0.46	0.37	0.03	0.00	0.07	0.12	0.22	0.48	0.30	2.29	87.50
1961/62	0.19	0.06	0.31	0.07	0.12	0.21	0.09	0.16	0.14	0.22	0.39	0.38	2.34	89.84
1962/63	0.25	0.09	0.25	0.08	0.54	0.07	0.11	0.10	0.02	0.03	0.48	0.46	2.48	92.32
1963/64	0.11	0.10	0.44	0.08	0.33	0.18	0.07	0.16	0.04	0.21	0.43	0.32	2.47	94.79
1964/65	0.00	0.09	0.21	0.14	0.23	0.30	0.08	0.07	0.03	0.15	0.41	0.36	2.14	96.93
1965/66	0.10	0.15	0.37	0.00	0.36	0.33	0.07	0.10	0.14	0.22	0.40	0.33	2.57	99.50
1966/67	0.14	0.19	0.11	0.00	0.17	0.08	0.02	0.15	0.14	0.21	0.48	0.41	2.10	101.60
1967/68	0.18	0.11	0.27	0.38	0.51	0.06	0.12	0.11	0.14	0.21	0.35	0.43	2.87	104.47
1968/69	0.31	0.11	0.23	0.12	0.26	0.01	0.01	0.10	0.11	0.15	0.48	0.37	2.26	106.73

IRRIGATION ABSTRACTION UPSTREAM OF CHELMSFORD DAM BASED ON 1984 LEVEL (10**6 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1969/70	0.03	0.27	0.25	0.22	0.12	0.25	0.10	0.10	0.11	0.16	0.32	0.36	2.29	109.02
1970/71	0.07	0.15	0.43	0.04	0.29	0.08	0.03	0.04	0.13	0.17	0.38	0.37	2.18	111.20
1971/72	0.09	0.21	0.06	0.13	0.15	0.00	0.12	0.10	0.13	0.21	0.45	0.46	2.11	113.31
1972/73	0.10	0.09	0.39	0.24	0.11	0.12	0.00	0.16	0.14	0.22	0.26	0.25	2.08	115.39
1973/74	0.17	0.01	0.23	0.00	0.02	0.16	0.03	0.14	0.07	0.18	0.42	0.42	1.91	117.30
1974/75	0.18	0.01	0.12	0.05	0.00	0.16	0.05	0.11	0.14	0.22	0.46	0.07	1.57	118.87
1975/76	0.19	0.05	0.01	0.00	0.06	0.00	0.08	0.05	0.14	0.21	0.46	0.39	1.64	120.51
1976/77	0.04	0.24	0.23	0.02	0.36	0.03	0.11	0.10	0.14	0.21	0.47	0.32	2.27	122.78
1977/78	0.11	0.33	0.15	0.00	0.20	0.02	0.02	0.16	0.14	0.22	0.35	0.34	2.04	124.82
1978/79	0.06	0.35	0.47	0.30	0.12	0.23	0.13	0.13	0.10	0.08	0.29	0.23	2.49	127.31
1979/80	0.20	0.13	0.12	0.02	0.01	0.06	0.13	0.16	0.14	0.22	0.46	0.21	1.91	129.22
1980/81	0.11	0.14	0.11	0.18	0.02	0.26	0.10	0.15	0.05	0.22	0.39	0.27	2.00	131.22
1981/82	0.21	0.24	0.38	0.17	0.45	0.03	0.16	0.10	0.13	0.21	0.48	0.39	2.95	134.17
1982/83	0.04	0.30	0.43	0.28	0.48	0.09	0.11	0.08	0.12	0.15	0.42	0.41	2.97	137.14
1983/84	0.05	0.01	0.00	0.07	0.44	0.00	0.09	0.16	0.09	0.15	0.29	0.40	1.75	138.89
AVERAGE	0.13	0.15	0.22	0.14	0.20	0.09	0.08	0.11	0.11	0.18	0.42	0.34	2.17	
% TOTAL	5.80	6.69	10.05	6.67	9.37	4.10	3.74	5.11	5.05	8.30	19.48	15.62	100.00	

MEAN(LOG)= 0.329913 STD. DEV.= 0.077997 MEAN ANNUAL VALUE = 2.17

IRRIGATION ABSTRACTION UPSTREAM OF ROYPOINT LAISED ON 1934 LEVEL (10**5 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1920/21	0.00	0.06	0.03	0.08	0.04	0.00	0.03	0.03	0.04	0.06	0.12	0.05	0.59	0.59
1921/22	0.05	0.00	0.01	0.05	0.05	0.01	0.03	0.02	0.02	0.05	0.07	0.08	0.44	1.03
1922/23	0.01	0.00	0.03	0.01	0.07	0.08	0.03	0.02	0.02	0.05	0.07	0.08	0.44	1.47
1923/24	0.04	0.07	0.09	0.02	0.04	0.01	0.03	0.03	0.04	0.05	0.11	0.06	0.53	2.00
1924/25	0.03	0.01	0.03	0.05	0.03	0.00	0.01	0.03	0.03	0.05	0.12	0.07	0.53	2.53
1925/26	0.03	0.02	0.10	0.04	0.07	0.02	0.03	0.03	0.01	0.06	0.12	0.03	0.55	3.08
1926/27	0.03	0.03	0.05	0.03	0.03	0.01	0.03	0.04	0.04	0.03	0.11	0.03	0.54	3.62
1927/28	0.02	0.07	0.03	0.04	0.08	0.01	0.03	0.03	0.04	0.06	0.11	0.07	0.59	4.21
1928/29	0.03	0.07	0.05	0.06	0.09	0.00	0.03	0.03	0.01	0.03	0.11	0.03	0.54	4.75
1929/30	0.03	0.00	0.05	0.01	0.09	0.05	0.02	0.04	0.03	0.04	0.10	0.09	0.55	5.30
1930/31	0.05	0.09	0.02	0.00	0.06	0.04	0.03	0.04	0.04	0.05	0.12	0.11	0.64	5.94
1931/32	0.05	0.05	0.09	0.06	0.00	0.01	0.03	0.01	0.03	0.05	0.12	0.10	0.60	6.54
1932/33	0.05	0.04	0.04	0.11	0.09	0.02	0.02	0.04	0.03	0.05	0.12	0.11	0.71	7.25
1933/34	0.07	0.00	0.03	0.00	0.10	0.02	0.02	0.02	0.04	0.03	0.08	0.11	0.52	7.77
1934/35	0.03	0.01	0.01	0.06	0.04	0.01	0.02	0.03	0.02	0.06	0.12	0.09	0.50	8.27
1935/36	0.05	0.08	0.09	0.02	0.03	0.00	0.03	0.00	0.04	0.05	0.12	0.10	0.61	8.88
1936/37	0.03	0.00	0.11	0.00	0.01	0.05	0.03	0.04	0.04	0.05	0.12	0.09	0.58	9.46
1937/38	0.06	0.07	0.01	0.05	0.07	0.05	0.01	0.04	0.00	0.06	0.10	0.10	0.60	10.06
1938/39	0.01	0.07	0.01	0.04	0.01	0.01	0.04	0.01	0.03	0.02	0.11	0.09	0.51	10.57
1939/40	0.04	0.00	0.02	0.06	0.07	0.06	0.02	0.00	0.00	0.05	0.12	0.07	0.51	11.08
1940/41	0.05	0.01	0.02	0.04	0.03	0.01	0.00	0.04	0.04	0.05	0.12	0.10	0.51	11.59
1941/42	0.04	0.07	0.06	0.00	0.03	0.02	0.02	0.02	0.02	0.05	0.10	0.07	0.51	12.10
1942/43	0.02	0.00	0.02	0.00	0.09	0.00	0.00	0.02	0.04	0.06	0.04	0.10	0.33	12.43
1943/44	0.01	0.01	0.00	0.06	0.00	0.03	0.05	0.03	0.00	0.00	0.04	0.10	0.33	12.76
1944/45	0.02	0.07	0.10	0.10	0.07	0.00	0.03	0.03	0.03	0.06	0.12	0.10	0.73	13.49
1945/46	0.08	0.09	0.13	0.02	0.06	0.00	0.03	0.03	0.04	0.06	0.12	0.11	0.77	14.26
1946/47	0.02	0.01	0.03	0.09	0.00	0.01	0.02	0.04	0.01	0.04	0.12	0.10	0.55	14.81
1947/48	0.04	0.00	0.02	0.01	0.07	0.01	0.03	0.03	0.04	0.05	0.12	0.08	0.50	15.31
1948/49	0.02	0.05	0.09	0.00	0.02	0.01	0.00	0.04	0.04	0.06	0.12	0.09	0.54	15.85
1949/50	0.02	0.02	0.01	0.04	0.06	0.02	0.02	0.02	0.03	0.05	0.10	0.10	0.47	16.32
1950/51	0.03	0.06	0.03	0.07	0.05	0.02	0.02	0.03	0.03	0.04	0.08	0.10	0.56	16.88
1951/52	0.03	0.09	0.04	0.03	0.10	0.03	0.02	0.03	0.04	0.02	0.12	0.10	0.65	17.53
1952/53	0.06	0.01	0.08	0.02	0.00	0.03	0.02	0.04	0.03	0.06	0.08	0.10	0.53	18.06
1953/54	0.06	0.01	0.09	0.06	0.00	0.01	0.03	0.02	0.02	0.06	0.08	0.07	0.55	18.61
1954/55	0.02	0.00	0.09	0.00	0.00	0.03	0.03	0.03	0.03	0.06	0.12	0.10	0.51	19.12
1955/56	0.02	0.05	0.08	0.09	0.02	0.00	0.03	0.01	0.04	0.06	0.12	0.03	0.60	19.72
1956/57	0.03	0.00	0.00	0.04	0.06	0.00	0.01	0.04	0.02	0.00	0.09	0.00	0.29	20.01
1957/58	0.01	0.08	0.09	0.01	0.05	0.01	0.00	0.04	0.04	0.05	0.12	0.08	0.58	20.59
1958/59	0.02	0.04	0.04	0.07	0.03	0.03	0.02	0.02	0.04	0.04	0.12	0.08	0.58	21.17
1959/60	0.02	0.01	0.06	0.08	0.05	0.04	0.00	0.03	0.04	0.05	0.10	0.10	0.58	21.75
1960/61	0.03	0.03	0.00	0.12	0.09	0.01	0.00	0.02	0.03	0.06	0.12	0.03	0.61	22.36
1961/62	0.05	0.02	0.03	0.02	0.03	0.05	0.02	0.04	0.04	0.06	0.10	0.10	0.61	23.07
1962/63	0.05	0.02	0.06	0.02	0.14	0.02	0.03	0.03	0.01	0.01	0.12	0.12	0.64	23.71
1963/64	0.03	0.03	0.11	0.02	0.08	0.05	0.02	0.04	0.01	0.01	0.11	0.08	0.63	24.34
1964/65	0.00	0.02	0.05	0.04	0.06	0.08	0.02	0.04	0.01	0.04	0.10	0.09	0.55	24.89
1965/66	0.03	0.04	0.09	0.00	0.09	0.08	0.02	0.03	0.04	0.06	0.10	0.08	0.55	25.44
1966/67	0.04	0.05	0.03	0.00	0.04	0.02	0.01	0.04	0.04	0.05	0.12	0.10	0.54	26.09
1967/68	0.05	0.03	0.07	0.10	0.13	0.02	0.03	0.03	0.04	0.05	0.09	0.11	0.75	26.84
1968/69	0.08	0.03	0.06	0.03	0.07	0.00	0.00	0.03	0.03	0.04	0.12	0.09	0.58	27.42

IRRIGATION ABSTRACTION UPSTREAM OF ROYPOINT BASED ON 1984 LEVEL (10**6 M**3 / A)

YEAR	DCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1969/70	0.01	0.07	0.05	0.06	0.03	0.06	0.03	0.03	0.03	0.04	0.09	0.09	0.59	28.01
1970/71	0.02	0.04	0.11	0.01	0.07	0.02	0.01	0.01	0.03	0.04	0.10	0.09	0.55	28.56
1971/72	0.02	0.05	0.02	0.03	0.04	0.00	0.03	0.03	0.03	0.05	0.11	0.12	0.53	29.09
1972/73	0.03	0.02	0.10	0.06	0.03	0.03	0.00	0.04	0.04	0.05	0.07	0.06	0.54	29.63
1973/74	0.04	0.00	0.07	0.00	0.01	0.04	0.01	0.04	0.02	0.05	0.11	0.11	0.50	30.13
1974/75	0.05	0.00	0.03	0.01	0.00	0.04	0.01	0.03	0.04	0.06	0.12	0.02	0.41	30.54
1975/76	0.05	0.01	0.00	0.00	0.02	0.00	0.02	0.01	0.04	0.05	0.12	0.10	0.42	30.96
1976/77	0.01	0.06	0.06	0.01	0.09	0.01	0.03	0.03	0.04	0.05	0.12	0.08	0.59	31.55
1977/78	0.03	0.08	0.04	0.00	0.05	0.01	0.01	0.04	0.04	0.05	0.09	0.09	0.54	32.09
1978/79	0.02	0.09	0.12	0.08	0.03	0.06	0.03	0.03	0.03	0.02	0.07	0.06	0.64	32.73
1979/80	0.05	0.05	0.03	0.01	0.00	0.02	0.03	0.04	0.04	0.06	0.12	0.05	0.50	33.23
1980/81	0.03	0.04	0.03	0.05	0.01	0.07	0.03	0.04	0.01	0.06	0.10	0.07	0.54	33.77
1981/82	0.05	0.06	0.10	0.04	0.11	0.01	0.04	0.03	0.03	0.05	0.12	0.10	0.74	34.51
1982/83	0.01	0.08	0.12	0.07	0.12	0.02	0.03	0.02	0.03	0.04	0.11	0.10	0.75	35.26
1983/84	0.01	0.00	0.00	0.02	0.11	0.00	0.02	0.04	0.02	0.04	0.07	0.10	0.43	35.69
AVERAGE	0.03	0.04	0.05	0.04	0.05	0.02	0.02	0.03	0.03	0.05	0.11	0.09	0.56	
% TOTAL	5.97	6.56	9.89	6.78	9.27	4.17	3.81	5.32	5.30	8.38	19.22	15.33	100.00	

MEAN(LOG)=-0.260025 STD. DEV.= 0.077000 MEAN ANNUAL VALUE = 0.56

AFFORESTATION ABSTRACTION UPSTREAM OF SCHURVEPOORT WEIR BASED ON 1984 LEVEL (10**6 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1920/21	0.38	0.11	0.02	0.02	0.03	0.31	0.11	0.00	0.01	0.01	0.00	0.00	1.00	1.00
1921/22	0.02	0.33	0.31	0.08	0.02	0.04	0.02	0.02	0.01	0.01	0.01	0.02	0.89	1.89
1922/23	0.35	0.31	0.29	0.27	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.01	1.32	3.21
1923/24	0.00	0.01	0.02	0.32	0.13	0.21	0.07	0.00	0.01	0.00	0.01	0.01	0.79	4.00
1924/25	0.03	0.31	0.12	0.23	0.28	0.27	0.08	0.01	0.00	0.00	0.00	0.01	1.34	5.34
1925/26	0.02	0.04	0.03	0.03	0.04	0.03	0.01	0.01	0.01	0.01	0.01	0.03	0.27	5.61
1926/27	0.02	0.03	0.04	0.27	0.32	0.10	0.01	0.00	0.00	0.01	0.01	0.00	0.31	6.42
1927/28	0.03	0.02	0.04	0.04	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.01	0.23	6.55
1928/29	0.02	0.02	0.04	0.04	0.02	0.35	0.12	0.00	0.01	0.02	0.00	0.04	0.68	7.33
1929/30	0.05	0.25	0.10	0.28	0.10	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.83	8.16
1930/31	0.01	0.00	0.05	0.30	0.11	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.51	8.67
1931/32	0.00	0.02	0.02	0.03	0.37	0.32	0.07	0.01	0.02	0.01	0.00	0.00	0.97	9.54
1932/33	0.01	0.02	0.04	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.22	9.76
1933/34	0.00	0.37	0.34	0.28	0.09	0.02	0.01	0.01	0.01	0.01	0.01	0.02	1.17	10.93
1934/35	0.01	0.05	0.32	0.12	0.04	0.04	0.02	0.01	0.01	0.01	0.00	0.00	0.63	11.56
1935/36	0.01	0.01	0.02	0.35	0.13	0.24	0.08	0.01	0.01	0.01	0.00	0.00	1.19	12.75
1936/37	0.01	0.37	0.13	0.29	0.31	0.08	0.01	0.00	0.00	0.00	0.00	0.00	1.20	13.95
1937/38	0.01	0.01	0.37	0.14	0.02	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.65	14.60
1938/39	0.30	0.11	0.31	0.31	0.28	0.09	0.01	0.01	0.01	0.01	0.01	0.01	1.47	16.07
1939/40	0.01	0.35	0.14	0.03	0.02	0.02	0.01	0.04	0.04	0.01	0.01	0.00	0.88	16.75
1940/41	0.01	0.04	0.31	0.12	0.22	0.08	0.02	0.01	0.01	0.00	0.00	0.00	0.82	17.57
1941/42	0.01	0.01	0.03	0.35	0.31	0.09	0.01	0.01	0.01	0.01	0.00	0.00	0.85	18.42
1942/43	0.03	0.32	0.33	0.10	0.03	0.27	0.23	0.07	0.01	0.01	0.00	0.07	1.76	20.18
1943/44	0.03	0.04	0.26	0.10	0.24	0.09	0.00	0.00	0.03	0.02	0.01	0.03	0.85	21.03
1944/45	0.04	0.02	0.01	0.01	0.03	0.33	0.11	0.01	0.00	0.00	0.00	0.00	0.56	21.59
1945/46	0.01	0.00	0.00	0.04	0.05	0.26	0.09	0.00	0.00	0.00	0.01	0.00	0.46	22.05
1946/47	0.02	0.04	0.02	0.02	0.34	0.13	0.02	0.01	0.00	0.01	0.01	0.00	0.62	22.67
1947/48	0.00	0.32	0.33	0.28	0.08	0.03	0.01	0.01	0.00	0.01	0.00	0.00	1.07	23.74
1948/49	0.03	0.03	0.02	0.35	0.32	0.08	0.03	0.01	0.00	0.00	0.00	0.01	0.87	24.61
1949/50	0.03	0.03	0.31	0.12	0.03	0.03	0.04	0.02	0.02	0.00	0.00	0.00	0.63	25.24
1950/51	0.01	0.02	0.04	0.03	0.04	0.03	0.02	0.01	0.00	0.01	0.02	0.02	0.25	25.49
1951/52	0.03	0.02	0.04	0.29	0.10	0.01	0.02	0.01	0.00	0.00	0.02	0.01	0.57	26.06
1952/53	0.00	0.32	0.12	0.03	0.28	0.10	0.01	0.01	0.00	0.00	0.01	0.00	0.88	26.94
1953/54	0.01	0.04	0.03	0.03	0.34	0.13	0.01	0.01	0.01	0.00	0.01	0.00	0.62	27.56
1954/55	0.03	0.29	0.11	0.31	0.31	0.09	0.01	0.01	0.01	0.00	0.00	0.00	1.16	28.72
1955/56	0.02	0.03	0.03	0.03	0.34	0.31	0.07	0.01	0.00	0.00	0.00	0.00	0.94	29.56
1955/57	0.03	0.29	0.31	0.09	0.03	0.25	0.09	0.01	0.01	0.03	0.03	0.26	1.43	30.99
1957/58	0.27	0.06	0.02	0.37	0.14	0.02	0.04	0.03	0.01	0.01	0.00	0.01	0.98	31.97
1958/59	0.02	0.04	0.29	0.11	0.03	0.03	0.02	0.02	0.02	0.00	0.00	0.00	0.58	32.55
1959/60	0.02	0.30	0.12	0.02	0.03	0.03	0.03	0.02	0.01	0.00	0.00	0.01	0.59	33.14
1960/61	0.02	0.28	0.31	0.08	0.02	0.04	0.24	0.08	0.01	0.01	0.00	0.02	1.11	34.25
1961/62	0.02	0.04	0.04	0.26	0.11	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.52	34.77
1962/63	0.01	0.05	0.05	0.30	0.10	0.02	0.01	0.00	0.02	0.30	0.10	0.00	0.96	35.73
1963/64	0.02	0.28	0.09	0.31	0.12	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.87	36.60
1964/65	0.33	0.13	0.03	0.27	0.10	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.92	37.52
1955/66	0.02	0.05	0.03	0.04	0.04	0.02	0.01	0.00	0.00	0.01	0.00	0.01	0.23	37.75
1966/67	0.02	0.02	0.32	0.32	0.30	0.08	0.02	0.01	0.00	0.00	0.00	0.00	1.09	38.34
1967/68	0.02	0.04	0.04	0.03	0.01	0.03	0.03	0.01	0.01	0.00	0.01	0.00	0.22	39.06
1968/69	0.01	0.03	0.04	0.05	0.03	0.27	0.10	0.01	0.00	0.00	0.01	0.01	0.56	39.52

AFFORESTATION ABSTRACTION UPSTREAM OF SCHURVEPOORT WEIR BASED ON 1984 LEVEL (10**6 M**3 / A)

YEAR	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1969/70	0.04	0.03	0.03	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.23	
1970/71	0.04	0.02	0.12	0.02	0.03	0.03	0.02	0.00	0.00	0.00	0.63	39.85
1971/72	0.04	0.27	0.27	0.24	0.06	0.00	0.01	0.00	0.00	0.00	1.21	40.48
1972/73	0.01	0.02	0.32	0.12	0.03	0.02	0.01	0.00	0.02	0.03	0.65	41.69
1973/74	0.03	0.04	0.27	0.07	0.02	0.02	0.01	0.00	0.01	0.00	0.77	42.34
1974/75	0.00	0.32	0.30	0.28	0.02	0.01	0.00	0.00	0.00	0.00	43.11	44.47
1975/76	0.02	0.04	0.04	0.04	0.09	0.01	0.01	0.00	0.00	0.02	1.36	44.47
1976/77	0.03	0.04	0.08	0.03	0.02	0.00	0.00	0.00	0.01	0.01	0.54	45.01
1977/78	0.04	0.29	0.28	0.07	0.02	0.01	0.01	0.00	0.00	0.01	0.82	45.83
1978/79	0.04	0.03	0.02	0.02	0.01	0.01	0.00	0.01	0.00	0.01	0.80	46.53
1979/80	0.02	0.02	0.33	0.07	0.01	0.00	0.00	0.01	0.03	0.04	0.27	46.90
1980/81	0.02	0.03	0.10	0.02	0.00	0.01	0.00	0.00	0.00	0.01	0.84	47.74
1981/82	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.51	48.25
1982/83	0.03	0.01	0.01	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.14	48.39
1983/84	0.03	0.30	0.08	0.04	0.03	0.01	0.00	0.00	0.01	0.01	0.19	48.58
AVERAGE	0.04	0.11	0.12	0.10	0.04	0.02	0.01	0.01	0.01	0.02	1.12	49.70
% TOTAL	5.61	13.98	16.00	17.75	12.39	4.97	2.03	1.07	1.41	1.75	100.00	

MFAN(CLOS)=-0.168399 STD. DEV.= 0.248588 MEAN ANNUAL VALUE = 0.78

NATURALIZED STREAMFLOW UPSTREAM FROM ZAAIHOEK DAM (10**5 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1920/21	73.10	38.12	2.85	2.56	7.79	28.19	22.79	1.83	1.10	0.71	0.50	0.51	180.02	180.02
1921/22	1.06	59.37	59.15	11.83	2.68	2.61	2.07	1.54	1.23	0.96	1.09	1.42	155.02	335.04
1922/23	27.30	52.41	34.29	14.26	6.85	2.28	1.00	0.45	0.35	0.41	0.46	0.39	140.96	476.00
1923/24	0.47	0.86	1.30	2.21	3.03	9.56	9.05	1.72	1.05	0.69	0.53	0.54	31.41	507.41
1924/25	1.67	16.26	16.84	16.01	21.21	72.76	67.50	2.29	1.45	0.96	0.68	0.94	218.47	725.38
1925/26	1.62	9.32	9.16	2.36	3.14	3.74	3.01	1.30	1.16	1.33	1.32	1.32	38.41	764.29
1926/27	1.99	1.96	2.23	24.09	52.09	31.54	3.30	1.43	0.71	0.90	1.25	0.91	122.45	886.74
1927/28	4.09	4.83	13.50	14.05	3.00	4.53	3.72	1.83	1.18	0.76	0.62	0.89	53.00	939.74
1928/29	1.17	1.12	5.51	7.23	3.49	24.25	24.07	1.54	1.10	1.34	1.20	4.03	76.06	1015.80
1929/30	17.10	20.44	17.47	36.31	26.87	1.69	0.92	0.62	0.45	0.52	0.72	0.72	123.33	1139.63
1930/31	0.60	0.55	1.27	26.66	27.29	2.79	2.10	1.43	0.84	0.71	0.80	0.58	65.67	1205.30
1931/32	0.42	0.78	1.21	1.38	25.74	36.39	12.51	2.15	1.71	1.42	0.85	0.54	85.30	1290.60
1932/33	0.74	1.49	2.30	2.16	2.37	2.82	2.07	1.25	0.72	0.69	1.42	1.41	247.68	1556.22
1933/34	0.62	34.57	71.94	82.46	46.25	2.83	2.25	1.67	1.20	1.06	1.42	0.45	66.40	1622.62
1934/35	1.11	5.12	25.53	22.39	2.95	3.15	2.56	1.35	0.74	0.57	0.48	0.45	98.79	1721.41
1935/36	0.62	0.79	1.03	22.62	23.41	13.44	12.93	10.34	10.56	1.65	0.82	0.58	223.33	1944.74
1936/37	0.86	27.42	27.94	45.40	80.64	37.30	1.40	0.69	0.45	0.38	0.35	0.50	66.35	2011.09
1937/38	1.04	1.14	25.12	26.21	2.51	1.69	1.86	1.97	1.47	1.26	1.14	0.84	66.35	2259.06
1938/39	9.05	3.03	20.11	34.88	86.54	74.95	5.34	1.50	1.11	1.26	1.71	1.61	247.97	2340.25
1939/40	1.32	25.23	28.27	5.23	2.92	2.48	1.94	3.82	4.73	2.81	1.55	0.89	57.42	2397.67
1940/41	0.83	1.09	1.80	17.59	18.04	3.23	3.23	2.47	1.24	0.63	0.47	0.44	65.53	2463.20
1941/42	1.97	14.67	35.79	23.81	2.66	10.51	9.91	1.63	1.26	1.13	0.88	1.01	156.53	2559.73
1942/43	0.68	2.70	9.10	9.37	39.35	39.19	2.01	0.85	1.05	1.65	1.23	1.24	110.31	2770.04
1943/44	2.57	2.75	1.65	1.04	1.56	16.74	16.61	1.24	0.62	0.47	0.42	0.36	45.90	2815.94
1944/45	2.43	0.31	0.34	4.57	10.72	15.14	9.64	1.16	0.58	0.45	0.40	0.35	43.97	2859.91
1945/46	0.31	1.76	1.84	1.67	11.39	11.86	2.30	1.45	0.87	0.87	0.90	0.67	36.45	2398.36
1946/47	0.87	5.18	17.33	23.03	11.73	2.63	2.39	1.45	0.78	0.54	0.44	0.65	66.87	2963.23
1947/48	0.67	1.64	1.63	11.25	18.24	9.02	7.32	6.95	1.48	0.77	0.54	0.56	60.49	3023.72
1948/49	1.09	1.17	11.28	11.31	2.78	2.83	3.15	2.75	1.38	1.09	0.87	0.88	42.34	3066.06
1949/50	1.00	1.43	3.22	3.67	9.80	9.70	1.94	1.36	1.07	0.80	1.14	1.52	36.65	3102.71
1951/52	6.70	6.77	1.87	10.16	10.02	1.61	1.38	1.18	0.76	1.05	1.47	1.02	43.99	3146.70
1952/53	0.59	13.49	14.51	2.36	37.27	37.61	2.46	1.69	0.99	0.62	0.56	0.58	112.73	3259.43
1953/54	0.61	9.06	9.88	2.16	13.32	13.90	2.72	1.98	1.49	1.02	0.66	0.80	57.60	3317.03
1954/55	1.61	9.78	9.59	16.53	50.31	40.51	6.93	1.70	0.97	0.64	0.50	0.42	139.49	3456.52
1955/56	0.89	1.97	2.63	2.16	16.03	41.93	27.63	1.61	1.23	0.89	0.61	0.61	98.19	3554.71
1956/57	1.62	16.59	50.96	37.11	2.86	11.32	11.23	1.99	1.18	1.64	2.54	2.3	162.69	3717.40
1957/58	31.51	10.18	1.72	35.62	35.95	1.85	2.14	2.37	1.39	0.69	0.51	0.71	124.64	3842.04
1958/59	1.34	2.07	18.57	18.50	2.16	2.06	1.83	1.65	1.58	1.09	0.68	0.67	52.20	3894.24
1959/60	1.33	14.18	14.57	2.24	2.21	2.75	3.10	2.72	1.52	0.77	0.71	0.92	47.02	3941.26
1960/61	2.45	9.18	55.87	23.09	6.29	8.92	27.51	5.51	3.79	2.01	1.24	0.99	146.85	4088.11
1961/62	4.25	11.41	22.52	22.96	8.11	3.56	1.19	0.85	0.53	0.42	0.37	0.65	75.82	4164.93
1962/63	0.77	3.85	8.74	11.59	6.33	1.59	0.65	0.66	1.72	51.73	4.40	1.44	103.36	4268.29
1963/64	1.94	18.66	5.57	17.85	8.03	1.71	0.39	0.71	0.47	0.80	0.55	0.34	57.24	4325.53
1964/65	10.73	26.35	13.24	8.60	15.08	1.54	1.32	0.57	0.22	0.18	0.40	0.37	30.05	4405.58
1965/66	0.74	9.67	4.30	8.02	10.80	1.21	0.47	0.29	0.22	0.18	0.40	0.37	36.67	4442.25
1966/67	0.82	0.82	8.28	17.61	46.66	7.36	7.86	1.81	1.18	0.99	0.78	0.61	94.78	4537.03
1967/68	0.36	12.89	5.94	2.61	1.10	3.32	1.40	0.49	0.29	0.20	0.45	0.38	29.43	4566.46
1968/69	0.11	3.60	11.45	4.53	1.78	6.20	11.06	2.54	1.04	0.74	0.57	0.33	44.00	4610.46

NATURALIZED STREAMFLOW UPSTREAM FROM ZAAIHOEK DAM (10***6 M**3 / A)

YEAR	UCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1969/70	9.01	2.88	9.53	4.73	10.03	1.81	0.49	0.45	0.40	0.30	0.61	0.30	40.54	4651.00
1970/71	2.94	3.14	0.75	9.24	5.30	4.37	16.46	4.36	1.72	0.88	0.63	0.78	50.57	4701.57
1971/72	1.89	6.78	33.31	14.89	15.23	21.32	7.95	2.75	1.63	0.97	0.80	0.45	107.97	4809.54
1972/73	0.38	1.21	1.93	1.25	11.80	3.60	11.44	1.59	0.66	0.62	4.86	2.07	41.55	4851.09
1973/74	8.80	10.94	15.43	17.09	27.33	8.72	10.63	1.27	2.18	2.13	1.07	0.76	106.35	4957.44
1974/75	0.41	9.54	43.35	41.13	31.95	15.25	5.80	2.44	1.69	1.26	1.08	4.05	158.45	5115.89
1975/76	3.67	9.55	34.35	24.77	40.84	27.37	24.39	12.93	3.55	2.88	2.56	1.60	188.45	5304.35
1976/77	7.39	12.05	10.14	17.84	50.11	10.16	5.95	2.04	1.57	0.98	0.87	1.60	119.86	5424.21
1977/78	1.09	1.27	4.78	38.81	18.10	16.65	3.54	1.67	1.15	1.12	0.85	1.32	90.36	5514.57
1978/79	7.21	3.28	2.93	1.33	1.65	0.57	0.31	0.20	0.16	0.31	0.69	1.04	19.63	5534.20
1979/80	0.90	2.13	3.37	10.42	19.02	5.57	0.88	0.39	0.31	0.29	0.41	0.38	44.57	5578.77
1980/81	0.47	2.36	7.04	5.26	15.71	9.23	1.03	0.90	0.53	0.42	0.48	3.25	46.68	5625.45
1981/82	1.18	1.38	1.35	6.51	1.00	0.45	0.21	0.13	0.14	0.16	0.35	0.29	13.16	5638.61
1982/83	0.12	1.23	0.29	0.87	0.48	0.11	0.27	9.04	0.09	0.11	0.60	0.32	4.53	5643.14
1983/84	0.69	3.50	15.61	13.61	27.77	8.78	4.49	2.07	2.16	6.27	2.76	11.77	99.48	5742.62
AVERAGE	4.29	9.38	14.45	15.43	17.38	12.84	7.79	2.51	1.34	1.81	1.02	1.50	89.73	
% TOTAL	4.78	10.45	16.11	17.20	19.36	14.32	8.67	2.80	1.49	2.01	1.14	1.67	100.00	

MEAN(CLOG) = 1.853441 STD. DEV. = 0.321241 MEAN ANNUAL VALUE = 89.73

NATURALIZED STREAMFLOW UPSTREAM OF SCHURVEPOORT WEIR (10**6 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1920/21	105.90	55.23	4.14	3.71	11.29	40.77	33.02	2.65	1.59	1.02	0.73	0.74	260.81	260.81
1921/22	1.53	86.01	100.19	17.14	3.88	3.77	3.01	2.24	1.78	1.39	1.57	2.05	224.56	485.37
1922/23	40.28	75.92	49.63	20.65	9.93	3.31	1.46	0.64	0.52	0.59	0.56	0.57	204.21	589.58
1923/24	0.69	1.25	1.89	3.19	4.40	13.85	13.12	2.49	1.52	0.99	0.77	1.35	45.51	735.09
1924/25	2.41	23.56	24.11	23.20	30.73	105.39	97.93	3.32	2.09	1.38	0.98	1.35	316.45	1051.54
1925/26	2.34	13.49	13.27	3.42	4.54	5.42	4.35	1.88	1.67	1.92	1.38	1.90	55.58	1107.12
1926/27	2.88	2.95	3.22	34.89	75.46	45.70	4.78	2.15	1.03	1.31	1.81	1.31	177.39	1284.51
1927/28	5.93	7.00	19.56	20.37	4.35	6.57	5.38	2.64	1.72	1.11	0.89	1.30	76.80	1361.31
1928/29	1.69	1.62	7.99	10.47	5.05	35.15	34.87	2.22	1.59	1.93	1.73	5.84	110.15	1471.46
1929/30	24.77	29.50	25.30	52.60	38.92	2.44	1.33	0.90	0.65	0.75	1.05	1.04	179.35	1650.81
1930/31	0.88	0.79	1.83	38.63	39.53	4.05	3.03	2.15	1.21	1.02	1.17	0.85	95.14	1745.95
1931/32	0.60	1.13	3.32	1.99	37.29	52.71	18.11	3.11	2.76	2.05	1.23	0.77	123.50	1869.45
1932/33	1.07	2.16	3.32	3.14	3.43	4.08	3.00	1.80	1.05	1.01	1.08	0.83	25.97	1895.42
1933/34	0.89	50.08	104.22	119.46	66.99	4.11	3.27	2.43	1.73	1.53	2.06	2.05	358.82	2254.24
1934/35	1.62	7.42	36.98	32.44	4.27	4.56	3.71	1.96	1.06	0.82	0.70	0.64	96.18	2350.42
1935/36	0.90	1.14	1.43	32.76	33.90	19.47	2.02	14.99	15.30	2.38	1.19	0.84	143.07	2493.49
1936/37	1.24	39.71	40.48	65.77	116.82	54.04	2.02	1.01	0.66	0.54	0.50	0.73	323.52	2817.01
1937/38	1.50	1.64	36.38	37.96	3.63	2.45	2.70	2.86	2.12	1.83	1.65	1.36	56.08	2913.09
1938/39	13.10	14.35	29.12	50.52	125.37	108.56	7.73	2.18	1.60	1.83	2.47	2.34	359.17	3372.26
1939/40	1.91	36.54	40.96	7.58	4.24	3.59	2.80	5.53	6.84	4.08	2.24	1.29	117.60	3389.86
1940/41	1.20	4.39	27.04	27.27	6.32	4.67	4.68	3.57	1.79	0.91	0.69	0.63	83.16	3473.02
1941/42	0.98	1.59	2.60	25.48	26.13	15.23	14.36	2.35	1.83	1.64	1.27	1.46	94.92	3567.94
1942/43	2.86	21.26	51.84	34.49	3.85	27.86	74.32	50.40	3.10	3.08	5.99	5.64	284.69	3852.63
1943/44	3.72	3.90	13.17	13.58	57.00	56.77	2.90	1.22	1.53	3.08	1.79	1.80	159.77	4012.40
1944/45	3.53	3.98	2.40	1.50	2.25	24.26	24.05	1.79	0.90	0.69	0.60	0.51	66.46	4078.86
1945/46	0.44	0.45	0.50	6.63	15.52	21.92	13.97	1.68	0.83	0.66	0.58	0.51	63.69	4142.55
1946/47	1.27	2.54	2.67	2.43	16.49	17.17	3.32	2.09	1.14	1.25	1.30	0.98	52.76	4195.31
1947/48	0.98	7.50	25.11	33.37	16.99	3.88	3.47	2.09	1.14	0.79	0.63	0.93	96.88	4292.19
1948/49	1.59	2.37	2.36	16.30	26.43	13.06	10.61	10.07	2.15	1.11	0.77	0.80	87.62	4379.81
1949/50	1.69	3.34	16.35	16.39	4.03	4.17	4.56	3.98	2.72	1.58	1.26	1.27	61.34	4441.15
1950/51	1.44	2.06	4.66	5.31	14.19	14.06	2.82	1.97	1.54	1.17	1.66	2.20	53.08	4494.23
1951/52	9.71	9.80	2.71	14.71	14.51	2.34	1.99	1.71	1.09	1.51	2.13	1.47	163.28	4557.91
1952/53	0.85	19.54	21.01	3.43	53.98	54.48	3.57	2.45	1.44	0.89	0.80	0.84	83.44	4804.63
1953/54	0.88	13.12	14.31	3.14	19.29	20.14	3.95	2.87	2.15	1.47	0.96	1.16	202.08	5006.71
1954/55	2.34	14.17	13.89	23.95	72.89	58.67	10.04	2.46	1.41	0.93	0.73	0.89	142.28	5183.99
1955/56	1.30	2.86	3.81	3.14	23.22	60.74	40.02	2.34	1.78	1.29	0.89	34.25	235.69	5384.68
1956/57	2.34	24.04	73.82	53.76	4.15	16.39	16.27	2.89	1.70	1.00	3.69	1.04	180.56	5565.24
1957/58	45.64	14.74	2.49	51.61	52.07	2.63	3.09	3.44	2.02	1.00	0.74	0.97	75.64	5640.88
1958/59	1.93	3.01	26.91	26.81	3.13	2.98	2.64	2.40	2.30	1.58	0.98	1.33	68.09	5708.97
1959/60	1.93	20.55	21.11	3.24	3.20	3.98	4.48	3.93	2.21	1.11	1.02	1.43	212.69	5921.66
1960/61	3.56	13.30	80.93	33.44	9.10	12.91	39.84	7.98	5.49	2.91	1.80	1.43	111.23	6032.89
1961/62	6.15	16.54	32.61	33.25	11.74	5.15	1.72	1.24	0.76	0.60	0.53	0.94	149.70	6182.59
1962/63	1.12	5.57	12.65	31.11	9.18	2.30	1.30	0.95	2.49	0.76	0.79	0.50	82.94	6265.53
1963/64	2.81	27.04	8.06	25.85	11.64	2.47	1.91	1.03	0.69	1.15	0.79	0.80	115.95	6381.48
1964/65	15.54	38.18	19.17	12.45	21.85	2.23	1.91	0.83	0.41	0.25	0.59	0.54	53.07	6434.55
1965/66	1.06	1.20	6.22	11.61	15.64	1.76	0.63	0.41	0.31	0.25	0.59	0.54	137.36	6571.91
1966/67	1.19	1.20	12.00	25.52	67.58	10.67	11.39	2.63	1.72	1.43	1.14	0.89	42.64	6614.55
1967/68	0.53	18.67	8.60	3.79	1.60	4.80	2.04	0.70	0.43	0.28	0.66	0.54	63.72	6678.27
1968/69	0.15	5.21	16.58	6.55	2.58	8.99	16.02	3.68	1.51	1.03	0.83	0.54	63.72	6678.27

NATURALIZED STREAMFLOW UPSTREAM OF SCHURVEPOORT WEIR (10**6 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1969/70	13.04	4.18	13.31	6.85	14.54	2.63	0.72	0.64	0.58	0.44	0.89	0.43	58.75	6737.02
1970/71	4.26	4.55	1.08	13.38	7.67	6.33	23.84	6.32	2.49	1.28	0.91	1.14	73.25	6810.27
1971/72	2.74	9.81	48.25	21.58	22.05	30.89	11.51	3.99	2.36	1.41	1.16	0.65	156.41	6965.68
1972/73	0.56	1.75	2.85	1.80	17.09	5.21	16.57	2.43	0.95	0.90	7.03	3.01	60.16	7026.84
1973/74	12.74	15.84	22.36	24.75	39.58	12.53	15.40	1.85	3.17	3.09	1.54	1.10	154.05	7180.39
1974/75	0.60	13.32	63.51	59.57	46.27	22.08	8.40	3.53	2.45	1.52	1.56	5.86	229.47	7410.36
1975/76	5.31	13.33	49.76	35.89	59.16	39.65	35.32	18.74	5.14	4.18	3.70	2.32	273.00	7683.36
1976/77	10.70	17.45	14.69	25.85	72.58	14.72	8.61	2.95	2.28	1.43	1.25	1.11	173.53	7856.99
1977/78	1.57	1.85	6.92	56.22	26.22	24.12	5.13	2.42	1.67	1.63	1.24	1.92	130.91	7937.90
1978/79	10.45	4.75	4.17	1.92	2.38	0.93	0.45	0.30	0.24	0.44	1.00	1.51	28.45	8016.35
1979/80	1.31	3.09	5.60	15.10	27.55	8.08	1.27	0.56	0.45	0.43	0.60	0.55	64.59	8080.94
1980/81	0.68	3.41	10.21	7.63	22.76	13.37	1.50	1.30	0.77	0.60	0.70	4.72	67.65	8148.59
1981/82	1.70	2.00	1.95	9.44	1.44	0.66	0.30	0.20	0.21	0.23	0.52	0.43	19.08	8167.67
1982/83	0.18	1.79	0.43	1.26	0.70	0.16	0.40	0.07	0.14	0.17	0.86	0.47	6.63	8174.30
1983/84	0.99	5.06	22.62	19.72	40.22	12.73	6.50	3.01	3.13	9.09	4.00	17.04	144.11	8318.41
AVERAGE	6.21	13.59	20.93	22.36	25.17	18.61	11.27	3.63	1.94	2.62	1.48	2.17	129.93	
% TOTAL	4.78	10.45	16.11	17.20	19.36	14.32	8.67	2.80	1.49	2.01	1.14	1.67	100.00	

MEAN(LOG) = 2.014430 STD. DEV. = 0.320981 MEAN ANNUAL VALUE = 129.98

NATURALIZED STREAMFLOW UPSTREAM OF CHELMSFORD DAM (10**6 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1920/21	18.02	8.93	3.50	2.69	4.60	23.25	13.01	2.73	1.20	0.68	0.44	1.74	80.84	80.84
1921/22	2.57	95.61	81.95	22.85	7.06	8.90	5.93	2.82	1.84	1.26	1.31	2.56	235.16	316.00
1922/23	8.69	43.36	30.30	39.56	20.37	3.90	1.13	0.41	0.39	0.59	0.53	0.41	149.73	465.73
1923/24	0.57	0.81	1.05	9.22	14.32	10.14	5.20	2.27	0.99	0.59	0.50	1.45	47.12	512.85
1924/25	2.91	9.38	17.63	11.33	19.91	130.40	62.62	5.84	2.14	1.09	0.69	1.02	265.01	777.86
1925/26	1.99	3.77	3.31	4.22	5.41	5.17	3.14	1.37	1.13	1.22	0.79	2.97	34.54	812.40
1926/27	4.61	4.57	5.35	13.76	24.59	23.40	9.23	1.79	0.59	0.77	1.03	0.73	90.43	902.83
1927/28	1.91	2.22	3.94	6.97	6.25	6.30	4.74	2.23	0.98	0.58	0.57	1.16	37.85	940.68
1928/29	2.07	1.90	2.93	3.96	3.38	36.95	19.52	2.36	1.40	2.13	1.91	4.56	82.97	1023.65
1929/30	6.08	22.60	14.53	36.46	19.31	3.39	1.93	1.29	0.73	0.66	0.87	0.99	108.84	1132.49
1930/31	1.05	0.74	3.63	47.26	26.54	5.52	2.58	1.18	0.57	0.56	0.57	0.37	79.46	1302.52
1931/32	0.41	1.10	1.47	2.37	34.15	24.20	6.71	3.37	2.74	1.60	0.80	0.54	22.38	1324.90
1932/33	0.61	1.41	3.90	3.32	2.13	2.96	3.12	1.87	0.89	0.85	0.82	0.50	238.94	1563.84
1933/34	0.36	15.81	22.67	122.75	57.93	5.42	3.19	2.47	1.77	1.70	2.68	2.19	109.19	1673.03
1934/35	1.79	4.72	43.70	23.74	7.38	12.87	8.40	3.17	1.45	0.85	0.57	0.55	95.19	1768.22
1935/36	0.72	0.55	0.78	4.86	16.43	32.50	14.96	11.93	8.13	2.66	1.01	0.56	202.30	1970.52
1936/37	1.18	35.61	18.88	62.04	60.40	18.43	2.87	2.10	0.55	0.40	0.34	0.44	44.21	2014.73
1937/38	0.59	0.62	10.34	9.33	6.18	3.96	2.89	2.10	2.04	2.51	2.19	1.46	130.27	2145.00
1938/39	4.22	4.70	22.93	18.12	41.14	3.12	5.38	2.63	1.88	2.07	2.17	1.61	103.40	2248.40
1939/40	1.41	20.28	34.91	16.16	5.26	3.12	1.77	4.51	7.13	5.15	2.19	1.51	58.41	2346.81
1940/41	1.68	4.05	25.72	16.73	16.57	11.45	11.31	6.87	2.06	0.83	0.54	0.49	103.72	2450.53
1941/42	0.77	1.00	1.99	33.25	37.09	14.96	5.02	3.05	2.11	1.43	1.21	1.84	353.72	2804.25
1942/43	3.91	48.44	48.43	51.80	22.06	17.14	73.16	35.51	4.45	4.45	28.68	15.69	198.63	3002.88
1943/44	12.01	22.49	52.18	25.00	48.69	25.33	3.14	0.88	1.73	2.31	1.36	3.51	48.07	3050.95
1944/45	10.70	7.00	2.24	1.06	1.70	12.00	8.37	2.61	1.04	0.60	0.43	0.32	50.97	3101.92
1945/46	0.24	0.16	0.12	2.55	5.44	25.23	13.29	2.02	0.77	0.50	0.37	0.28	98.41	3200.33
1946/47	1.57	4.91	4.78	2.86	44.75	26.04	6.11	2.77	1.52	1.40	1.01	0.69	128.45	3328.78
1947/48	1.04	11.53	32.92	45.52	19.96	7.20	5.00	2.42	1.11	0.64	0.43	0.61	105.18	3433.96
1948/49	2.32	3.18	2.50	28.77	35.49	15.59	7.92	5.30	2.13	0.86	0.51	0.61	36.91	3572.50
1949/50	2.21	4.58	33.94	24.69	9.45	5.96	6.62	6.48	3.88	1.74	1.17	0.91	35.64	3608.14
1950/51	1.56	2.00	4.25	5.26	5.88	5.48	4.87	2.32	1.26	0.98	1.94	2.10	118.06	3726.20
1951/52	2.47	1.76	2.43	10.11	7.01	2.96	2.08	1.41	0.81	1.60	1.10	1.18	127.80	3854.00
1952/53	0.63	3.95	5.30	3.58	61.19	38.84	8.06	3.00	0.92	0.58	0.43	0.33	156.29	4010.29
1953/54	3.75	26.70	14.64	28.51	51.91	22.56	4.12	1.84	2.20	1.41	0.75	0.59	73.44	4083.73
1954/55	1.35	2.43	2.69	2.12	8.93	32.73	15.98	2.93	1.90	1.10	0.59	0.59	212.37	4296.10
1955/56	1.95	17.82	56.39	30.42	8.90	19.03	12.49	4.38	1.96	4.15	5.97	48.91	142.43	4438.53
1956/57	47.00	14.67	2.45	18.07	14.99	14.09	18.06	8.35	2.14	0.83	0.52	0.76	53.45	4491.98
1957/58	2.48	4.06	5.92	5.60	14.07	9.56	3.95	2.97	2.14	1.27	0.79	0.64	40.63	4532.66
1958/59	2.53	5.73	6.25	4.45	4.75	4.33	4.60	3.68	1.75	0.79	0.82	0.98	113.36	4651.02
1959/60	1.59	2.97	57.63	28.69	2.61	3.77	7.18	6.83	3.76	1.63	0.76	0.94	81.60	4732.62
1960/61	0.69	5.66	11.11	26.73	26.85	6.50	1.20	0.48	0.37	0.11	0.59	0.41	47.48	4780.10
1961/62	0.85	5.08	6.98	18.34	4.91	6.14	0.53	0.05	0.10	3.84	0.24	0.41	44.20	4824.30
1962/63	2.80	17.45	3.45	10.54	3.43	4.01	0.04	0.07	0.66	0.39	0.59	0.77	175.23	4999.53
1963/64	15.51	49.75	31.80	25.57	37.31	6.03	2.85	0.70	0.62	1.37	1.77	1.90	59.31	5058.84
1964/65	1.00	3.77	4.59	18.01	21.87	2.57	2.21	1.32	1.10	0.81	1.36	0.70	208.79	5257.63
1965/66	1.60	5.69	26.67	46.31	94.19	12.35	11.72	4.29	1.20	1.08	1.36	1.33	35.80	5303.43
1966/67	2.23	6.00	5.42	1.87	2.32	8.12	1.35	1.35	0.71	1.76	1.47	3.20	70.21	5373.64
1967/68	0.71	4.03	9.83	8.58	1.49	14.51	23.01	2.95	1.67	0.97	0.73	1.73		

NATURALIZED STREAMFLOW UPSTREAM OF CHELMSFORD DAM (10**5 M**3 / A)

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YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1969/70	12.63	3.81	15.25	3.69	31.68	3.03	0.09	0.31	0.11	0.95	1.65	1.33	74.53	5448.17
1970/71	10.93	4.62	0.53	21.46	24.03	11.87	14.07	3.85	1.50	1.07	2.27	0.33	96.58	5544.75
1971/72	2.21	1.66	17.75	29.92	36.57	51.81	11.40	2.71	1.84	0.93	0.32	0.30	157.47	5702.22
1972/73	0.87	3.22	1.99	0.63	5.04	0.95	9.86	0.25	0.31	0.20	4.50	1.22	29.03	5731.25
1973/74	2.69	9.35	10.56	48.60	77.89	12.69	14.52	3.05	1.20	2.39	1.13	0.30	184.37	5915.62
1974/75	0.25	12.06	15.03	31.56	119.50	22.11	11.15	3.00	2.06	0.63	2.47	9.55	229.42	6145.04
1975/76	2.89	5.03	27.64	68.27	56.04	43.34	24.47	18.16	3.53	2.34	2.28	1.29	255.28	6400.32
1976/77	9.70	3.99	3.54	23.05	54.62	20.21	8.40	0.85	0.93	1.34	0.76	0.27	127.66	6527.98
1977/78	0.33	2.74	6.93	86.44	46.17	33.02	7.67	2.08	0.14	1.71	1.38	2.85	191.46	6719.44
1978/79	3.76	4.39	9.11	3.36	7.33	0.77	1.38	0.13	0.11	0.35	1.63	1.07	33.39	6752.83
1979/80	1.44	0.85	3.89	23.81	29.53	13.37	1.41	0.49	0.93	0.75	0.93	1.04	78.44	6831.27
1980/81	0.27	1.32	5.81	14.51	43.92	14.10	1.91	0.83	1.28	0.92	0.95	4.30	90.12	6921.39
1981/82	0.60	1.13	0.39	7.45	0.58	0.56	0.28	0.13	0.39	0.59	0.51	0.40	13.11	6934.50
1982/83	0.70	1.99	0.96	1.39	1.06	1.32	0.59	0.10	0.15	0.22	0.44	0.43	9.35	6943.85
1983/84	1.31	16.08	16.56	45.01	18.11	32.88	12.23	1.91	1.51	1.20	1.83	2.25	150.88	7094.73
AVERAGE	3.76	10.01	14.53	22.07	25.04	16.35	8.84	3.36	1.59	1.31	1.65	2.34	110.86	
% TOTAL	3.39	9.03	13.11	19.91	22.59	14.75	7.98	3.03	1.43	1.18	1.49	2.11	100.00	

MEAN(LOG)= 1.944305 STD. DEV.= 0.320585 MEAN ANNUAL VALUE = 110.86

NATURALIZED STREAMFLOW UPSTREAM OF RDYPOINT (10***S M***3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1920/21	4.60	2.29	0.89	0.69	1.17	5.93	3.32	0.70	0.31	0.17	0.11	0.44	20.62	20.62
1921/22	0.66	24.33	20.90	5.83	1.80	2.27	1.51	0.72	0.47	0.32	0.46	0.65	59.97	30.59
1922/23	2.22	11.06	7.73	10.09	5.19	0.39	0.29	0.10	0.10	0.15	0.16	0.10	38.18	118.77
1923/24	0.15	0.21	0.27	2.35	3.65	2.59	1.33	0.58	0.25	0.15	0.13	0.37	12.03	130.80
1924/25	0.74	2.39	4.51	2.89	5.08	33.25	15.97	1.49	0.55	0.28	0.18	0.25	67.59	198.39
1925/26	0.51	0.36	0.84	1.08	1.38	1.32	0.80	0.35	0.30	0.31	0.20	0.76	8.81	207.20
1926/27	1.18	1.17	1.37	3.51	6.27	5.97	2.35	0.46	0.15	0.20	0.26	0.19	23.08	230.28
1927/28	0.49	0.57	1.00	1.78	1.59	1.61	1.21	0.57	0.25	0.15	0.15	0.30	9.67	239.95
1928/29	0.53	0.48	0.75	1.01	0.86	9.40	4.98	0.60	0.36	0.54	0.49	1.16	21.16	261.11
1929/30	1.55	5.76	3.71	9.30	4.92	0.86	0.43	0.33	0.19	0.17	0.22	0.25	27.75	288.86
1930/31	0.27	0.19	0.93	12.05	6.77	1.41	0.66	0.30	0.15	0.14	0.15	0.09	23.11	311.97
1931/32	0.10	0.23	0.37	0.60	8.71	6.17	1.71	0.86	0.70	0.41	0.20	0.14	20.25	332.22
1932/33	0.16	0.36	0.99	0.85	0.54	0.75	0.80	0.48	0.23	0.22	0.21	0.13	5.72	337.94
1933/34	0.09	4.03	5.78	31.30	14.77	1.38	0.81	0.63	0.45	0.43	0.68	0.56	60.91	398.85
1934/35	0.46	1.20	11.14	6.05	1.88	3.28	2.14	0.81	0.37	0.22	0.15	0.14	27.84	426.69
1935/36	0.18	0.17	0.20	1.24	1.88	8.29	3.81	3.04	2.07	0.64	0.26	0.14	24.27	450.96
1936/37	0.30	9.08	4.81	15.82	15.40	4.70	0.73	0.29	0.14	0.10	0.09	0.11	51.57	502.53
1937/38	0.15	0.16	2.64	2.38	10.49	1.01	0.74	0.54	0.52	0.22	0.56	0.37	11.29	513.82
1938/39	1.08	1.20	5.85	4.62	1.58	5.97	1.37	0.67	0.48	0.53	0.55	0.41	33.22	547.04
1939/40	0.36	0.36	8.90	4.12	1.34	9.46	0.45	1.15	1.82	1.31	0.56	0.39	26.37	573.41
1940/41	0.43	1.04	6.56	8.27	4.25	2.92	2.88	1.75	0.53	0.21	0.14	0.42	25.10	598.51
1941/42	0.20	0.25	0.51	4.48	9.46	3.81	1.28	0.78	0.54	0.21	0.31	0.47	26.45	624.96
1942/43	1.00	12.35	12.35	13.21	5.63	4.37	18.66	9.06	1.13	1.13	7.31	4.00	90.20	715.16
1943/44	3.06	5.73	13.31	6.37	12.42	6.46	0.80	0.22	0.44	0.59	0.35	0.90	50.65	765.81
1944/45	0.06	0.04	0.03	0.65	0.43	3.05	2.13	0.67	0.27	0.15	0.11	0.08	12.25	778.06
1945/46	0.40	1.25	1.22	0.73	11.41	6.64	3.39	0.52	0.20	0.13	0.09	0.07	13.00	791.06
1946/47	0.27	2.94	8.39	11.61	5.09	1.84	1.27	0.62	0.28	0.36	0.26	0.18	25.11	816.17
1947/48	0.59	0.81	0.64	7.34	9.05	3.98	2.02	1.35	0.54	0.22	0.11	0.17	32.75	848.92
1948/49	0.56	1.17	8.65	6.30	2.41	1.52	1.69	1.65	0.99	0.44	0.30	0.23	26.83	875.75
1949/50	0.40	0.51	1.03	1.34	1.50	1.40	0.99	0.59	0.32	0.25	0.49	0.54	9.41	901.66
1950/51	0.63	0.45	0.63	2.58	1.79	0.75	0.53	0.36	0.21	0.41	0.48	0.27	30.10	920.16
1951/52	0.16	1.01	1.35	4.36	13.70	6.59	1.24	0.64	0.29	0.16	0.28	0.32	32.57	952.36
1952/53	0.23	0.75	0.95	0.91	15.60	9.90	2.06	0.76	0.56	0.36	0.19	0.30	39.85	1022.68
1953/54	0.96	6.81	3.73	7.27	13.24	5.75	1.05	0.47	0.23	0.15	0.11	0.08	39.85	1041.41
1954/55	0.34	0.62	0.69	0.54	2.28	8.35	4.07	0.75	0.48	0.28	0.15	0.18	18.73	1095.56
1955/56	0.50	4.54	14.38	7.76	2.27	4.85	3.18	1.12	0.50	1.06	1.52	12.47	1041.41	1095.56
1956/57	11.98	3.74	0.62	4.61	3.82	3.59	4.61	2.26	0.55	0.21	0.13	0.19	54.15	1131.87
1957/58	0.63	1.04	1.51	1.43	3.59	2.44	1.01	0.76	0.55	0.32	0.20	0.16	36.31	1145.51
1958/59	0.65	1.46	1.59	1.13	1.21	1.11	1.17	0.94	0.45	0.20	0.21	0.25	10.37	1155.88
1959/60	0.41	0.76	14.70	7.32	0.67	0.96	1.83	1.74	0.96	0.42	0.19	0.24	30.20	1186.08
1960/61	0.18	1.44	2.83	6.82	5.85	1.66	0.31	0.12	0.09	0.03	0.15	0.33	20.81	1206.89
1961/62	0.22	1.30	1.78	4.68	1.25	1.57	0.14	0.01	0.03	0.98	0.06	0.10	12.12	1219.01
1962/63	0.71	4.45	0.83	2.69	0.87	1.02	0.01	0.02	0.17	0.10	0.15	0.20	11.27	1230.28
1963/64	3.96	12.69	8.11	6.52	9.51	1.55	0.73	0.18	0.16	0.35	0.45	0.48	44.69	1274.97
1964/65	0.25	0.96	1.17	4.59	5.58	0.66	0.56	0.34	0.28	0.21	0.35	0.18	15.13	1290.10
1965/66	0.41	1.45	6.80	11.81	24.02	3.15	2.99	1.09	0.31	0.28	0.47	0.47	53.25	1343.35
1966/67	0.41	1.53	1.34	0.48	0.59	2.07	0.34	0.34	0.18	0.45	0.37	0.82	9.12	1352.47
1967/68	0.57	1.03	2.51	2.19	0.38	3.70	5.87	0.75	0.43	0.25	0.19	0.44	17.92	1370.39
1968/69	0.18	1.03												

NATURALIZED STREAMFLOW UPSTREAM OF ROYPOINT (10**6 M**3 / A)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1969/70	3.22	0.97	3.89	0.94	8.08	0.77	0.02	0.03	0.03	0.24	0.42	0.34	19.00	1389.39
1970/71	2.79	1.18	0.15	5.47	6.13	3.03	3.59	0.98	0.38	0.27	0.58	0.08	24.63	1414.02
1971/72	0.56	0.42	4.53	7.63	9.33	13.21	2.91	0.69	0.47	0.25	0.08	0.03	40.16	1454.18
1972/73	0.22	0.82	0.50	0.16	1.29	0.24	2.51	0.05	0.08	0.05	1.15	0.31	7.39	1461.57
1973/74	0.69	2.38	2.69	12.39	19.86	3.24	3.70	0.78	0.31	0.61	0.29	0.08	47.02	1508.59
1974/75	0.06	3.08	3.85	8.05	30.47	5.64	2.84	0.76	0.53	0.16	0.63	2.44	58.51	1567.10
1975/76	0.74	1.28	7.05	17.41	14.29	11.05	6.24	4.63	0.90	0.60	0.58	0.33	65.10	1632.20
1976/77	2.47	1.02	0.90	5.88	13.93	5.15	2.14	0.22	0.24	0.34	0.19	0.07	32.55	1664.75
1977/78	0.08	0.70	1.77	22.04	11.77	8.42	1.96	0.53	0.04	0.44	0.35	0.73	48.83	1713.58
1978/79	0.96	1.12	2.32	0.86	1.87	0.20	0.35	0.03	0.03	0.09	0.42	0.27	8.52	1722.10
1979/80	0.37	0.22	0.93	6.07	7.53	3.41	0.36	0.12	0.24	0.19	0.24	1.10	20.01	1742.11
1980/81	0.07	0.34	1.43	3.70	11.20	3.60	0.49	0.21	0.33	0.23	0.24	0.10	22.99	1765.10
1981/82	0.15	0.29	0.10	1.90	0.15	0.17	0.07	0.03	0.10	0.15	0.13	0.10	3.34	1768.44
1982/83	0.18	0.51	0.24	0.35	0.27	0.34	0.15	0.03	0.04	0.06	0.11	0.11	2.39	1770.83
1983/84	0.33	4.10	4.22	11.48	4.62	8.38	3.12	0.49	0.39	0.31	0.47	0.57	38.48	1809.31
AVERAGE	0.96	2.55	3.71	5.63	6.38	4.17	2.25	0.86	0.41	0.33	0.42	0.60	28.27	
% TOTAL	3.39	9.03	13.11	19.91	22.58	14.75	7.97	3.03	1.44	1.13	1.49	2.11	100.00	

MEAN(LOG) = 1.350924 STD. DEV. = 0.320502 MEAN ANNUAL VALUE = 28.27

RAINFALL AT ZAAIHOEK DAM (MM)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1920/21	271.10	84.09	126.56	92.06	160.29	189.41	30.46	25.95	0.96	0.00	0.00	23.16	1004.04	1004.04
1921/22	142.80	326.34	139.12	120.89	176.15	75.63	7.59	29.89	20.37	0.00	68.81	47.95	1206.04	2210.08
1922/23	264.66	212.57	119.07	85.72	119.64	27.20	19.03	30.00	10.09	12.97	5.36	1.25	878.26	3088.34
1923/24	110.03	116.47	94.65	238.04	90.43	131.03	54.58	30.45	0.67	0.00	7.21	97.05	823.66	3912.00
1924/25	57.73	237.37	66.60	238.04	93.60	259.23	56.22	24.12	18.74	7.98	0.00	38.60	1260.53	5112.58
1925/26	97.73	196.14	107.54	106.57	112.05	54.43	5.09	47.57	64.10	0.00	0.00	118.30	871.12	6003.70
1926/27	45.74	134.15	163.18	144.63	104.65	56.51	42.19	1.25	0.00	61.60	0.00	25.75	845.01	6343.71
1927/28	207.86	68.52	300.22	95.81	158.08	153.28	42.19	7.02	0.00	0.00	11.15	76.38	845.01	7969.82
1928/29	66.60	59.01	162.79	149.82	130.02	94.18	42.86	12.11	56.87	19.41	5.77	132.91	965.62	8935.44
1929/30	193.55	67.56	150.78	236.41	110.80	18.16	42.19	0.00	1.25	32.39	25.75	10.47	904.97	9940.41
1930/31	25.75	108.30	88.32	108.21	88.32	18.16	42.19	0.00	0.00	57.76	0.00	0.00	904.97	10888.55
1931/32	30.46	137.62	150.11	73.13	155.87	81.59	56.89	69.57	25.37	2.59	0.00	16.91	898.33	11486.88
1932/33	84.95	137.62	150.11	73.13	155.87	81.59	56.89	69.57	25.37	2.59	0.00	16.91	898.33	11486.88
1933/34	58.33	334.52	290.61	279.84	93.21	97.15	56.51	31.42	6.92	29.89	0.00	14.51	791.48	12278.36
1934/35	64.48	177.02	238.81	131.27	118.97	113.88	16.82	13.25	5.00	43.73	53.82	9.51	1358.66	13637.02
1935/36	64.77	53.43	125.22	270.71	92.25	171.83	13.84	150.97	5.67	1.15	3.55	18.26	903.15	14540.17
1936/37	72.94	273.98	94.18	310.50	248.23	43.53	32.10	0.00	0.00	1.25	0.00	27.29	973.68	15513.85
1937/38	90.72	36.13	260.53	131.95	63.14	73.42	111.67	6.25	0.00	0.00	0.00	56.03	1131.49	16645.34
1938/39	183.55	89.95	231.70	184.22	420.05	124.74	19.99	47.19	0.00	66.21	39.79	33.64	1441.03	18981.86
1939/40	64.29	248.03	124.74	129.25	119.74	86.30	59.49	115.32	38.73	14.61	23.83	24.51	1060.85	20022.71
1940/41	39.59	174.23	197.10	130.79	134.06	108.50	78.03	0.00	0.00	0.00	2.79	46.90	885.93	20908.64
1941/42	75.63	94.75	152.41	189.61	108.59	165.29	29.31	31.91	31.52	0.19	0.86	22.58	952.63	21861.27
1942/43	123.58	192.30	203.59	99.56	111.28	173.75	218.15	47.28	2.31	104.56	69.19	32.00	1383.55	23244.82
1943/44	119.16	94.75	175.19	157.32	265.43	89.95	2.50	2.50	87.16	0.00	0.00	99.13	1053.14	24337.95
1944/45	115.22	81.97	44.69	103.31	103.50	186.72	9.71	7.21	0.00	0.00	1.25	7.21	660.79	24998.75
1945/46	15.95	54.97	39.02	187.88	127.43	130.89	7.02	8.94	0.00	0.48	1.05	9.23	582.87	25531.52
1946/47	109.94	100.14	85.34	113.11	134.06	77.25	50.16	0.00	17.01	35.75	4.23	16.43	743.43	26325.05
1947/48	62.75	156.16	183.74	161.26	84.86	127.04	29.79	10.96	0.00	0.10	0.00	62.37	879.03	27204.08
1948/49	53.43	137.33	52.65	200.08	140.40	85.72	134.25	12.88	3.46	0.00	0.00	40.84	861.82	28065.90
1949/50	93.70	151.74	185.57	104.65	87.55	120.61	74.77	42.28	5.77	1.73	38.25	22.87	929.49	28995.39
1950/51	77.17	121.75	162.41	130.89	158.08	60.93	40.27	40.55	5.19	4.32	79.28	26.33	907.18	29902.57
1951/52	173.65	27.77	160.78	177.11	55.16	82.55	60.06	7.59	0.00	78.03	0.10	6.63	829.43	30732.00
1952/53	42.00	231.41	106.95	80.34	241.60	95.43	63.71	14.42	2.31	0.00	23.64	14.22	916.04	31648.04
1953/54	202.48	202.48	105.04	117.53	170.96	99.56	48.63	42.57	6.44	2.40	1.54	68.62	911.23	32559.27
1954/55	102.54	169.52	62.65	232.85	259.66	147.90	45.26	18.16	1.35	2.11	4.90	7.59	1054.50	33613.77
1955/56	111.28	130.79	149.82	66.89	211.90	210.46	9.99	56.03	0.00	7.11	0.29	47.47	1002.03	34615.80
1956/57	143.77	151.07	267.25	111.00	125.12	150.38	71.79	10.38	21.91	84.28	50.84	187.01	1375.30	35991.10
1957/58	135.12	53.82	129.25	266.77	63.23	61.31	124.16	1.92	0.00	0.00	0.00	80.24	915.82	36906.92
1958/59	78.99	128.77	223.43	109.65	104.65	96.48	32.48	77.84	0.29	5.48	3.84	52.76	914.66	37821.58
1959/60	101.48	199.12	122.43	90.33	146.26	105.61	112.24	5.86	0.10	2.50	32.67	50.15	968.76	38790.34
1960/61	98.21	198.93	326.15	82.26	115.22	143.38	130.41	53.14	27.97	0.10	0.48	99.94	1281.20	40071.54
1961/62	75.63	168.56	172.02	176.73	102.83	74.86	49.11	11.24	2.88	0.00	18.16	45.34	897.96	40969.50
1962/63	54.10	195.76	140.21	242.65	38.15	100.04	37.96	15.09	91.10	195.76	0.00	4.13	1114.95	42084.45
1963/64	31.01	191.14	42.19	230.83	55.54	55.16	53.91	0.48	7.50	0.00	0.00	16.82	781.97	42866.42
1964/65	285.42	181.09	135.12	205.17	92.93	44.21	46.42	4.61	31.42	9.42	24.51	29.41	1019.73	43886.15
1965/66	70.44	153.86	102.73	114.65	131.65	12.20	18.45	14.70	6.34	0.00	22.20	68.42	715.65	44601.80
1966/67	102.83	50.26	218.34	259.28	233.43	63.14	63.04	7.50	0.00	27.10	8.36	14.70	1047.98	45649.78
1967/68	93.79	177.88	145.50	108.69	44.11	153.47	13.07	4.42	0.29	2.02	4.305	7.21	793.50	46443.28
1968/69	33.92	182.78	142.71	141.46	78.61	166.64	79.28	41.71	2.21	4.90	0.10	56.12	935.44	47378.72

RAINFALL AT ZAAIHOEK DAM (MM)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1969/70	147.80	99.56	178.75	113.78	114.55	36.71	28.54	12.11	13.65	11.34	32.96	38.25	823.00	48206.72
1970/71	135.31	101.00	81.40	183.74	72.36	66.31	146.26	43.05	0.96	1.92	14.30	41.42	882.53	49035.25
1971/72	120.03	171.92	169.81	200.46	148.67	114.25	29.60	36.13	1.92	0.00	3.17	3.94	999.91	50095.16
1972/73	59.10	159.43	82.84	144.53	196.81	101.58	120.32	4.42	0.00	0.86	83.03	32.74	1035.66	51130.82
1973/74	76.02	152.13	135.21	168.18	132.81	34.66	94.38	23.93	19.60	24.70	6.63	11.53	919.78	52050.60
1974/75	50.64	209.21	236.12	210.27	179.61	88.60	49.97	12.97	0.10	0.67	0.19	90.91	1129.26	53179.86
1975/76	65.54	146.36	160.97	139.92	128.29	138.19	78.80	55.45	0.00	0.00	2.40	20.47	936.35	54116.25
1976/77	121.28	113.49	212.43	206.71	105.57	109.65	22.87	0.38	0.00	0.00	8.17	60.45	962.95	55078.30
1977/78	100.14	129.06	130.50	260.82	161.05	70.92	52.47	7.88	0.00	0.00	42.09	72.36	1027.30	56105.60
1978/79	152.80	123.49	114.84	72.65	61.89	45.84	42.38	4.23	4.61	38.54	79.47	81.78	822.52	56928.12
1979/80	58.81	107.44	127.24	211.42	216.51	19.22	13.55	2.31	0.43	0.00	6.44	61.89	825.31	57753.43
1980/81	43.44	188.45	126.47	180.38	191.24	116.67	34.69	22.97	10.57	7.78	31.71	64.10	1018.47	58771.90
1981/82	68.90	82.45	98.50	187.97	24.03	56.12	10.57	4.23	1.25	9.42	0.00	14.99	558.43	59330.33
1982/83	118.30	34.50	39.85	88.89	34.40	98.41	41.90	53.43	10.47	12.59	39.21	5.48	627.43	59957.76
1983/84	156.64	160.68	215.17	356.34	93.31	133.77	35.08	1.35	29.12	58.52	75.25	24.39	1340.12	61297.88
AVERAGE	100.05	143.16	150.12	160.08	133.22	104.50	52.79	23.27	11.97	16.97	17.72	43.93	957.78	
% TOTAL	10.45	14.95	15.67	16.71	13.91	10.91	5.51	2.43	1.25	1.77	1.85	4.59	100.00	

MEAN(LOG) = 2.973200 STD. DEV. = 0.084633 MEAN ANNUAL VALUE = 957.78

RAINFALL AT CHELMSFORD DAM (MM)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1920/21	167.68	75.36	104.23	98.53	142.90	163.05	34.29	20.25	0.66	0.00	0.00	104.09	916.03	916.09
1921/22	49.27	360.88	213.83	126.23	128.87	135.55	31.55	39.28	13.03	1.70	71.22	50.63	1227.25	2143.34
1922/23	151.76	213.65	164.76	211.10	107.95	19.78	10.55	4.14	14.04	18.18	3.53	1.60	921.09	3054.43
1923/24	58.69	50.66	83.45	195.46	145.54	120.20	31.46	13.47	0.09	1.41	12.43	84.21	812.07	3376.50
1924/25	82.24	169.75	170.88	136.78	165.51	363.71	76.11	19.69	5.65	7.44	1.22	64.34	1263.32	5139.82
1925/26	75.17	132.26	75.45	156.56	108.24	97.50	18.09	13.23	42.01	0.00	0.00	132.54	851.10	5990.92
1926/27	68.01	117.56	144.03	170.69	165.13	149.02	10.64	0.75	0.00	37.59	15.45	4.14	883.01	6873.93
1927/28	115.39	55.58	167.11	154.68	93.92	132.45	29.86	14.41	0.28	0.00	22.89	61.32	847.89	7721.82
1928/29	73.29	62.27	144.60	113.61	76.36	222.31	19.50	8.01	47.01	40.32	6.31	142.05	956.24	8678.06
1929/30	70.46	190.75	136.68	215.15	79.13	54.64	52.38	4.80	2.35	20.32	24.96	33.63	685.75	9563.81
1930/31	45.78	36.55	191.41	236.07	120.39	62.17	35.23	0.09	0.28	20.35	0.00	0.94	749.26	10313.07
1931/32	46.35	95.24	81.53	124.16	219.25	134.80	16.11	79.32	6.59	2.54	0.00	23.93	825.87	11139.94
1932/33	60.88	105.22	154.58	55.58	86.19	107.11	49.55	2.17	6.31	27.83	0.57	4.43	640.47	11779.41
1933/34	29.48	221.18	172.57	374.73	72.63	99.57	42.67	48.51	1.04	46.82	60.01	6.12	1175.33	12954.74
1934/35	77.90	162.87	229.94	117.66	143.09	139.13	54.54	12.62	10.83	0.09	4.52	31.65	984.84	13939.58
1935/36	42.01	46.82	85.25	188.78	154.68	172.76	27.69	142.52	0.19	1.32	0.00	18.84	880.86	14820.44
1936/37	82.61	237.95	62.17	300.97	187.93	56.71	34.76	0.00	0.47	0.75	0.09	34.76	999.17	15819.61
1937/38	33.72	56.14	211.01	129.62	111.34	52.00	77.34	5.56	60.85	27.04	25.43	23.27	813.32	16632.93
1938/39	151.66	69.24	214.21	155.34	204.04	127.64	4.33	63.58	2.54	55.77	19.88	31.84	1100.07	17733.00
1939/40	56.99	211.76	194.43	116.71	101.92	44.37	47.29	126.51	59.53	1.04	1.41	63.40	1025.36	18758.36
1940/41	49.08	159.48	196.12	147.33	153.36	111.16	124.34	0.00	0.00	4.99	1.13	27.32	974.31	19732.67
1941/42	53.22	67.73	125.19	230.79	168.19	100.79	55.95	34.57	24.59	0.00	37.49	64.90	2476.41	22209.08
1942/43	112.00	240.02	194.99	222.41	84.59	169.65	232.67	47.19	1.51	101.55	138.10	11.59	1556.27	23765.35
1943/44	162.59	167.02	234.37	121.14	231.36	73.66	1.51	6.41	34.50	0.00	0.00	137.16	1219.72	24985.07
1944/45	126.89	60.10	67.54	67.16	103.62	169.84	39.28	7.54	2.35	0.47	1.04	9.80	655.63	25640.70
1945/46	10.64	29.11	38.25	179.07	121.24	174.08	10.64	13.09	0.00	0.00	0.19	7.06	583.37	26224.07
1946/47	113.61	150.15	88.83	86.00	248.41	114.92	54.35	0.38	38.15	0.00	1.70	25.56	935.31	27159.38
1947/48	66.13	192.26	199.33	207.33	110.03	125.29	35.80	17.14	0.00	0.94	0.00	51.90	1006.15	28165.53
1948/49	103.90	89.96	86.29	231.45	169.94	110.40	111.16	3.67	1.51	0.28	0.19	43.24	951.99	29117.52
1949/50	107.20	131.41	217.70	158.73	117.28	94.95	116.05	53.41	2.83	4.05	31.56	11.40	1046.57	30164.09
1950/51	91.66	74.32	167.85	112.38	130.94	87.79	53.98	19.69	3.20	24.12	67.92	22.14	856.00	31020.09
1951/52	92.60	26.85	151.00	173.52	62.74	74.04	46.72	11.30	0.28	68.58	1.51	10.83	719.97	31740.06
1952/53	37.87	182.47	104.00	189.15	221.46	84.40	66.13	2.35	4.43	0.09	59.25	13.66	965.26	32705.32
1953/54	37.40	155.43	91.84	121.14	268.00	137.34	22.61	57.93	14.41	0.00	0.00	73.85	979.95	33685.27
1954/55	118.88	192.54	82.99	222.22	205.83	85.63	39.94	11.30	3.20	2.07	0.00	11.02	976.00	34661.27
1955/56	100.98	92.60	105.03	75.74	178.04	178.13	11.49	60.76	1.41	0.00	0.38	46.91	851.47	35512.74
1956/57	93.92	190.94	242.75	153.36	122.46	157.69	82.99	5.65	21.01	108.14	46.82	205.26	1430.99	36943.73
1957/58	151.47	53.32	80.16	214.02	137.25	142.05	126.98	1.32	0.38	2.54	0.00	54.92	964.41	37908.14
1958/59	105.13	113.51	157.41	105.97	167.02	83.18	50.59	55.43	0.00	11.96	2.35	30.24	882.84	38790.98
1959/60	122.93	153.07	121.61	97.03	131.41	68.77	104.00	10.36	0.00	0.94	36.83	27.69	874.64	39665.62
1960/61	79.79	117.47	278.55	47.29	77.53	136.68	117.55	44.84	4.80	0.00	0.00	60.10	964.61	40630.23
1961/62	45.69	142.71	102.02	190.38	157.97	49.64	45.88	1.79	0.00	33.25	0.00	28.26	797.59	41427.82
1962/63	29.86	130.37	120.20	182.94	21.85	99.29	29.39	13.94	47.67	87.23	0.00	0.19	762.93	42190.75
1963/64	83.46	126.51	59.35	186.89	88.27	58.78	55.77	1.41	39.09	2.64	18.93	50.30	771.40	42962.15
1964/65	214.96	130.28	137.25	156.37	121.80	18.93	47.38	4.52	41.54	14.98	25.15	34.85	948.01	43910.16
1965/66	91.09	107.76	80.15	246.43	79.69	6.59	57.84	24.87	1.04	0.00	30.43	49.17	775.07	44685.23
1966/67	63.87	94.48	174.27	329.70	139.70	93.92	23.82	3.77	0.00	1.32	0.38	9.89	1005.12	45690.35
1967/68	48.98	124.34	112.38	71.97	30.90	104.19	93.83	11.30	0.00	1.04	49.55	7.15	585.74	46276.09
1968/69	16.11	125.10	123.90	167.49	110.97	175.05	105.41	24.87	7.25	14.51	0.00	31.65	909.32	47185.41

RAINFALL AT CHELMSFORD DAM (MM)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	ACCUMULATED
1969/70	155.24	65.28	121.33	123.50	158.54	37.68	38.25	23.36	6.59	13.47	59.91	34.95	838.10	48023.51
1970/71	113.23	107.20	61.70	206.11	103.34	94.77	88.92	70.08	1.98	18.75	35.42	32.12	933.62	43957.13
1971/72	97.21	85.53	202.25	162.37	147.61	212.14	23.83	22.04	3.53	0.94	7.35	0.57	965.92	49923.05
1972/73	93.73	131.88	75.03	119.07	160.71	77.24	110.97	0.85	0.00	0.47	80.92	77.43	928.35	50851.40
1973/74	54.26	188.63	106.15	257.54	201.78	66.88	34.69	4.24	25.72	15.33	13.38	9.04	1028.20	51879.60
1974/75	48.80	183.22	170.13	197.54	487.36	65.00	72.72	11.49	0.00	0.00	3.30	156.84	1396.90	53276.50
1975/76	47.38	152.79	234.93	315.57	183.60	255.38	51.15	60.57	0.00	2.26	4.14	24.96	1332.73	54609.23
1976/77	144.60	76.58	129.52	220.62	80.54	137.44	31.34	13.33	0.00	1.60	2.07	50.87	889.06	55493.29
1977/78	79.03	41.54	157.79	238.23	132.63	148.65	94.58	0.00	0.00	0.00	49.27	43.24	924.96	56483.25
1978/79	124.72	34.38	50.40	97.59	159.39	43.90	19.83	6.50	8.95	55.30	69.14	83.03	753.23	57236.43
1979/80	42.39	96.74	170.69	220.05	213.27	104.66	11.02	1.51	0.00	0.00	4.05	93.35	957.73	58194.21
1980/81	77.53	111.06	173.99	140.36	201.21	33.72	36.64	3.20	33.44	0.00	32.12	71.50	914.77	59108.98
1981/82	40.51	76.96	77.71	142.05	48.98	125.10	4.33	13.47	2.25	2.64	0.00	14.50	548.61	59697.59
1982/83	146.48	53.32	42.96	104.66	41.82	87.04	31.27	42.30	4.80	14.98	22.61	10.83	603.07	60260.66
1983/84	129.81	207.62	259.24	189.25	53.60	206.49	42.77	0.19	18.18	14.22	71.59	19.97	1212.93	51473.59
AVERAGE	85.10	123.68	140.44	168.89	163.46	113.18	53.30	22.55	11.40	14.29	20.49	43.75	960.52	
% TOTAL	8.86	12.88	14.62	17.58	17.02	11.78	5.55	2.35	1.19	1.49	2.13	4.56	100.00	

MEAN(LOG) = 2.968743 STD. DEV. = 0.105701 MEAN ANNUAL VALUE = 960.52

APPENDIX B

LISTINGS OF DATA FOR ANALYSIS PROGRAMS

	Page
1. Optimization Program Input Files	B - 1
2. Simulation Program Input Files	
2.1 Existing Operating Rule	B - 4
2.2 Combined System Simulation Files	B - 14
2.3 Zaaihoek Simulation Files	B - 23
2.4 Chelmsford Simulation Files	B - 30

6 2 2 7 4 -1 1977
 1 1 1 15 CHELMSFORD DAM
 0

10	34.43	1245.11	1230.00	1245.11	1245.11	1234.50
1245.11	1245.11	1245.11	1245.11	1245.11	1245.11	1245.11
1245.11	1245.11	1245.11	1245.11	1245.11	1245.11	1245.11
116.	126.	109.	101.	88.	85.	69.
64.	68.	100.	100.	88.	85.	69.
1226.52	1236.22	1238.11	1239.47	1240.57	1241.52	1242.37
1243.86	1245.11	1238.11	1239.47	1240.57	1241.52	1242.37
0.00	19.92	39.77	59.70	79.61	99.50	119.45
159.36	199.10	199.10	199.10	199.10	199.10	199.10
0.530	8.476	12.649	16.609	19.605	22.272	24.633
29.188	34.430	34.430	34.430	34.430	34.430	34.430

1 2 14 ZAAIHOEK DAM

0	10	12.69	1730.00	1700.00	1730.00	1705.30
1730.00	1730.00	1730.00	1730.00	1730.00	1730.00	1730.00
1730.00	1730.00	1730.00	1730.00	1730.00	1730.00	1730.00
116.	126.	109.	101.	88.	85.	69.
64.	68.	100.	100.	88.	85.	69.
1687.00	1690.00	1695.00	1700.00	1705.00	1710.00	1720.00
1725.00	1730.00	1695.00	1700.00	1705.00	1710.00	1720.00
0.00	0.05	1.04	7.07	18.92	36.20	60.52
141.54	199.26	199.26	199.26	199.26	199.26	199.26
0.00	0.04	0.59	1.80	2.88	4.06	5.78
10.41	12.69	12.69	12.69	12.69	12.69	12.69

3 0 0 17 ROYPOINT ABSTRACTION

1 3 3 SCURVEPOORT WEIR

5 0 0 NEWCASTLE

1 2 2 12 CONFLUENCE

3 10 0 0 CONFLUENCE

2 11 13 CONFLUENCE

2 13 11 CONFLUENCE

18 1 0 0.053

1 5 0.000

1 3 0.000

2 0 0.000

2 4 0.000

2 0 1.500

2 4 0.000

3 0 0.324

3 3 0.040

3 5 0.000

3 6 0.000

4 5 0.000

4 6 0.000

5 0 0.824

5 0 0.592

6 0 0.000

6 0 0.015

0 0 0.015

\DANHAUSER DEMAND
 \NEWCASTLE LINK
 \STREAMFLOW
 \VOLKSRUST
 \VOLKSRUST RETURN
 \MAJUBA SUPPLY-YIELD
 \ZAAIHOEK - SCHURVEPOORT
 \ISCOR SUPPLY
 \ISCOR RETURN FLOW
 \ROYPOINT TO NEWCASTLE
 \ROYPOINT TO CONFLUENCE
 \SCHURVEPOORT TO NEWCASTLE
 \SCHURVEPOORT TO CONFLUENCE
 \NEWCASTLE RETURN FLOW
 \NEWCASTLE DEMAND
 \COMPENSATION RELEASE
 \SYSTEM SPILLAGE
 \MINE DEWATERING

2
3 5
1 2
0.0 1.0

```

***** VAA' :- DP ALGORITHM 28 STATES
-1 2 28 2 2 1 1
0.0032 0.0001 0.1 2.0
0.0032 0.0001 0.1 2.0
40
3
1 1245.11 1245.11
2 1230.00 1245.11
29 1234.50 1234.50
3
1 1730.00 1730.00
2 1700.00 1730.00
29 1705.30 1705.30
1
1 0.00 9999.
1
1 0.00 9999.
1245.1100 1730.0000
1245.0225 1729.4890
1245.1100 1730.0000
1245.0219 1729.3203
1244.6471 1728.3672
1244.9326 1728.3263
1245.0520 1727.4883
1244.5498 1726.2429
1244.0552 1725.0565
1243.9381 1724.5438
1245.1100 1725.5603
1244.7201 1725.3533
1244.2256 1723.6630
1244.2385 1723.2432
1245.1100 1725.0317
1244.8323 1723.6833
1244.4756 1722.4839
1244.0300 1721.4530
1244.1232 1721.0830
1243.4949 1719.4196
1242.7974 1717.2551
1242.3420 1715.4573
1241.9285 1712.9746
1241.2070 1709.8793
1240.3589 1705.6013
1241.6909 1706.3455
1245.0099 1714.1846
1245.1100 1711.9122
1234.5000 1705.3000

```

BUFFALO-VAAL SUBSYSTEM YIELD ANALYSIS
ANALYSIS OF THE EXISTING OPERATING POLICY
1920-1983 REFERENCE HYDROLOGY HISTORICAL RECORDS
768 1 1921 1 758 -3
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
31.00 28.25 31.00 30.00 31.00 30.00 31.00 31.00 30.00 31.00 30.00 31.00
64 1 1 4 H 0
1
30.00
54.67

4	4	MCM	2	1	1	14	41	2	10	1.
ZAAIHDEK DAM										
12.690		.000		1	1	14	41	2	10	1.
0										
1587.00		1690.00		1695.00		1700.00	1705.00		1710.00	1715.00
1725.00		1730.00								1720.00
0.00		0.05		1.04		7.07	13.92		36.20	60.52
141.54		199.26		0.59		1.80	2.88		4.06	5.78
0.00		0.04		126.		109.	101.		83.	85.
10.41		12.69		33.		100.				59.
116.		126.								
64.		68.								
CHELMSFORD DAM										
34.430		.000		2	2	15	42	1	10	1.
0										
1226.52		1236.22		1239.11		1239.47	1240.57		1241.52	1242.37
1243.86		1245.11								1243.15
0.00		19.92		39.77		59.70	79.61		99.50	119.45
159.36		199.10		12.649		16.609	19.605		22.272	24.633
0.530		8.476								26.835
29.189		34.430		126.		109.	101.		88.	85.
115.		126.		83.		100.				69.
54.		68.								
NODE NUMBER 43										
0.000		.000		0	3	17	43	0	0	1.
0										
SCHURWEPDOORT WEIR										
0.000		.000		0	4	15	45	0	0	1.
0										

73 - NEWCASTLE RETURN FLOW
76 - ISCOR RETURN FLOW

77 - DURMACOL MINE DEWATERING

```

7 1 1 2 1 1000. 1000.
SURCHG 3 1 1 1000. 1000.
DRDWN 3 1 1 1. 2.
LEVEL1 3 1 1 11. 12.
LEVEL2 3 1 1 21. 22.
LEVEL3 3 1 1 31. 32.
LEVEL4 3 1 1 41. 42.
EVAPST 3 1 1 1000. 1000.
41 1 1730.00 1700.00 1687.00 \ ZAAIHOEK DAM
42 1 1245.11 1230.63 1226.52 \ CHELMSFORD DAM
0
41 1715.60 1715.60 1715.60 1715.60 1715.60 1715.60 1715.60 1715.60 1715.60 1715.60
41 1713.00 1713.00 1713.00 1713.00 1713.00 1713.00 1713.00 1713.00 1713.00 1713.00
41 1711.80 1711.80 1711.80 1711.80 1711.80 1711.80 1711.80 1711.80 1711.80 1711.80
41 1710.60 1710.60 1710.60 1710.60 1710.60 1710.60 1710.60 1710.60 1710.60 1710.60
41 1701.00 1701.00 1701.00 1701.00 1701.00 1701.00 1701.00 1701.00 1701.00 1701.00
42 1239.82 1239.82 1239.82 1239.82 1239.82 1239.82 1239.82 1239.82 1239.82 1239.82
42 1237.95 1237.95 1237.95 1237.95 1237.95 1237.95 1237.95 1237.95 1237.95 1237.95
42 1237.26 1237.26 1237.26 1237.26 1237.26 1237.26 1237.26 1237.26 1237.26 1237.26
42 1236.67 1236.67 1236.67 1236.67 1236.67 1236.67 1236.67 1236.67 1236.67 1236.67
42 1231.00 1231.00 1231.00 1231.00 1231.00 1231.00 1231.00 1231.00 1231.00 1231.00

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411730.00 421245.11

0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044
CHELMSFORD IRRIGATION
0.307 0.307 0.307 0.307 0.307 0.307 0.307 0.307 0.307 0.307 0.307 0.307 0.307 0.307 0.307
0.153 0.153 0.153 0.153 0.153 0.153 0.153 0.153 0.153 0.153 0.153 0.153 0.153 0.153 0.153
0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044 0.044
NGJE 46 IRRIGATION
0.263 0.263 0.263 0.263 0.263 0.263 0.263 0.263 0.263 0.263 0.263 0.263 0.263 0.263 0.263
0.131 0.131 0.131 0.131 0.131 0.131 0.131 0.131 0.131 0.131 0.131 0.131 0.131 0.131 0.131
0.092 0.092 0.092 0.092 0.092 0.092 0.092 0.092 0.092 0.092 0.092 0.092 0.092 0.092 0.092

```
SYSTEM ENERGY DEMAND          99  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
WATER YIELD DISTRIBUTION      61  
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
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BU-FALO-VAAL SUBSYSTEM YIELD ANALYSIS
ANALYSIS OF NEW OPERATING RULES
1920-1983 REFERENCE HYDROLOGY HISTORICAL RECORDS
768 1 1921 1 768 -3 1 0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
31.00 28.25 31.00 30.00 31.00 30.00 31.00 31.00 30.00 31.00 30.00 31.00
64 1 1 4 H 0
1
54.00 51.50 45.00 50.00 52.50 55.00 57.50 60.00 65.00
34.67 94.67 94.67 94.67 94.67 94.67 94.67 94.67 94.67 94.67 94.67 94.67

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4      4      MCM      2
ZAAIHDEK DAM
12.690      .000      1      14      41      2      10      1.
0
1687.00      1690.00      1695.00      1700.00      1705.00      1710.00      1715.00      1720.00
1725.00      1730.00
0.00      0.05      1.04      7.07      18.92      36.20      60.52      95.13
141.54      199.26      0.59      1.80      2.88      4.06      5.78      8.10
0.00      0.04      10.41      12.69      109.      88.      85.      69.
116.      126.      126.      109.
54.      69.      93.      100.
CHELMSFORD DAM
34.430      .000      2      2      16      42      1      10      1.
0
1226.52      1236.22      1238.11      1239.47      1240.57      1241.52      1242.37      1243.15
1243.86      1245.11
0.00      19.92      39.77      59.70      79.61      99.50      119.45      139.50
159.36      199.10      12.649      16.609      19.605      22.272      24.633      26.835
29.133      34.430      116.      126.      109.      88.      85.      69.
54.      68.      83.      100.
NODE NUMBER 43
0.000      .000      0      3      17      43      0      0      1.
0
SCHURWEPDORT WEIR
0.000      .000      0      4      15      45      0      0      1.
0

```

```

3
1 3 200.0 0.0 200.0 0.
2 2 0.0 500.0
3 2 0.0 400.0
4 2 0.0 1.0
5 1 0.0
6 1 2.0
7 2 0.0 500.0
8 1 1.0
9 1 0.0
2
19 99 99 1
51 41 0 1
0
0
1 77 0 42 7
0
0
11
56 46 0 2
57 41 0 2
58 41 45 2
59 45 44 4
70 42 44 5
71 43 44 6
72 44 0 2
73 44 46 2
74 42 0 2
75 43 0 2
76 43 46 2
5
52 41 45 5
53 42 43 5
54 45 46 8
55 43 46 5
31 31 46 0 9
17
61 - YIELD TO MAJUBA
62 - SPILLAGE FROM ZAAIHOEK
63 - SPILLAGE FROM CHELMSFORD
64 - SPILLAGE FROM SCHURVEPOORT
65 - SPILLAGE FROM NODE 43
66 - SPILLAGE AND COMPENSATION
67 - VOLKSRUST SUPPLY
69 - SCHURVEPOORT NEWCASTLE LINK
70 - CHELMSFORD NEWCASTLE LINK
71 - 43 - NEWCASTLE LINK
72 - NEWCASTLE SUPPLY
74 - DANHAUSER SUPPLY
75 - ISCOR SUPPLY
81 - SYSTEM SPILLAGE
59 68 - VOLKSRUST RETURN FLOW
73 - NEWCASTLE RETURN FLOW
76 - ISCOR RETURN FLOW

\ WATER YIELD
\ MUNICIPAL DEMAND
\ IRRIGATION DEMAND
\ CHANNEL 69
\ GENERAL FLOW CHANNEL
\ PUMPING CHANNEL
\ MINE DEWATERING
\ ALTERNATIVE CHANNEL
\ SYSTEM SPILL CHANNELS

\ POWER CONTROL CH
\ WATER YIELD
\ #POWER CHANNELS
\ IRRIGATION PROJECT
\ DIVERSION CHANNELS

\ WATER SUPPLY
\ LOSS CHANNEL
\ MIN_MAX CHANNELS

\ GENERAL FLOW ARCS

\ CHANNELS FOR OUTPUT

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52 - SPILLAGE FROM ZAAIH05K
63 - SPILLAGE FROM CHELMSFORD
64 - SPILLAGE FROM SCHURVEPOORT
65 - SPILLAGE FROM NODE 43
66 - DOWNSTREAM COMPENSATION
67 - VOLKSRUST SUPPLY
68 - VOLKSRUST RETURN FLOW
69 - SCHURVEPOORT NEWCASTLE LINK
70 - CHELMSFORD NEWCASTLE LINK
71 - 43 - NEWCASTLE LINK
72 - NEWCASTLE SUPPLY
73 - NEWCASTLE RETURN FLOW
74 - DANNHAUSER SUPPLY
75 - ISCOR SUPPLY
76 - ISCOR RETURN FLOW
77 - DURNACOL MINE DEWATERING
81 - SYSTEM SPILLAGE

```

4 1 2
SURCHG 3 1 1000. 1000.
DRDYN 3 1 1. 2.
LEVEL4 3 1 10. 20.
DSL 3 1 1000. 1000.
41 1 0. 1730.00 1687.00 1687.00 \ ZAAIHJEK DAM
42 1 0. 1245.11 1226.52 1226.52 \ CHELMSFORD DAM
0
41 1730.00 1730.00 1730.00 1730.00 1730.00 1730.00 1730.00 1730.00 1730.00 1730.00
41 1700.00 1700.00 1700.00 1700.00 1700.00 1700.00 1700.00 1700.00 1700.00 1700.00
42 1245.11 1245.11 1245.11 1245.11 1245.11 1245.11 1245.11 1245.11 1245.11 1245.11
42 1230.63 1230.63 1230.63 1230.63 1230.63 1230.63 1230.63 1230.63 1230.63 1230.63

```

411730.00 421245.11


```

COMPENSATION D/S NODE 46
0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252
0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252 0.252
VOLKSRUST SUPPLY 66
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.300 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
VOLKSRUST RETURN FLOW 67
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
SCHURVEPDDORT NEWCASTLE LINK 68
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.300 0.300 0.300 0.300 0.300 0.300 0.300 0.300 0.300 0.300 0.300 0.300 0.300 0.300
CHELMSFORD NEWCASTLE LINK 69
0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860
RDYPOINT TO NEWCASTLE LINK 70
0.610 0.610 0.610 0.610 0.610 0.610 0.610 0.610 0.610 0.610 0.610 0.610 0.610 0.610
NEWCASTLE SUPPLY 71
0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526
0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526 0.526
NEWCASTLE RETURN FLOW 72
0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275
0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275 0.275
DANNHAUSER SUPPLY 73
0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018
0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018 0.018
ISCOR SUPPLY 74
0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276
0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276 0.276
ISCOR RETURN FLOW 75
0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040
0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040 0.040

```

```
SYSTEM ENERGY DEMAND          99  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
WATER YIELD DISTRIBUTION      61  
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
```

BUFFALO-VAAL SUBSYSTEM YIELD ANALYSIS
ANALYSIS OF ZAAIHOEK YIELD
1920-1983 REFERENCE HYDROLOGY HISTORICAL RECORDS
768 1 1921 1 768 -3 0 0
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
31.00 30.00 31.00 31.00 28.25 31.00 30.00 31.00 30.00 31.00 31.00 30.00
64 1 7 8 H 0
1
20.00 45.00 47.64 50.00 55.00 60.00 65.00
94.67 94.67 94.67 94.67 94.67 94.67 94.67 94.67 94.67 94.67
EWATER4.NATFLOW.BINJPARAM26.DAT

	1	1	MCM	1		41	1	10	1.
ZAAIHOEK DAM									
12.590	.000	1	14						
0									
1687.00	1690.00	1695.00	1700.00	1705.00	1710.00	1715.00	1720.00		
1725.00	1730.00	1.04	7.07	18.92	36.20	50.52	95.13		
0.00	0.05								
141.54	199.26	0.59	1.80	2.88	4.06	5.78	8.10		
0.00	0.04								
10.41	12.69	126.	109.	101.	83.	85.	69.		
116.	126.	83.	100.						
64.	58.								

411730.00


```
SYSTEM ENERGY DEMAND          99  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
WATER YIELD DISTRIBUTION      61  
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
```

BUFFALO-VAAL SUBSYSTEM YIELD ANALYSIS
 ANALYSIS OF CHELMSFORD YIELD
 1920-1983 REFERENCE HYDROLOGY HISTORICAL RECORDS
 768 1 1921 1 768 -3 0
 JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
 31.00 28.25 31.00 30.00 31.00 30.00 31.00 31.00 30.00 31.00 30.00 31.00
 64 1 1 1 4 H 0
 1
 65.00 73.00 70.00 75.30 80.00 85.00 90.00
 99.65 93.65 99.65 99.65 99.65 99.65 99.65 99.65 99.65 99.65 99.65

```

3      3      MCM      1
CHELMSFORD DAM
34.430      .000      1      1      16      42      1      10      1.
0
1226.52    1236.22    1238.11    1239.47    1240.57    1241.52    1242.37    1243.15
1243.86    1245.11    39.77      53.70      79.61      99.50     119.45     139.50
159.36    199.10    12.649    16.609    19.605    22.272    24.633    26.835
0.530     8.476    126.      109.      101.      88.      85.      69.
29.188    34.430    116.     64.     68.
116.     64.     68.
NODE NUMBER 43      .000      0      2      17      43      0      0      1.
0
SCHURWEPDRT WEIR
0.000     .000     .000     0      3      15      45      0      0      1.
0

```

```

8
1 3 200.0 0.0 200.0 0.
2 2 0.0 500.0
3 2 0.0 400.0
4 2 0.0 1.0
5 1 0.0
6 1 2.0 500.0
7 2 0.0
8 1 10.0

99 99 1
72 44 0 1
0
1 77 0 42 7
0
0
4
59 45 44 4
70 42 44 5
71 43 44 6
74 42 0 2
3
53 42 43 5
64 45 0 8
65 43 0 8
9
63 - SPILLAGE FROM CHELMSFORD
64 - SPILLAGE FROM SCHURVEPOORT
65 - SPILLAGE FROM NODE 43
69 - SCHURVEPOORT NEWCASTLE LINK
70 - CHELMSFORD NEWCASTLE LINK
71 - 43 - NEWCASTLE LINK
72 - NEWCASTLE SUPPLY
74 - DANHAUSER SUPPLY
77 - DURNACOL MINE DEWATERING

WATER YIELD
MUNICIPAL DEMAND
IRRIGATION DEMAND
CHANNEL 59
GENERAL FLOW CHANNEL
PUMPING CHANNEL
MINE DEWATERING
ALTERNATIVE CHANNEL

POWER CONTROL CH
WATER YIELD
#POWER CHANNELS
IRRIGATION PROJECT
DIVERSION CHANNELS

WATER SUPPLY
LOSS CHANNEL
MIN_MAX CHANNELS

GENERAL FLOW ARCS

```

```
4 1 1
SURCHG 3 1 1 1000.
DRDWN 3 1 1 1.
LEVEL4 3 1 1 10.
DSL 3 1 1 1000.
42 1 0. 1245.11 1226.52 1245.11 \ CHELMSFORD DAM
0
42 1245.11 1245.11 1245.11 1245.11 1245.11 1245.11 1245.11 1245.11 1245.11
42 1230.63 1230.63 1230.63 1230.63 1230.63 1230.63 1230.63 1230.63 1230.63
```

421245.11


```

SCHURVEPOORT NEWCASTLE LINK          69
0.289 0.272 0.300 0.279 0.291 0.276 0.272 0.296 0.300 0.290 0.281 0.290
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
CHELMSFORD NEWCASTLE LINK          70
2.491 2.491 2.491 2.491 2.491 2.491 2.491 2.491 2.491 2.491 2.491 2.491
RDYPOINT TO NEWCASTLE LINK          71
0.610 0.610 0.610 0.610 0.610 0.610 0.610 0.610 0.610 0.610 0.610 0.610
CANNHAUSER SUPPLY                  74
0.053 0.053 0.053 0.053 0.053 0.053 0.053 0.053 0.053 0.053 0.053 0.053
0.053 0.053 0.053 0.053 0.053 0.053 0.053 0.053 0.053 0.053 0.053 0.053
    
```

```
SYSTEM ENERGY DEMAND          99
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
WATER YIELD DISTRIBUTION       72
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
```

APPENDIX C

COEFFICIENT DATA FILES FOR FAMILY OF CURVES GENERATION

	Page
1. Introduction	C - 1
2. Coefficient data file for long-term stochastic Family of Curves	C - 2
3. Coefficient data files for short-term stochastic Family of Curves	C - 3

EXPLANATION OF THE FAMILY OF CURVES GENERATION1. INTRODUCTION

The aim of the family of curves analysis is to generate a set of yield vs. reliability curves with the same characteristics as those derived from the stochastic simulation results. A family is derived for each stochastic analysis viz. the long-term analysis (41 64-year sequences), and the short-term stochastic analysis (201 5-year sequences) for the 100 %, 80 %, 60 %, 40 %, 20 % and 10 % start conditions. In the stochastic simulation analysis, the system response over a number of generated hydrological sequences is investigated, for a specified range of target drafts. Polynomial curves are fitted to the percent deficit data for each target draft. Thereafter follows a rigorous analysis of the coefficients of each curve (described in detail later), after which a coefficient data file is created. The coefficient data file for a particular analysis (e.g. short-term stochastic, 100 % start) is used to determine the yield-reliability characteristics of any range of target drafts, without having to run a simulation analysis for those target drafts. The defined family of curves can also be used to generate the family of curves for an intermediate start volume for the subsystem.

2. CURVE FITTING

The results from a stochastic analysis are in the form of percent deficits of target draft, which are converted to actual yield deficits by :

$$\text{Yield deficit} = (\text{target draft}) \times (\text{percent deficit})$$

Assume in an analysis of N sequences that there were n percent deficit (or n failure) values. Adding any one of the zero deficit values to the data set means we have a set of n+1 data points. These are ranked from largest to smallest

and assigned a probability of occurrence as follows:

largest deficit : $1 / n+1$

smallest deficit : $n+1/n+1$

(i.e. the zero deficit

point added to the data set)

The (X;Y) set for curve fitting is thus in the form:

(probability of occurrence ; yield deficit)

where $0 \leq X \leq 1$ and $0 \leq Y \leq$ largest yield deficit.

One equation type is used when fitting curves to the yield deficit vs. probability of occurrence data:

$$Y = A + Bx + Cx^2 + Dx^3 \quad (\text{polynomial to degree 3})$$

where Y = yield deficit X = probability of deficit occurrence
and A, B, C, D are real numbers

The equation may be used in a straight line, quadratic or cubic form.

Thus a family of curves is always a family of polynomial curves up to degree 3. The curves are called yield-reliability curves and are plotted in the form of base yield vs. exceedance probability (an explanation of this transformation will be given later).

Note: The probability of zero deficit occurrence, w.r.t the number of sequences analysed (as opposed to the number of deficits that actually occurred), defines the Firm Yield Point. In terms of reliability, the firm yield points for each target draft curve define the Firm Yield Line.

3. ESTABLISHING THE COEFFICIENT DATA FILE

Once the curves for each target draft have been defined, the characteristics of each of the like-coefficients (i.e. all the coefs. 'A', 'B', 'C' and 'D') are studied w.r.t. target draft (TD). The value of each coefficient of each curve is non-dimensionalised by dividing by the relevant TD value, and then plotted against TD. An example of a graph of coefficient factor vs. target draft, is given in Figure C.1.

Either of the equation types 1 or 2 below, are used to define the curves of coef/TD vs. Target Draft (TD) for each coef. A, B, C and D. The curve type giving the best fit is selected.

Type 1 : $\text{Coef/TD} = ae^{b \cdot \text{TD}} + ce^{d \cdot \text{TD}} + f$

Type 2 : $\text{Coef/TD} = a + b(\text{TD}) + c(\text{TD})^2 + d(\text{TD})^3$

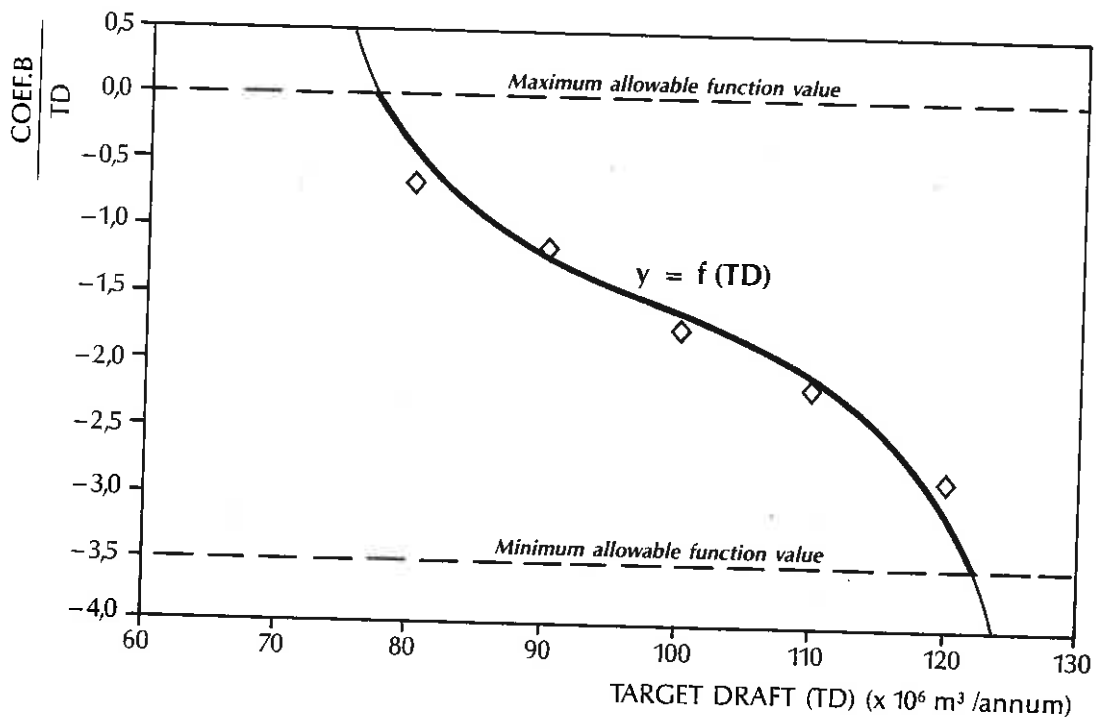


Figure C-1: Typical graph of coefficient value vs. target draft

4. THE COEFFICIENT DATA FILE

A typical coefficient data file is listed below.

Column

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	1	-5.801	-0.021	0.0	0.0	1.354	0.0	1.0
2	1	-0.146E-02	0.648E-01	0.185E-01	0.0	0.0	-3,5	0.0
0	1	0,0	0.0	0.0	0.0	0.0	0.0	+9999.
4	2	3.062E+03	-8.161E+01	0.725	-0.215E-03	0.0	-2.8	0.0
5	2	0.0	0.0	0.0	0.0	0.0	-9999.	+9999.
6	1	1.298	0.305E-03	0.701E-09	0.157	-1.327	-9999.	+9999.

Col(1): Definition for each coefficient of a yield deficit curve
 1 = A, 2 = B, 3 = C, 4 = D, 5 = F

Line 5 is no longer used, but originally accommodated the definition of coefficient F in the equation type:

$$y = Ae^{Bx} + Ce^{Dx} + F$$

Line 6 defines the firm yield line. Its (x;y) coordinate set is in the form of : (target draft; risk (as % of sequences observed N)).

Col(2): Coefficient curve type (1:exponential 2:polynomial)

Col(3) to Col(7): Coefficients a, b, c, d, f for coefficient equations

Col(8): Minimum allowable value of function, i.e. minimum value of Coef/TD.

The shape of the polynomials used in the family of curves definition, is governed by the magnitude and sign of the coefficients. Criteria can be established which define the

The curve number for the coefficient to be defined in terms of the others is therefore assigned zero in Col(1) and further information is not required.

5. THE TRANSFORMATION FROM (YIELD DEFICIT vs. PROBABILITY OF DEFICIT OCCURENCE) TO (BASE YIELD vs. EXCEEDANCE PROBABILITY)

It should be noted that once the coefficients of a Yield Deficit vs. Probability of Deficit Occurance curve have been determined, the curve must be transformed into the form of Base Yield vs. Exceedance Probability. This is done as follows:

Suppose that there are n yield deficits from a stochastic simulation of N sequences, for a target draft (TD).

One zero-deficit value is added to the data, making $n+1$ points. The yield deficits are ranked from the largest to the smallest (zero) value, and assigned probabilities of occurrence of $1/n+1$ through to $n+1/n+1$ respectively. Curves are then fitted to this data, where the probability range is from 0 to 1 for every TD curve. It is necessary though, to reference the number of yield deficits to the number of sequences (N) analysed, to obtain the true probability of occurrence of each yield deficit.

∴ Risk of largest deficit = $1/N = (1/n+1) \cdot (n+1/N)$;
Risk of zero deficit = $n+1/N = (1/n+1) \cdot (n+1/N)$ &
Exceedance Probability = $1 - \text{RISK}$.

(Note: The Firm Yield Exceedance Probability for a specific target draft is thus: $1 - (n+1)/N$)

To plot the results in the form required (i.e. Base Yield vs Exceedance Probability):

Base Yield = 1 - Yield Deficit and,

Exceedance probability = $1 - x \cdot (n+1/N)$

where $0 \leq x \leq 1$

For exceedance probability increasing from zero (0 %), base yield remains equal to target draft until the Firm Yield Exceedance Probability is reached. Thereafter, the base yield decreases according to the defined curve, to the base yield at 100 % exceedance probability.

0129D/ss/1243B
1989-05-02

C - 2

1	2	1.00	0.00	0.0	0.0	0.0	0.0	1.
2	2	-9.35	0.138	0.0	0.0	0.0	-3.0	0.
0	2	0.0	0.0	0.0	0.0	0.0	0.0	9999.
4	2	-5.4	0.07	0.0	0.0	0.0	-3.0	0.
5	2	0.0	0.0	0.0	0.0	0.0	-9999.0	9999.
6	1	3.44471	0.00959085	-0.0013508	0.0825635	-5.13947	0.0	9999.

Coefficient data files for Long-Term stochastic Family of Curves

1	2	1.00	0.00	0.0	0.0	0.0	0.0	1.0
2	2	0.4	-0.02	0.0	0.0	0.0	-2.50	0.0
0	2	0.0	0.0	0.0	0.0	0.0	0.0	9999.0
4	2	1.2	-0.02	0.0	0.0	0.0	-2.00	0.0
5	2	0.0	0.0	0.0	0.0	0.0	-9999.0	9999.0
6	1	.0102387	.0363643	.00000060938	.123596	-.0590908	0.0	9999.0

1. Coefficient data for system start volume at 100 % of Full Supply Volume

1	2	1.00	0.00	0.0	0.0	0.0	0.0	1.0
2	2	0.6	-0.026	0.0	0.0	0.0	-2.5	0.0
0	2	0.0	0.0	0.0	0.0	0.0	0.0	9999.0
4	2	1.2	-0.022	0.0	0.0	0.0	-2.0	0.0
5	2	0.0	0.0	0.0	0.0	0.0	-9999.0	9999.0
6	1	0.114358	0.0104761	0.226852-04	0.11088	-0.162717	0.0	9999.0

2. Coefficient data for system start volume at 80 % of Full Supply Volume

1	2	1.00	0.00	0.0	0.0	0.0	0.0	1.0
2	2	1.2	-0.032	0.0	0.0	0.0	-2.5	0.0
0	2	0.0	0.0	0.0	0.0	0.0	0.0	9999.0
4	2	1.20	-0.02	0.0	0.0	0.0	-3.0	0.0
5	2	0.0	0.0	0.0	0.0	0.0	-9999.0	9999.0
6	1	0.562284	0.000602346	0.00200104	0.0686373	-0.581505	0.0	9999.0

3. Coefficient data for system start volume at 60 % of Full Supply Volume

1	2	1.00	0.00	0.0	0.0	0.0	0.0	1.0
2	2	0.8	-0.037	0.0	0.0	0.0	-2.5	0.0
0	2	0.0	0.0	0.0	0.0	0.0	0.0	9999.0
4	2	1.20	-0.02	0.0	0.0	0.0	-3.0	0.0
5	2	0.0	0.0	0.0	0.0	0.0	-9999.0	9999.0
6	1	0.204663	-0.0106728	0.0279532	0.0452527	-0.233223	0.0	9999.0

4. Coefficient data for system start volume at 40 % of Full Supply Volume

1	2	1.00	0.00	0.0	0.0	0.0	0.0	1.0
2	2	-0.65	-0.02177	0.0	0.0	0.0	-3.0	0.0
0	2	0.0	0.0	0.0	0.0	0.0	0.0	9999.0
4	2	0.8	-0.028	0.0	0.0	0.0	-3.0	0.0
5	2	0.0	0.0	0.0	0.0	0.0	-9999.0	9999.0
6	1	-0.356637	0.0112748	0.115884	0.0384265	0.236720	0.0	9999.0

5. Coefficient data for system start at 20 % of Full Supply Volume

1	2	1.00	0.00	0.0	0.0	0.0	0.0	1.0
2	2	-0.23	-0.084	0.0	0.0	0.0	-3.0	0.0
0	2	0.0	0.0	0.0	0.0	0.0	0.0	9999.0
4	2	1.17	-0.078	0.0	0.0	0.0	-3.0	0.0
5	2	0.0	0.0	0.0	0.0	0.0	-9999.0	9999.0
6	1	0.125477	0.0178975	0.29086E-02	0.180991	-0.137364	0.0	9999.0

6. Coefficient data for system start volume at 10 % of Full Supply Volume