



**DEPARTMENT: WATER AFFAIRS AND FORESTRY
DIRECTORATE: RESOURCE DIRECTED MEASURES**

**OLIFANTS/DORING CATCHMENT
ECOLOGICAL WATER REQUIREMENTS
STUDY**

SCENARIO REPORT

**FINAL
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Milestone (Reporting) List

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Project Report 2: Delineation Report	March 2004	April 2004	May 2004
Project Report 3: Groundwater TOR	May 2004	December 2003	March 2004
Project Report 4.1: Riverine RDM Report (VOL 1)	March 2005	March 2005	
Project Report 4.2: Riverine RDM Report (VOL 2)	March 2005	March 2005	May 2005
Project Report 5: Estuarine RDM Report	July 2005		
Project Report 6: Scenario Report	May 2005	June 2005¹	July 2005
Project Report 7: Monitoring Appendix	October 2005		
Project Report 8: Main Summary Report	December 2005		
Scenario-creation database for the rivers (in electronic format)	December 2005	March 2005	May 2005

¹ This report was delayed as a result of changes to the scenarios presented to the estuarine team, which were decided on the basis of preliminary analysis of the original selection (May 2005).

EXECUTIVE SUMMARY

**OLIFANTS/DORING CATCHMENT
ECOLOGICAL WATER REQUIREMENTS STUDY –
SCENARIO REPORT**

INTRODUCTION

This report forms part of a Comprehensive Assessment of the Ecological Water Requirements of the Olifants/Doring River Catchment, initiated and funded by the Department of Water Affairs and Forestry: Directorate Resource Directed Measures (RDM). The project is being managed for the Client by Ninham Shand Consulting Services. The main technical consultant for the project is Southern Waters Ecological Research and Consulting cc, with the following main sub-consultants:

- CSIR;
- DH Environmental Services;
- E.S.J. Dollar Consulting cc.
- Freshwater Consulting Group;
- GEOSS;
- Ninham Shand Consulting Services;
- Streamflow Solutions;
- Stellenbosch University;
- University of Cape Town;
- University of Port Elizabeth;
- A. Bok and Associates.

Project duration is from July 2003 to March 2006.

This Scenario Report is the sixth in a series of eight project-related reports. The aims of the report are:

- to outline the scenarios investigated for delivery to the estuarine team for the determinations of the flow requirements for the estuary.
- discuss and clarify some of the difficulties with producing detailed future scenarios in the context of the Olifants/Doring catchment, viz. few gauging weirs and many proposals for development, and;
- to select four scenarios, in addition to naturalised and present day conditions, for assessment by the estuarine team.

SCENARIOS SELECTED FOR CONSIDERATION BY THE ESTUARINE TEAM

The scenarios considered have been loosely ordered in terms of increasing regulation of the catchment, starting from the natural condition. As the catchment becomes more regulated the water available at the estuary decreases unless additional EWR releases are made.

- Natural conditions – no developments in the catchment (Scenario 0).
- Present day infrastructure with Clanwilliam Dam storing 121 MCM. In addition to the current operating rule (Scenario 1), an additional scenario entails EWR releases for the river reaches downstream of the Bulshoek Barrage and downstream of the Doring confluence (Scenario 2).
- Additional development in the Olifants River - Clanwilliam Dam was raised by either 10 m (Scenario 6) or 15 m (Scenario 5) to store 265 or 362 MCM respectively. An additional scenario based on the 15 metre

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- raising also made EWR releases for the river reaches downstream of the Bulshoek Barrage and downstream of the Doring confluence (Scenario 7).
- Additional farm dams - All other scenarios assumed that Clanwilliam Dam would be raised 15 metres and that various levels of development would occur in the Doring River. The lowest assumed level of development was to increase the off-channel farm dams in the Kouebokkeveld region of the Doring River by 50 MCM and only allow water to be transferred to these dams during winter (Scenario 16).
 - Groot River Dam - The next level of development assumed that the Groot River Dam of about 160 MCM would be constructed in the upper reaches of the Doring River, in addition to raising Clanwilliam Dam. The Groot River Dam was analysed supplying full EWR releases in both the Olifants and Doring Rivers (Scenario 13), EWR in only the Doring River (Scenario 14), and reduced EWR releases in the Doring (Scenario 15).
 - Brandewyn River Dam. The next level of development assumed that a 160 MCM dam was constructed on the Brandewyn River, a tributary of the Doring River, in addition to raising Clanwilliam Dam. Water would also be pumped from a five MCM weir on the Doring River into the Brandewyn River Dam at a maximum rate of 5m³/s during April to October. In Scenario 17 the EWR releases were ignored. In Scenario 17B water was only diverted after the EWR requirements in the river were supplied, although releases were not made from the Brandewyn Dam itself once the water had been transferred into the Brandewyn Dam.
 - Melkbosrug Dam - Melkbosrug Dam would regulate almost all of the inflows from the Doring River and maximise the yield from the Olifants / Doring River system. This option was analysed supplying the EWR (Scenario 11) and ignoring the EWR (Scenario 10).

The main two criteria for selection of scenarios for presentation to the estuarine team (see Section 2) were that the scenarios be realistic approximations of possible future inflows to the Olifants/Doring estuary and that they cover as wide a range as possible in terms of differences in both the Mean Annual Runoff (MAR), and the distribution of the flows reaching the estuary. After due consideration of the inputs received from those consulted, the following scenarios were selected:

Scenario 0²: Naturalised conditions.

Scenario 1: Present day conditions, i.e., with no EWR releases.

Scenario 2: Present day level of development and meeting the EWR for the Recommended Ecological Category (REC) at each of eight EWR sites along the river.

Scenario 5: Raising Clanwilliam Dam by 15 m and meeting the Reserves for the REC at five of the eight EWR sites along the river. The three sites excluded are EWR Site 2, downstream of Bulshoek Barrage, EWR Site 7, downstream of the confluence of the Olifants and Doring Rivers and EWR Site 8 between Clanwilliam Dam and Bulshoek Barrage.

Scenario 17: Raising Clanwilliam Dam by 15 m, plus an abstraction weir at Melkbosrug (Brandewyn option) and meeting the EWRs at four of the eight EWR sites along the river. The four sites excluded are EWR Site 2, downstream of Bulshoek Barrage, EWR Site 5 downstream of Oudrif, EWR Site 7, downstream of the confluence of the Olifants and Doring Rivers and EWR Site 8 between Clanwilliam Dam and Bulshoek Barrage.

² Scenarios 0 and 1 MUST form part of the considerations of the estuarine team as it is these that provide the benchmarks for assessment of the other scenarios (see Inception Report).

Scenario 10: Raising Clanwilliam Dam by 15 m, plus a dam at Melkboom or Melkbosrug on the Doring River and not meeting any of the EWR.

In addition, depending on the time available at the Estuary Workshop, the estuarine Team Leaders agreed to try and consider an additional scenario, namely:

Scenario 7: Raising Clanwilliam Dam by 15 m and meeting the EWR for the REC at all eight EWR sites along the river.

An additional scenario (Scenario 16) was considered, but resulted in flows to the estuary that were very similar to those achieved from Scenario 5, and it was decided to rather replace it with Scenario 7, as above.

Scenario 16: Raising Clanwilliam Dam by 15 m, plus additional development of farm dams in the Kouebokkeveld and meeting the flow requirements at six of the eight EWR sites along the river. The two sites excluded are EWR Site 2, downstream of Bulshoek Barrage and EWR Site 7, downstream of the confluence of the Olifants and Doring Rivers.

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Glossary and Abbreviations

AEC	Alternative ecological category
CSIR	Centre of Scientific and Industrial Research
D: RDM	Directorate: Resource Directed Measures
DWAF	Department of Water Affairs and Forestry
ENVIRONMENTAL WATER REQUIREMENT	Flow in a river, or into a wetland or coastal zone (which may be groundwater) that maintains the ecosystem in a stipulated ecological condition
EWR	Ecological Water Requirements
HYDROLOGY	In its broadest sense hydrology is a science that relates to water and the hydrological cycle. In the context of this report hydrology focuses on the relationship between rainfall and runoff to estimate streamflows.
LORWUA	Lower Olifants River Water Users Association
MCM	Million Cubic Metres
NS	Ninham Shand
PMC	Project Management Committee
REC	Recommended Ecological Category
RDM	Resource Directed Measures
WRYM	Water Resource Yield Model.

1. BACKGROUND

This report forms part of a Comprehensive Assessment of the Ecological Water Requirements (EWR) of the Olifants/Doring River Catchment, initiated and funded by the Department of Water Affairs and Forestry (DWAF): Directorate Resource Directed Measures (D: RDM). The project is being managed for the Client by Ninham Shand Consulting Services (NS). The main technical consultant for the project is Southern Waters Ecological Research and Consulting cc, with the following main sub-consultants:

- CSIR;
- DH Environmental Services;
- E.S.J. Dollar Consulting cc;
- Freshwater Consulting Group;
- GEOSS;
- Ninham Shand Consulting Services;
- Streamflow Solutions;
- Stellenbosch University;
- University of Cape Town;
- University of Port Elizabeth;
- A. Bok and Associates.

Project duration is from July 2003 to March 2006.

1.1 OBJECTIVES AND LAYOUT OF THIS REPORT

1.1.1 Objectives of this report

This Scenario Report is the sixth in a series of eight project-related reports and it reports on Task 8: Scenario Generation. It discusses the development of a wide range of alternative scenarios to provide flow sequences at the estuary for assessment by the estuarine specialists. The main aim objective of Task 8 is to provide 6 scenarios, inclusive of natural and present day conditions, to the estuarine team for their consideration in Task 7.

The objectives of the report are to:

- discuss and clarify some of the difficulties with producing detailed future scenarios in the context of the Olifants/Doring catchment, viz. few gauging weirs and many proposals for development;
- outline the various scenarios investigated for delivery to the estuarine team for the determinations of the flow requirements for the estuary;
- summarise the outcome of the various scenario selection meetings and discussions that informed the selection of the six scenarios that were presented to the estuarine team.

1.1.2 Layout of this report

This report is divided into several discrete sections.

- Section 1: Provides a brief background to the project and an outline of this report. Additional background to the project is available in the Inception Report.
- Section 2: Outlines the approach adopted in selecting four scenarios from a short-list of 17 scenarios each representing levels of future water-resource development.
- Section 3: Addresses some of the limitations imposed on the study as a result of the distribution of the EWR sites, availability of daily hydrological data and various other assumptions that have to be made in a predictive study of this nature.
- Section 4: Provides summaries of the estuary inflow sequences resulting from the modelling of each of the 17 scenarios.
- Section 5: Lists the scenarios that were selected for consideration by the estuarine team.

The outcome of the estuarine team's deliberations will be presented in Report 5: Estuarine RDM report, which is scheduled for completion in July 2005.

2. SELECTING SUITABLE SCENARIOS FOR THE ESTUARINE TEAM

2.1 APPROACH ADOPTED

The main aim objective of the scenario generation task is to present six scenarios, inclusive of natural and present day conditions, to the estuarine team for their consideration. The estuarine team will then use the scenarios to determine the Ecological Category of the estuary associated with each of the flow scenarios. Results from the evaluation of these scenarios will then used to select the 'recommended EWR scenario', defined as the run-off scenario, or a slight modification thereof, that represents the highest reduction in river inflow that will still protect the aquatic ecosystem of the estuary and keep it in the Recommended Ecological Category.

Thus, in this context it is important that the scenarios presented to the estuarine team:

- are realistic approximations of the affect that possible future water resource developments in the catchment are likely to have on inflows to the Olifants/Doring estuary;
- cover as wide a range as possible in terms of differences in both the Mean Annual Runoff (MAR), and the distribution of flows reaching the estuary, arising from the possible different developments.

To generate the scenarios, the river EWRs for key points in the catchment needed to be considered. Where appropriate, the results for the river EWR sites were used directly, but in other cases these were extrapolated to sites of interest along the river (see Section 2.2).

In order to achieve this the approach adopted was as follows:

- seventeen possible scenarios involving different permutations of water resource developments (Section 2.3) and compliance to the EWR (quantity) for the river were identified (see Section 2.4);
- the scenarios were modelled to produce the flows to the estuary likely to result from each;
- these scenarios were presented to and discussed with:
 - the Olifants Doring Project Management Committee (PMC; 1 February 2005 and 12 April 2005);
 - representatives of DWAF Regional Office and several Water User Associations from the Olifants Doring catchment, and members of the PMC at a River Quantity Results Report Back and Scenario Discussion Meeting (1 April 2005);
 - the Estuarine Team Leaders (12 April 2005).
- following the above discussions a short-list of five scenarios was selected for consideration by the estuarine team (see Section 2.5).

2.2 EWR SITES AND EXTRAPOLATION SITES

The locations of the EWR sites in the Olifants-Doring catchment for which EWR determinations were done are given in Table 2.1 and Figure 2.1.

The Present Ecostatus, and the Recommended Ecological Category (REC) and Alternative Ecological Category (AEC) for which EWR were determined for each of the EWR sites are given in Table 2.2.

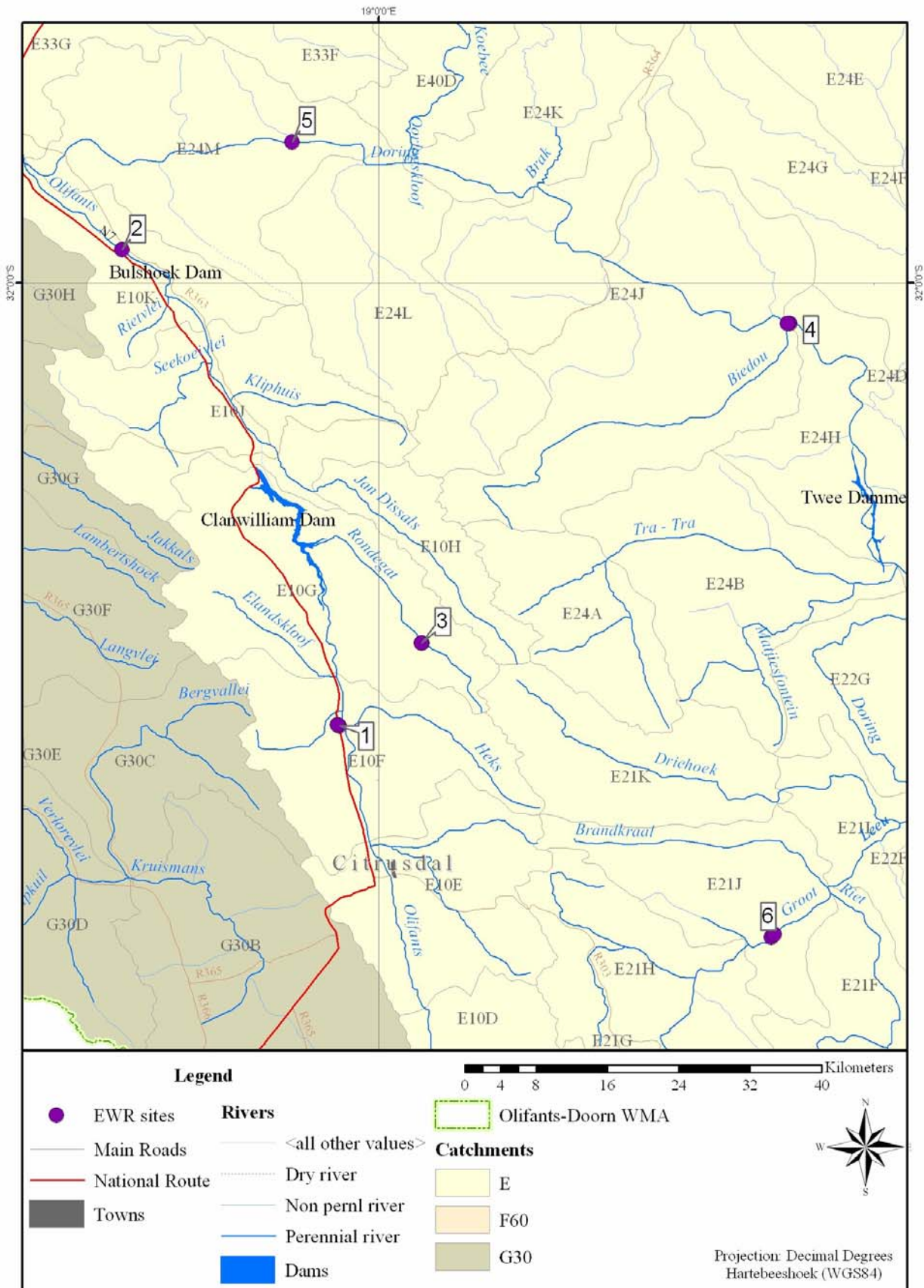


Figure 2.1 Map of the study area showing the location of the six EWR sites.

Table 2.1 Locations of each of the six EWR sites where EWR determinations were done.

Site No ³ .	River	Site Name	Description	Latitude	Longitude
1a 1b	Olifants	Olifants at Hex River	N7 downstream of the confluence with the Hex River.	32°26.764 32°26.680	18°57.601 18°57.504
2	Olifants	Olifants at Alwynskop	Downstream of Bulshoek Barrage, just downstream of Cascade Pools.	31°57.974	18°44.463
3a 3b	Rondegat	Rondegat at Algeria	Upstream of the Algeria staff accommodation, on the road between Algeria and Clanwilliam.	32°21.760 32°21.739	19°02.618 19°02.593
4a 4b	Doring	Doring at Biedou	Immediately upstream of the confluence with the Biedou River.	32°02.410 32°02.416	19°24.896 19°24.783
5	Doring	Doring at Ou Drif	At Ou Drif.	31°51.446	18°54.754
6a 6b	Groot	Groot at Mount Cedar	Upstream of the bridge at Groot Rivier.	32°39.552 32°39.377	19°23.786 19°23.982

Table 2.2 The Present Ecstatus, and the Recommended Ecological Category (REC) and Alternative Ecological Category (AEC) for which EWRs are presented in this report.

EWR Site	Present Ecstatus	REC	AEC
Site 1	D	D	None
Site 2	E	D	None
Site 3	B	B	C
Site 4	B/C	B	C
Site 5	B	B	C
Site 6	B/C	B/C	C

In addition, information on the flow requirements was required for the reaches between Clanwilliam Dam and Bulshoek Barrage and downstream of the confluence of the Olifants and Doring Rivers, which were not considered during the riverine portion of the study. Information on the flow requirements for these sites was extrapolated from the original EWR sites as follows:

EWR Site 7: Downstream of the confluence of the Olifants and Doring Rivers – extrapolated from EWR Site 2⁴;

EWR Site 8: Between Clanwilliam Dam and Bulshoek Barrage – extrapolated from EWR Site 1.

2.3 WATER RESOURCE DEVELOPMENTS INCLUDED IN THE SCENARIOS

The various water resource developments proposed for the Olifants/Doring catchment that were considered for inclusion in the different scenarios are presented below. Although there are other developments that have been proposed for the Olifants/Doring River, these were not included because they were not expected to have flow-related impacts on the estuary that differed appreciably from the water resource developments that were included.

³ The notations a and b in Table 2.1 refer to the transects that were surveyed at each site.

⁴ Please note that there is considerable doubt over the EWR provided for EWR Site 2, i.e., whether it will in fact result in a D-category river in the river reach that it represents (see River RDM report: Volume 2).

2.3.1 Olifants River

Raising Clanwilliam Dam (CWD):	Two scenarios were considered, viz. raising the wall of the existing Clanwilliam Dam on the Olifants River by 10 m (additional 143 MCM storage) or by 15 m (additional 240 MCM storage).
Development u/s CWD:	Either a 153 MCM dam on the Olifants River at Keerom or development of additional farms dams (153 MCM) in the Kouebokkeveld.

2.3.2 Doring River

Melkboom Dam:	A 470 MCM dam on the Doring River at either Melkboom or Melkbosrug.
Groot Dam:	A 159 MCM dam on the Doring River at Aspoort or a dam on the Groot River at De Mond.
Brandewyn (BrDW):	An 5 MCM abstraction weir on the Doring River near Melkbosrug, with a $5 \text{ m}^3\text{s}^{-1}$ pump and off-channel storage in the Brandewyn River. The abstraction weir is expected to have less impact on the floods in the Doring River than will a dam at Melkboom or Melkbosrug, but evaporation from the off-channel storage will be high.
Farm Dams:	Additional 50 MCM development of farms dams in the Kouebokkeveld. These developments assume that the farmers will only be allowed to divert water in the winter, i.e., they will not affect summer flows in the Doring River.

2.4 SCENARIOS CONSIDERED

The following seventeen scenarios were considered for selection for consideration by the estuarine team (Table 2.3).

- 0 Naturalised conditions.
- 1 Present day conditions, i.e., with no EWR releases.
- 2 Present day level of development and meeting the EWR for the REC at each of eight EWR sites along the river.
- 3 Present day level of development and meeting the EWR for the REC at six of the eight EWR sites along the river. The two sites excluded are EWR Site 2, downstream of Bulshoek Barrage and EWR Site 7, downstream of the confluence of the Olifants and Doring Rivers.
- 4 Present day level of development and meeting the EWR for the REC at six of the eight EWR sites along the river. The two sites excluded are EWR Site 2, downstream of Bulshoek Barrage and Site 8 between Clanwilliam Dam and Bulshoek Barrage.
- 5 Raising Clanwilliam Dam by 15 m and meeting the EWR for the REC at five of the eight EWR sites along the river. The three sites excluded are EWR Site 2, downstream of Bulshoek Barrage, EWR Site 7, downstream of the confluence of the Olifants and Doring Rivers, and EWR Site 8 between Clanwilliam Dam and Bulshoek Barrage.
- 6 Same as 5, except only raising Clanwilliam Dam by 10 m.
- 7 Raising Clanwilliam Dam by 15 m and meeting the EWR for the REC at all eight EWR sites along the river.
- 8 Raising Clanwilliam Dam by 15 m, plus additional developments upstream of Clanwilliam Dam and meeting the EWR for the REC at five of the eight EWR sites. The three sites excluded are EWR Site 2, EWR Site 7 and EWR Site 8.
- 9 Raising Clanwilliam Dam by 15 m, plus a dam at Melkboom or Melkbosrug on the Doring River and meeting the EWR for the REC at six of the eight EWR sites. The two sites excluded are EWR Site 2 and EWR Site 8.

Table 2.3 Summary of the permutations making up each of the scenarios considered.

Scenario		Target EWRs at EWR sites								
No.	Description	Olifants		Rondegat	Doring		Groot	Olifants		
		1	2	3	4	5	6	7	8	
0	Natural	None	None	None	None	None	None	None	None	None
1	Present Day (PD)	None	None	None	None	None	None	None	None	None
2	PD - All EWRs	REC	REC	REC	REC	REC	REC	REC	REC	REC
3	PD - No EWR Site 2 and 7	REC	None	REC	REC	REC	REC	None	REC	REC
4	PD – Only EWR at 7	None	None	None	None	None	None	REC	None	None
5	Raise CWD 15m – No EWR at 2, 7 or 8	REC	None	REC	REC	REC	REC	None	None	None
6	Raise CWD – 10 m – No EWR at 2, 7 or 8	REC	None	REC	REC	REC	REC	None	None	None
7	Raise CWD 15m – All EWRs	REC	REC	REC	REC	REC	REC	REC	REC	REC
8	Developments u/s CWD No EWR at 2, 7 or 8	REC	None	REC	REC	REC	REC	None	None	None
9	Raise CWD, plus Melkboom Dam - No EWR Site 2 and 7	REC	None	REC	REC	REC	REC	None	REC	REC
10	Raise CWD, plus Melkboom Dam - No EWR.	None	None	None	None	None	None	None	None	None
11	Raise CWD, plus Melkboom Dam - All EWRs	REC	REC	REC	REC	REC	REC	REC	REC	REC
12	Raise CWD, plus Groot Dam – No EWR at 2 or 8	REC	None	REC	REC	REC	REC	REC	None	None
13	Raise CWD, plus Groot Dam - No EWR at 2 or 7	REC	None	REC	REC	REC	REC	None	REC	REC
14	Raise CWD, plus Groot Dam - No EWR at 2, 7 or 8	REC	None	REC	REC	REC	REC	None	REC	REC
15	Raise CWD, plus Groot Dam - No EWR at 2 or 7 and reduced EWRs on the Doring River	REC	None	REC	AEC	AEC	REC	None	REC	REC
16	Raise CWD plus farm dams – No EWR at 2, 7 or 8	REC	None	REC	AEC	AEC	REC	None	REC	REC
17	Raise CWD plus Brandewyn – No EWR at 2, 5, 7 or 8	REC	None	REC	REC	None	REC	None	None	None
17B	Raise CWD plus Brandewyn – No EWR at 2, 7 or 8	REC	None	REC	REC	REC	REC	None	None	None

- 10 Raising Clanwilliam Dam by 15 m, plus a dam at Melkboom or Melkbosrug on the Doring River and not meeting any of the EWR.
- 11 Raising Clanwilliam Dam by 15 m, plus a dam at Melkboom or Melkbosrug on the Doring River and meeting the EWR for the REC at all eight EWR sites along the river.
- 12 Raising Clanwilliam Dam by 15 m, plus a dam on the Groot River and meeting the EWR for the REC at all eight EWR sites along the river.
- 13 Raising Clanwilliam Dam by 15 m, plus a dam on the Groot River and meeting the EWR for the REC at six of the eight EWR sites along the river. The site excluded is EWR Site 2, downstream of Bulshoek Barrage.
- 14 Raising Clanwilliam Dam by 15 m, plus a dam on the Groot River and meeting the EWR for the REC at five of the eight EWR sites along the river. The three sites excluded are EWR Sites 2, 7 and 8.
- 15 Raising Clanwilliam Dam by 15 m, plus a dam on the Groot River and with reduced ecological requirements at EWR Sites 4 and 5 on the Doring River. The three sites excluded are EWR Sites 2, 7 and 8.

- 16 Raising Clanwilliam Dam by 15 m, plus additional development of farm dams in the Kouebokkeveld and meeting at five of the eight EWR sites along the river. The three sites excluded are EWR Sites 2, 7 and 8.
- 17 Raising Clanwilliam Dam by 15 m, plus an abstraction weir at Melkbosrug (Brandewyn option) and meeting the EWR at four of the eight EWR sites along the river. The four sites excluded are EWR Sites 2, 5, 7 and 8.

Table 2.4 provides a summary of the target ecological conditions for each of the river reaches included in the scenarios.

Table 2.4 Summary of the target ecological conditions for each of the reaches in the scenarios considered.

Scenario		Target EWRs at EWR sites							
No.	Description	Olifants		Rondegat	Doring		Groot	Olifants	
		1	2	3	4	5	6	7	8
0	Natural	None	None	None	None	None	None	None	None
1	Present Day (PD)	None	None	None	None	None	None	None	None
2	PD - All EWRs	D	D	B	B	B	B/C	D	D
3	PD - No EWR Site 2 and 7	D	None	B	REC	REC	B/C	None	D
4	PD - Only EWR at 7	None	None	None	None	None	None	D	None
5	Raise CWD 15m – No EWR at 2, 7 or 8	D	None	B	B	B	B/C	None	None
6	Raise CWD – 10 m – No EWR at 2, 7 or 8	D	None	B	B	B	B/C	None	None
7	Raise CWD 15m – All EWRs	D	D	B	B	B	B/C	D	D
8	Developments u/s CWD No EWR at 2, 7 or 8	D	None	B	B	B	B/C	None	None
9	Raise CWD, plus Melkboom Dam - No EWR Site 2 and 7	D	None	B	B	B	B/C	None	None
10	Raise CWD, plus Melkboom Dam - No EWR.	None	None	None	None	None	None	None	None
11	Raise CWD, plus Melkboom Dam - All EWRs	D	D	B	B	B	B/C	D	D
12	Raise CWD, plus Groot Dam – No EWR at 2 or 8	D	None	B	B	B	B/C	D	None
13	Raise CWD, plus Groot Dam - No EWR at 2 or 7	D	None	B	B	B	B/C	None	D
14	Raise CWD, plus Groot Dam - No EWR at 2, 7 or 8	D	None	B	B	B	B/C	None	None
15	Raise CWD, plus Groot Dam - No EWR at 2 or 7 and reduced EWRs on the Doring River	D	None	B	C	C	B/C	None	None
16	Raise CWD, plus Farm Dams – No EWR at 2, 7 or 8	D	None	B	C	C	B/C	None	None
17	Raise CWD, plus Brandewyn – No EWR at 2, 7 or 8	D	None	B	B	B	B/C	None	None
17B	Raise CWD, plus Brandewyn – No EWR at 2, 5, 7 or 8	D	None	B	B	None	B/C	None	None

3. ASSUMPTIONS

3.1 HYDROLOGICAL DATA

As already highlighted in previous reports, there is a paucity of functioning DWAF gauging weirs in the Olifants/Doring catchment, which makes both the estimation of MAR, and the provision of daily flow records for the estuary extremely difficult. A flow measuring station was recently established at the Lutzville Bridge, which has provided some assistance in estimating flows. However, problems at that site, such as, debris that blocks the bridge culverts and alters the rating curve, and the short length of the record, limited the value of this data set.

While every effort was made to provide the best hydrological information on which to base the EWRs, it is essential that those using the data are aware of the inherent shortcomings thereof.

3.2 SUMMER FLOWS AT LUTZVILLE

During summer, the baseflow entering the estuary pushes the salt water back towards the sea and the magnitude of the baseflow determines how far the saline wedge extends up the Olifants River. If the baseflow is insufficient then additional releases may be required from Clanwilliam Dam, which would affect the yield of the dam. This baseflow comprises river flow, leaks from the Bulshoek Barrage (though some of this is currently intercepted and pumped back into the irrigation system), return flows from the irrigators, and possibly inflow from springs. The baseflow is difficult to determine because:

- The accuracy of the stage measurements at the bridge downstream of Lutzville depends on how well the bridge is cleaned of the debris that block the bridge culverts.
- The leaks from Bulshoek have been reduced. These were estimated to be about $0.5\text{m}^3\text{s}^{-1}$ (unconfirmed) in April 2002 and since then the Lower Olifants River Water Users Association (LORWUA) have pumped leakage water back into the canal or Bulshoek (see Appendix D).
- An unknown proportion of the return flows may have been intercepted by irrigators further downstream.
- The increasing use of drip irrigation may reduce return flows.
- There are unconfirmed reports of contributions from springs near Kapel.
- The gauge at Lutzville has not been in operation for very long and flows recorded, for instance, in summer of 2004/5, reflect a period of extreme drought, when irrigators may have relied on river water to supplement their supplies from the canal.

Figure 3.1 compares various estimates of the flows at the Lutzille Causeway:

- The solid black line provides the results from a continuous recorder, which was installed at the causeway to help estimate the streamflows. The water levels were used to estimate flows using an unofficial and unverified set of flow gaugings at the site. The flow gauge may have been stuck for certain periods, which have been highlighted in Figure 3.1, and it would be valuable to obtain records of when the gauge was cleaned to see if the water level inlet was blocked.
- The blue triangle is a spot reading collected by the CSIR using an impellor flow gauge, which will underestimate the flow rate in extremely shallow water when the impellers are not fully submerged.
- The red square is a spot reading by NS on 24 April 2005, when the estimated flow rate was about $0.8\text{m}^3\text{s}^{-1}$.

The flows in 2004/5 appear significantly lower than those in previous years but it is uncertain whether this is because of the drought or because more of the baseflow was intercepted. It would be valuable if the causeway at Lutzille could be cleaned thoroughly at the end of winter 2005, inspected regularly to identify blockages and used to monitor the 2005/6 summer flows. If the winter of 2005 is an

average winter then this will give an indication of the streamflow at Lutzville during normal years. In the longer term a low flow gauge should be constructed to measure the flows entering the estuary⁵.

For interest some pictures taken during the NS visit are included (Figure 3.2-Figure 3.4). Figure 3.2 illustrates that high streamflows have blocked the upstream face of the causeway and the recorder with reeds. Figure 3.3 shows that most of the streamflow is passing through the leftmost culvert if one faces downstream. To check whether any flow was being received from the Hols and Doring Rivers these sites were visited and no surface flow was visible though flow was observed in the Olifants River upstream of the Doring Confluence. The Hols River did however show signs of a recent flood that had overtopped the bridge (Figure 3.4).

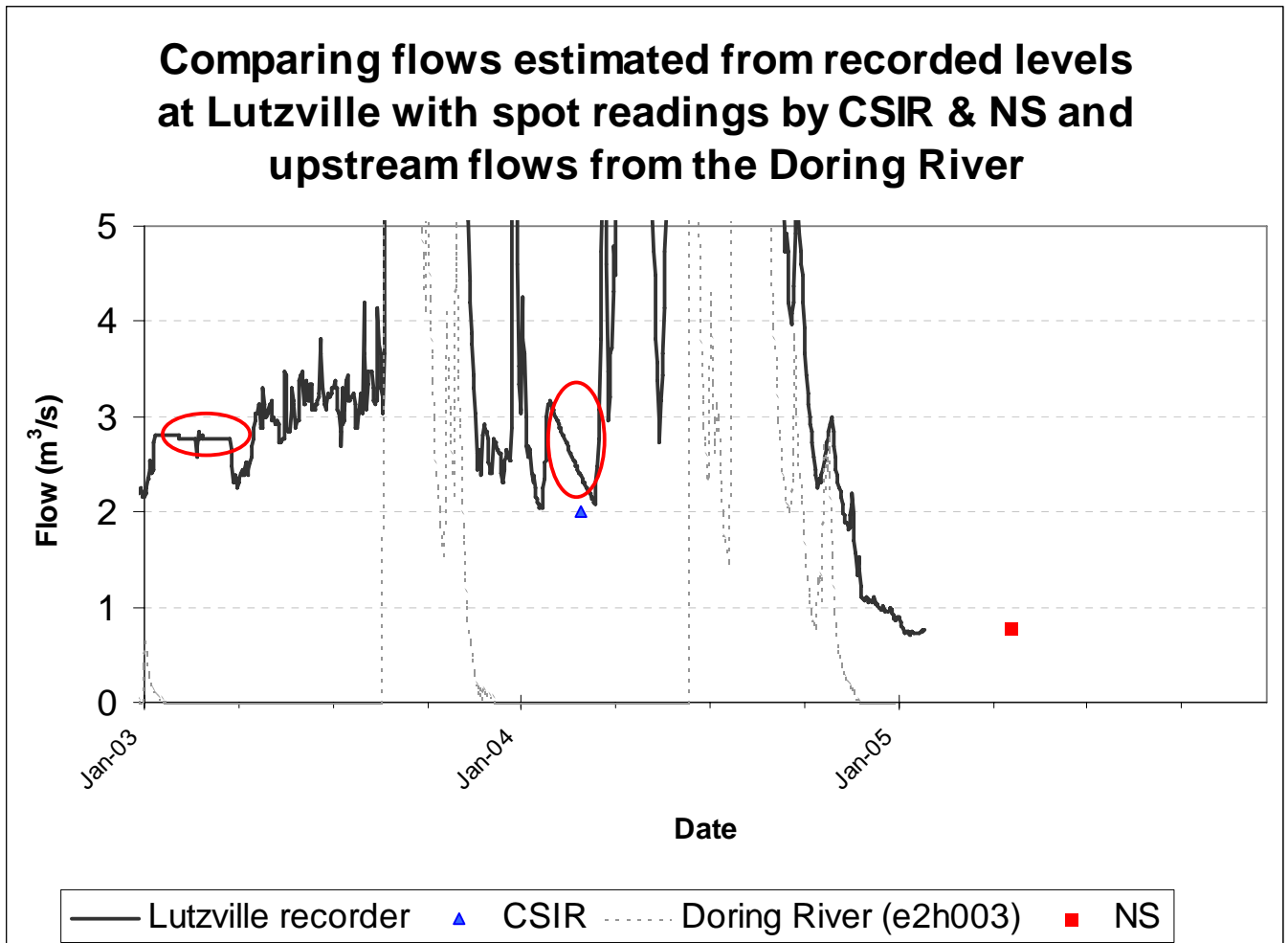


Figure 3.1 Estimated streamflows at Lutzville Causeway.

⁵ Alternatively, investigate whether the causeway can be modified sufficiently to improve measurement by:

- widening the central culverts to reduce blockage,
- increasing the soffit level of some of the culverts to encourage low flows to flow through the culverts near the banks that appear to be blocked less often, and,
- constructing a measurement weir just upstream / downstream of the bridge on the exposed rock bank.



Figure 3.2 Reeds blocking the causeway below Lutzille 24 April 2005.

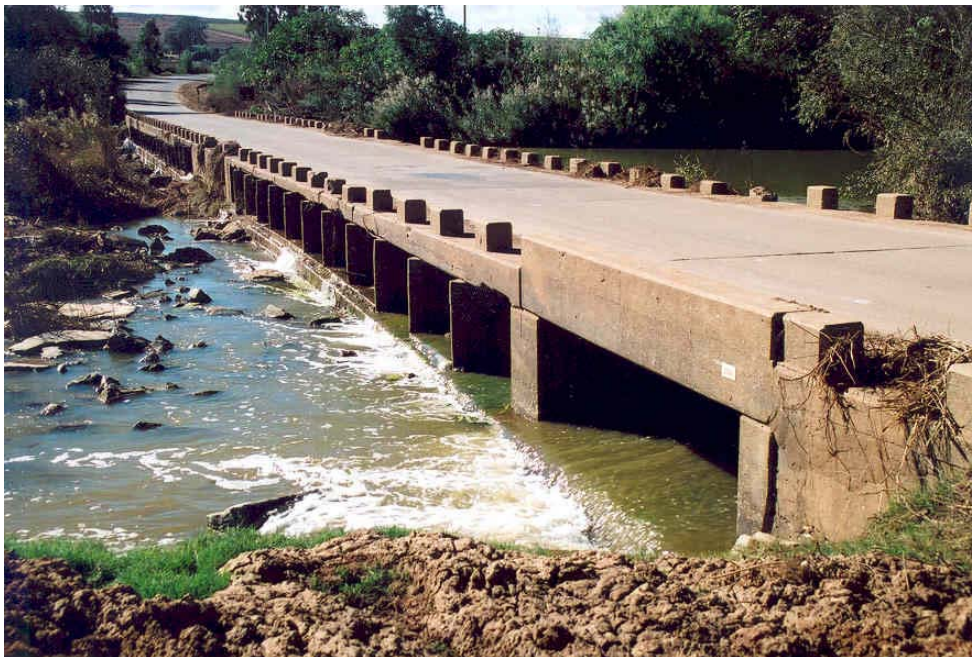


Figure 3.3 Most of the lowflows are passing through the wider culvert closest to the left bank (facing downstream) 24 April 2005.



Figure 3.4 Debris on bridge over dry riverbed of the Hols River 24 April 2005.

3.3 EWR FLOWS

Where possible, the EWR described in the Riverine RDM report were determined from daily streamflow sequences for present day development conditions. This flow sequence was derived from the present-day flow sequence by considering the contribution of each streamflow component (baseflow and floods of different sizes) to the seasonal requirements of the ecology and progressively omitting components that contributed the least the ecological condition in order to obtain daily flow sequences that maintained the river in a particular class using the least amount of water possible.

If flow-duration curves are used to model EWR flood releases in the WRYM model then flood releases might be repeated in successive months because the WRYM model does not have a mechanism to 'remember' having made a flood release in the preceding month. The WRYM currently does not ensure that the flood releases during a particular season (as opposed to month) do not exceed a certain value. For this reason, the sequences with the daily EWR streamflow requirements were aggregated into monthly sequences and used when modelling the EWR requirements in the WRYM. Unfortunately no EWR flow sequence could be prepared for EWR Site 2 because there was no acceptable daily streamflow record for present day conditions.

However, the daily EWR streamflow sequences only cover the latter period of the record and approximate EWR requirements were also required for the earlier portion of the record. For the earlier portion of the record a "maintenance" streamflow requirement was used for normal years and this was reduced to the "drought" requirement in drought years (assumed to be about 15% of the time). These drought years were selected by examining the streamflows in the Olifants and Doring Rivers and choosing years that appeared to be common to both rivers. The selected drought years are highlighted in Table 3.1. These drought years were only introduced in the early portion of the record when no suitable daily EWR requirement was specified.

In the Riverine RDM report these sequences were used to derive separate flow duration curves for each month. These flow duration curves were used to determine the flows required during "normal" years (approximately the mean flow for each month) and the flows required during "drought" years flows (approximately the driest 5% of the flow duration curve). These "normal" and "drought" flows are summarized in Table 3.2 for the different EWR sites and ecological classes considered. A more detailed breakdown of the baseflow and flood components is included in Appendix A. Interestingly, at EWR Sites 1 and 2 a high percentage of the natural flow (about 38%) is required to maintain a Category D river because farmers have bulldozed into the floodplain destroying habitat and have also constructed wellpoints adjacent to the river that remove summer baseflow. An integrated approach to managing the river, including altering agricultural practices, will have far more impact on the ecology than merely altering the river flows.

The EWR from the daily sequences have been aggregated into annual totals and summarized in Table 3.3. All the totals in Table 3.2 that exceed the total annual "maintenance" requirements in Table 3.2, have been shaded. For instance, in Table 3.2, 125 MCM per annum is required to maintain EWR Site 1 in a Category D condition during normal "Maintenance" years. In Table 3.3 all EWRs more than 125 MCM per annum have been shaded. As expected about half the values in the table have been shaded and are less than the "Maintenance" EWR. However for any month the annual "Drought" values in Table 3.2 are less than values in Table 3.3 because during a dry year there may still be one or two months of average streamflow⁶.

⁶ It must still be established whether the "drought" flow sequence specified in the report is 'acceptable'.

Table 3.1 Lowest drought flows at Lutzville – drought EWR requirements were applied throughout the system for the shaded years.

Annual total at Lutzville			
Natural		Current	
Year	Total	Year	Total
1968	319	1971	99.8
1971	362	1933	106
1933	367	1939	117
1939	382	1964	125
1964	417	1968	133
1959	424	1959	139
1965	445	1965	152
1977	452	1977	154
1927	459	1927	172
1948	460	1981	186
1926	478	1926	188
1929	486	1948	193
1981	503	1929	207
1979	515	1979	235
1925	518	1925	236
1972	552	1972	239
1937	564	1937	241
Median	922		613

Table 3.2 Typical intra-annual EWR requirements in normal and drought years.

Location & Class	Maintenance (M) / Drought	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	% Nat MAR	MAR		
																Natural	Present day	
1D	M	13.8	8.9	3.6	0.3	0.2	0.3	4.9	8.7	18.3	22.6	28.5	15.3	125	38%			
	D	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	4.8	4.5	6.0	3.8	21.4	6%	331	274	
2D	M	9.0	2.6	2.7	2.7	2.4	2.7	2.6	2.7	45.4	56.0	62.6	8.0	199.5	38%			
	D	1.0	0.0	0.0	2.7	1.1	0.0	0.0	0.4	1.9	3.2	8.6	8.3	27.2	5%	519	?	
3B	M	0.21	0.21	0.11	0.11	0.05	0.05	0.10	0.16	0.26	0.79	0.79	0.45	3.29	43%			
	D	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.03	0.03	0.03	0.03	0.14	2%	7.7	7.3	
3C	M	0.15	0.11	0.12	0.07	0.03	0.04	0.09	0.04	0.07	0.28	0.28	0.24	1.52	20%			
	D	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.03	0.03	0.03	0.03	0.14	2%	7.7	7.3	
4B	M	11.8	3.3	0.0	0.0	0.0	0.0	3.3	4.5	18.8	36.3	76.3	29.8	184.0	44%			
	D	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.8	0.2	3.6	1%	420	320	
4C	M	8.8	3.3	0.0	0.0	0.0	0.0	3.3	4.5	5.2	16.9	37.1	8.9	88.0	21%			
	D	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.8	0.2	3.6	1%	420	320	
5B	M	14.1	4.1	0.0	0.0	0.0	0.0	4.1	6.2	55.0	81.2	63.4	19.6	247.7	48%			
	D	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.5	1.3	0%	511	401	
5C	M	4.1	4.1	0.0	0.0	0.0	0.0	4.1	4.3	15.3	63.4	5.1	8.2	108.6	21%			
	D	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.5	1.3	0.3%	511	401	
6BC	M	2.9	0.5	0.1	0.0	0.0	0.1	1.2	1.6	8.7	18.4	25.0	7.8	66.3	48%			
	D	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.1	1.4	3.2	2%	138	104	
6C	M	1.5	0.5	0.1	0.0	0.0	1.1	1.2	1.1	4.6	7.7	19.0	3.8	40.6	29%			
	D	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.1	1.4	3.2	2%	138	104	
7		Add IFR 2 and IFR 5 together – assuming class B at site 5																
	M	23.2	6.7	2.7	2.7	2.4	2.7	6.7	8.9	100.4	137.3	126.1	27.6	447.2	44%			
	D	1.1	0.1	0.0	2.7	1.1	0.0	0.0	0.4	1.9	3.4	9.1	8.8	28.5	3%	1026		
8D		Apply 1.45 factor to IFR 1 to obtain an IFR downstream of Clanwilliam Dam																
	M	20.0	13.0	5.2	0.4	0.4	0.4	7.0	12.6	26.5	32.7	41.3	22.2	181.5	38%			
	D	1.5	0.0	0.0	0.0	0.0	0.0	0.0	1.4	7.0	6.6	8.7	5.6	31.0	6%	480	397	

Table 3.3 Annual totals aggregated from daily streamflow sequences.

SITE 1		SITE 3				SITE 4				SITE 5				SITE 6			
D		B		C		B		C		B		C		BC		C	
Ye	ar	Ye	ar	Ye	ar	Ye	ar	Ye	ar	Ye	ar	Ye	ar	Ye	ar	Ye	ar
Tot	al	Tot	al	Tot	al	Tot	al	Tot	al	Tot	al	Tot	al	Tot	al	Tot	al
'77	68	'72	2.2	'79	1.2	'71	32	'71	20	'71	36	'71	17	'79	21	'71	15
'81	90	'70	2.4	'72	1.2	'68	40	'65	30	'68	36	'65	24	'81	21	'81	16
'79	92	'71	2.5	'71	1.3	'64	41	'64	32	'64	51	'68	30	'71	22	'79	18
'85	94	'79	2.5	'82	1.4	'65	45	'77	35	'65	52	'64	36	'77	24	'77	20
'87	97	'74	2.5	'75	1.4	'77	46	'68	36	'77	59	'87	37	'78	37	'78	25
'83	98	'81	2.5	'74	1.5	'81	53	'87	39	'81	87	'77	42	'87	41	'70	33
'86	104	'77	2.9	'77	1.5	'79	73	'81	42	'79	98	'70	47	'74	41	'87	34
'78	125	'88	3.0	'81	1.5	'67	73	'67	46	'67	114	'81	49	'72	42	'74	37
'80	125	'78	3.2	'70	1.5	'87	93	'79	55	'87	118	'78	56	'70	44	'72	37
'88	129	'75	3.6	'86	1.6	'72	101	'72	56	'78	124	'72	57	'90	47	'85	49
'84	162	'80	3.8	'78	1.9	'78	103	'82	59	'72	129	'69	61	'85	64	'76	53
'82	186	'82	3.8	'87	1.9	'69	117	'74	69	'69	170	'79	61	'75	66	'75	55
'89	190	'86	3.9	'83	2.0	'70	123	'63	72	'88	186	'88	65	'91	74	'86	56
'90	241	'87	4.1	'88	2.0	'75	136	'69	79	'91	188	'63	67	'86	79	'90	57
		'89	4.7	'80	2.4	'63	150	'78	84	'74	190	'67	67	'83	79	'91	60
		'85	4.9	'85	2.6	'62	158	'62	92	'70	190	'85	83	'84	80	'84	65
		'83	5.1	'84	2.8	'84	163	'91	96	'75	196	'62	100	'80	85	'89	67
		'84	5.9	'76	2.8	'91	171	'85	97	'63	210	'91	107	'76	86	'83	74
		'76	6.4	'89	3.2	'88	179	'83	97	'62	227	'84	119	'88	91	'88	80
		'90	6.4	'90	3.7	'66	207	'84	115	'86	229	'76	127	'89	93	'80	82
		'73	9.4	'73	6.2	'74	223	'88	115	'84	236	'74	128	'82	97	'82	86
						'83	224	'70	126	'82	263	'86	139	'73	149	'73	144
						'86	229	'75	139	'83	285	'90	158				
						'85	278	'86	174	'66	304	'75	164				
						'82	291	'66	179	'90	386	'66	186				
						'90	304	'90	195	'60	429	'82	206				
						'60	325	'60	214	'80	441	'83	221				
						'80	427	'76	236	'61	457	'60	285				
						'76	447	'61	295	'76	458	'80	318				
						'73	478	'89	297	'85	473	'73	356				
						'89	487	'80	314	'73	492	'61	412				
						'61	543	'73	331	'89	585	'89	452				

3.4 TARGET DEMANDS

The historical firm yield of a system is the demand that can be supplied from the system using the historical inflow sequences without failure (i.e. curtailment). However, in the case of Clanwilliam Dam, if the applied demand was limited to the historical firm yield then the spillage from the system would increase. By increasing their target demands above the firm yield the irrigators increase the utilization of water from the system although during drought years the supply from the system must be reduced below the historical firm yield.

As is currently the case, many of the target demands applied to the system were above the firm yield. The drawdown of the dams was examined visually to see that the demand was not too excessive. The purpose of the analysis was to provide a wide spread of scenarios for the estuary rather than to determine the yields of the various scenarios for economic analyses. For each of the scenarios the drawdown of the dams and the supply from the proposed schemes is presented in Annexure E.

The reliability of the demand supplied for the scenarios varies significantly, partly because of the influence of the EWR releases. Note how in Scenario 2 (releasing the EWR from the current Clanwilliam Dam) the target draft is significantly above the yield causing the supply to vary significantly from year to year while in Scenario 10 (Raised Clanwilliam Dam plus Melkbosrug without EWR releases) the supply from Melkbosrug Dam is supplied for the full record without failure.

A more detailed analysis would have curtailed the demands when the storage dropped below a certain level. Increasing the target draft would have increased the frequency of the

curtailment until the level of curtailment became unacceptable. Alternatively, a long-term stochastic analysis could have been performed.

4. INFLOWS TO THE ESTUARY RESULTING FROM THE SCENARIOS CONSIDERED

For each of the scenarios the Mean Annual Runoff (MAR) at the estuary and the additional supply from the proposed schemes is presented in Table 4.1. Although the supply from the dams needs to be checked more rigorously, the results do indicate the significant impact of the EWR on the supply for different schemes. For instance, applying the EWR below Bulshoek Barrage (EWR Site 2) reduces the supply below the current level even if the Clanwilliam Dam is raised 15 metres (Scenario 7). EWR releases also reduce the supply of the proposed Groot Dam (Scenario 13) and Melkbosrug Dams (Scenario 11). A more detailed version of Table 4.1 has been included in Appendix B, which provides a breakdown of the contribution from the different schemes to the total supply. For interest, a copy of the WRYM system diagram for Scenario 1 is included in Appendix F.

Flow duration curves were prepared to summarise the altered flow distribution associated with each of the MARs⁷. For instance Figure 4.1 indicates that under natural flows a monthly flow of about 70 MCM per month (on the log scale) would have been exceeded about 40% of the time. If Melbosrug Dam is constructed to 470 MCM and no EWR releases are made (Scenario 10) then the flow with the exceedance probability of 40% will reduce from 70 to about 5 MCM per month. The number in front of the scenario description (260 in the case of Scenario 10) corresponds to the increase in average supply with respect to the present day supply.

The right hand half of these flow duration plots represents primarily summer flows. The model assumes that about 14% of the water supplied downstream of Bulshoek Barrage will be available to the estuary as return flows. This means that an increase in the supply from Clanwilliam Dam causes a corresponding increase in the return flows to the estuary during summer. The impact of additional farm dams in the Kouebokkeveld (Scenario 16) is difficult to determine because it depends on what extent they will intercept water from tributaries that have not yet been tapped. The impact could be more than has been modelled as the current model assumes that existing dams already try to intercept 30% of *all* the runoff from the Kouebokkeveld.

Each of the scenarios modelled results in a slightly different flow regime entering the Olifants/Doring estuary. Figure 4.1, Figure 4.2, Figure 4.3 and Figure 4.4 summarise the overall affect of each scenario using flow-duration curves of the monthly flows (MCM) entering the estuary. Additional details on the flow regimes are presented in Appendix E.

For winter highflows with an exceedance probability of less than 30% there are four main classes of impact:

- No impact (Natural);
- Present Day (Clanwilliam 121 MCM);
- Clanwilliam Raised by 15 metres (361 MCM) plus smaller additional schemes in the Doring River;
- Clanwilliam Dam raised by 15 metres (361 MCM) plus Melkbosrug Dam (470 MCM) in the Doring River.

A more detailed set of flow duration curves broken down by month is provided in Appendix E.

⁷ The modelled scenarios represent only approximations of the flow releases, requirements and inflows to the estuary. This will vary with climate, operation of the water resource developments and updated hydrological records for the system.

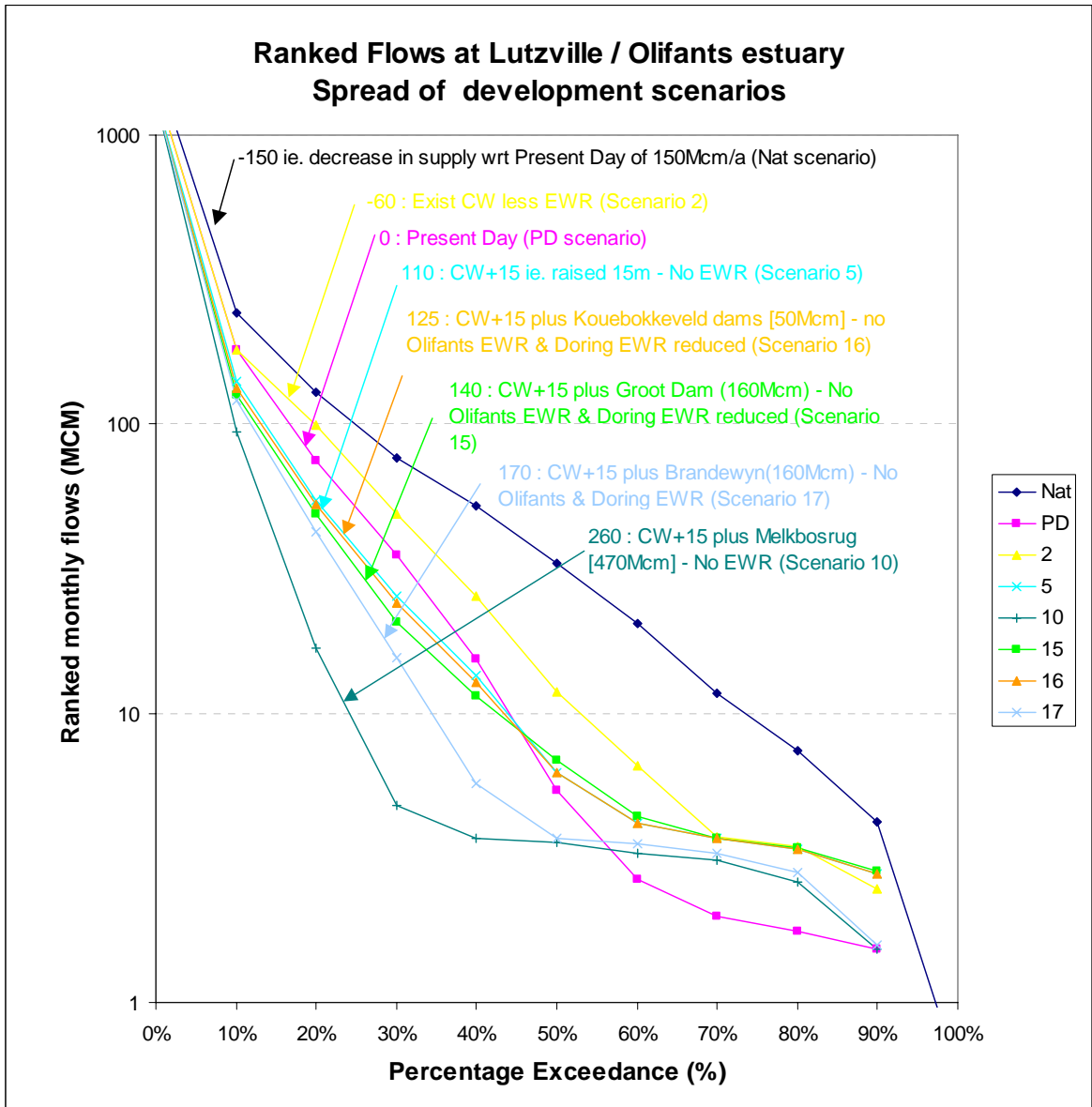


Figure 4.1 Ranked monthly flows (MCM) entering the estuary showing the spread of the scenarios that were modelled.

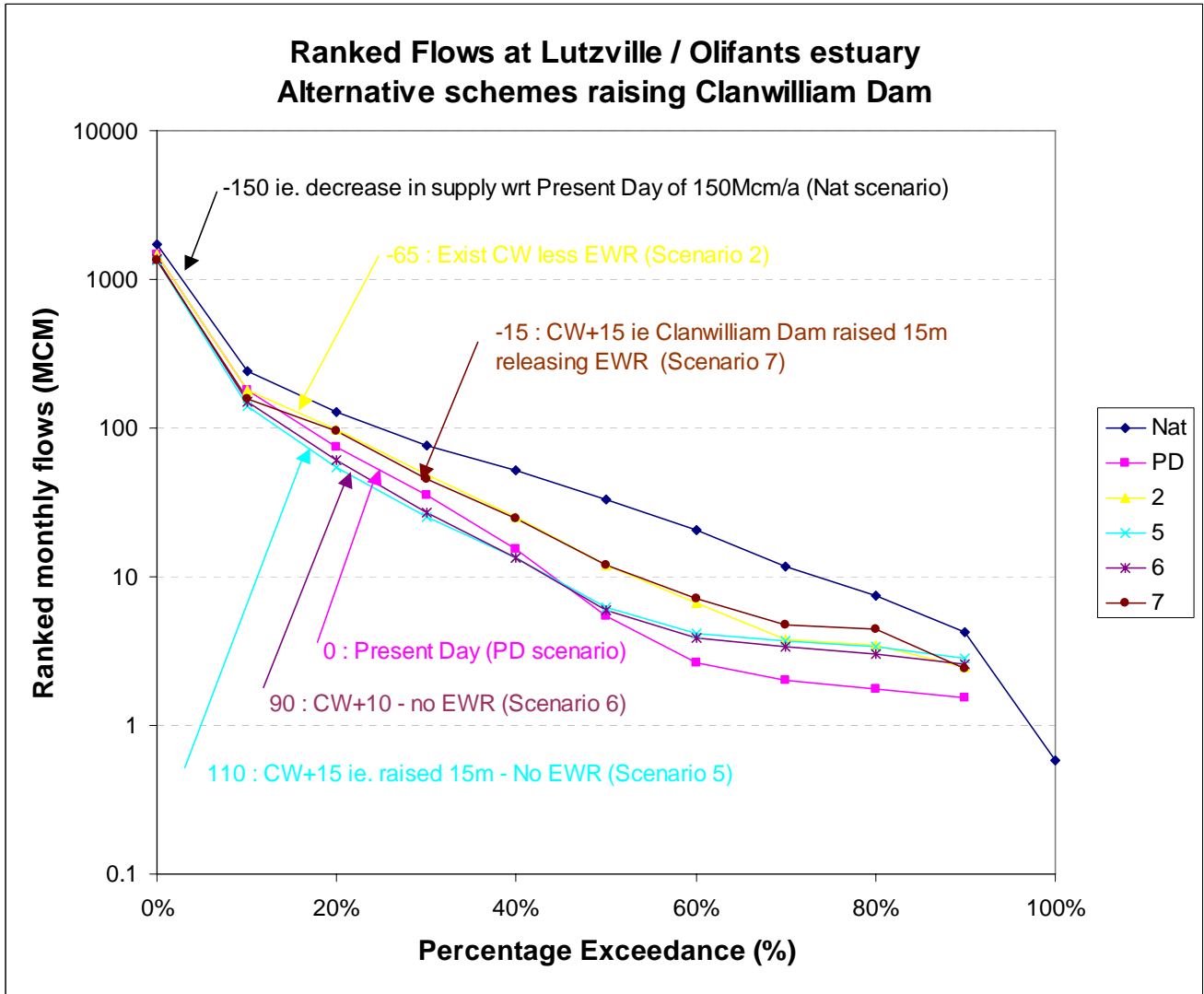


Figure 4.2 Flow duration curves for alternative schemes involving raising Clanwilliam Dam.

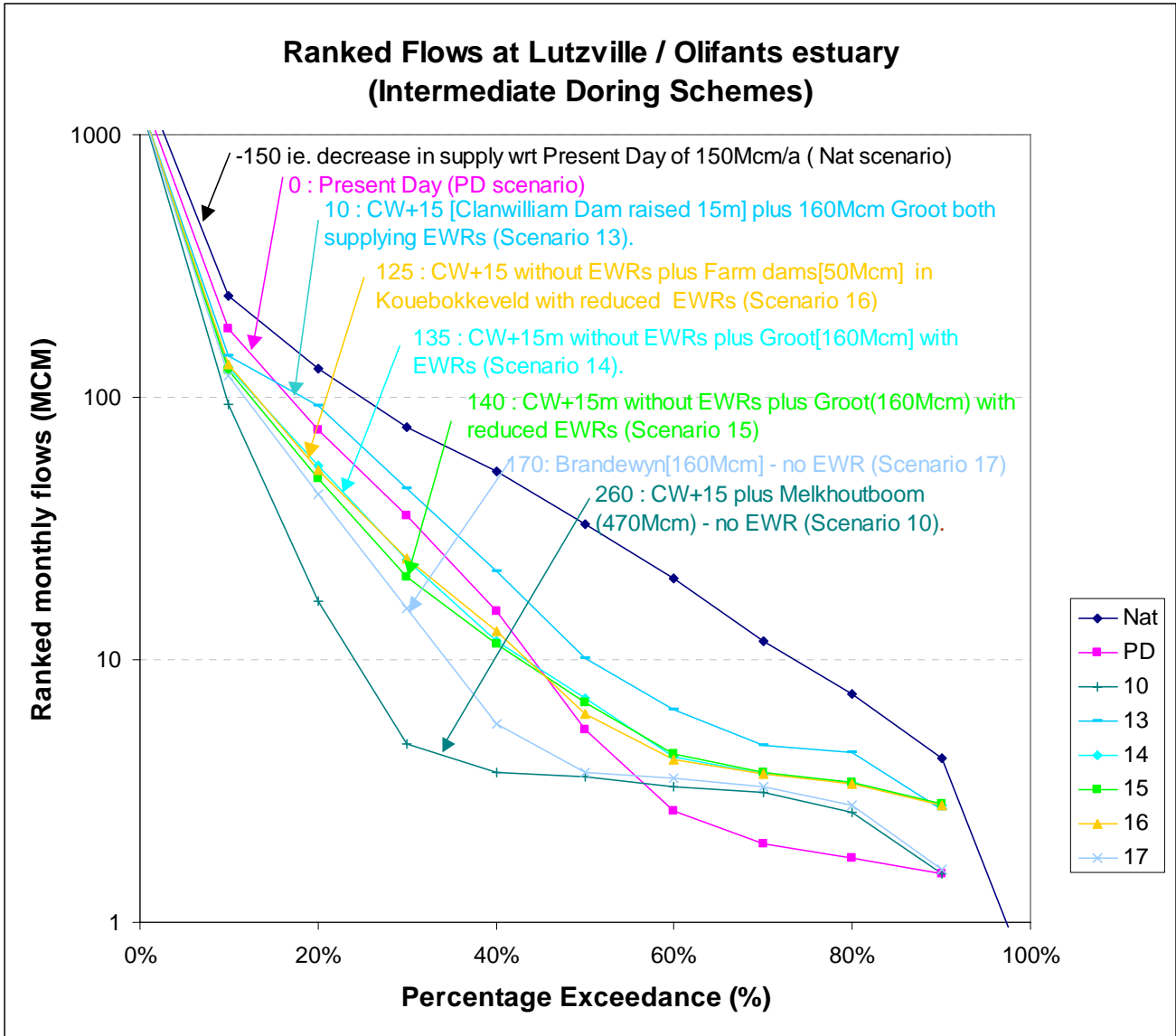


Figure 4.3 Flow duration curves for intermediate schemes in the Doring River.

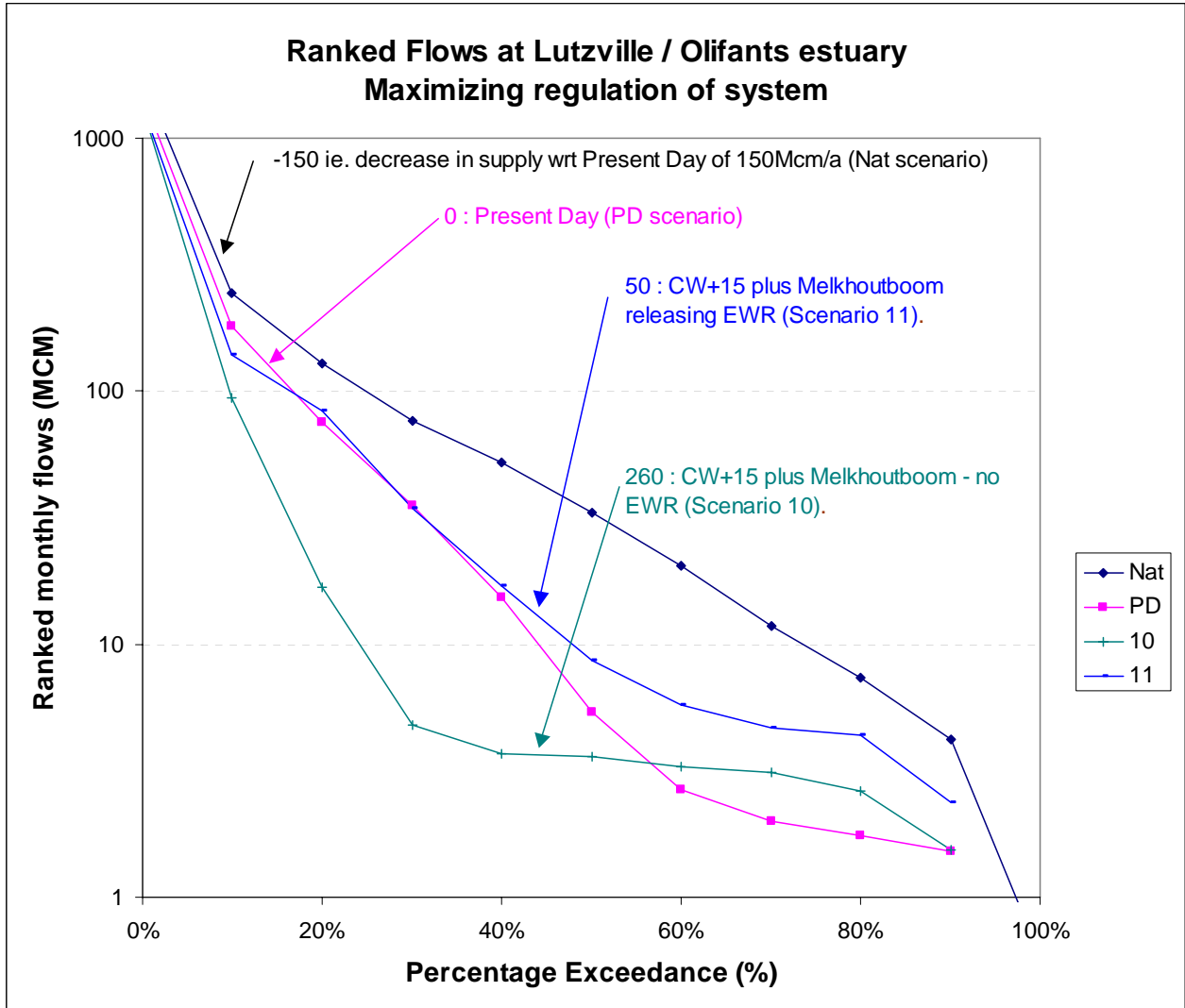


Figure 4.4 Flow duration curves for schemes maximizing the regulation of the system.

Table 4.1 Estuarine flows and approximate additional supply for the different scenarios⁸.

Scenario	Scenario ID	Variant	Schemes (Dam capacity in MCM)					Active EWR Sites							Key flows (MCM/a)		
			Additional Clanwilliam Dam (CwD) capacity	Melkbosrug	Brandewyn	Groot	F dams in Kouebokkeveld	Keerom Dam	Olifants (O)			Doring (D)			ds	Supply subtotal w/rt present day	Estuary
									1 : ds Hex	8 : 1.45x IFR 1 ds CwD	2 : ds Bulshoek	3 : on Rondegat trib	4 : us Biedou	5 : Oudrif	6 : on Groot trib		
Natural	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-148	1055
Present Day	1		+0	-	-	-	-	-	-	-	-	-	-	-	-	0	716
	2	EWR releases	+0	-	-	-	-	d	D	D	b	b	b	bc	y	-64	782
	3	EWR from CwD not Bulshoek	+0	-	-	-	-	d	D	-	b	b	b	bc	-		
	4	EWR @7	+0	-	-	-	-	-	-	-	-	-	-	-	y		
Maximize Olifants	5	Raise CwD 15m	+240	-	-	-	-	-	-	-	b	b	b	bc	-	109	597
	6	Raise CwD 10m	+143	-	-	-	-	-	-	-	b	b	b	bc	-	88	622
	7	Raise CwD 15m and release EWR	+240	-	-	-	-	d	D	D	b	b	b	bc	y	-13	725
	8	Developments u/s of CwD	+240	-	-	-	153	D	-	-	b	b	b	bc	-		
Dam Doring Headwaters	12	Groot	+240	-	-	159	-	d	-	-	b	B	B	bc	y		
	13	Groot + EWRs d/s CWD & DO confluence	+240	-	-	159	-	d	D	-	b	B	B	bc	y	11	691
	14	Groot without EWRs d/s CwD	+240	-	-	159	-	d	-	-	b	B	B	bc	-	134	565
	15	Groot with reduced EWRs on Doring	+240	-	-	159	-	d	-	-	b	C	C	bc	-	141	556
	16	Off-channel farm dams u/s proposed GrootR Dam in Kouebokkeveld	+240	-	-	-	50	d	-	-	b	c	C	bc	-	126	577
Intermediate Doring	17	Off-channel Brandewyn : No EWR d/s Brandewyn	+240	-	160	-	-	d	-	-	b	b	-	bc	-	169	518
	17B	Off-channel Brandewyn : EWR d/s Brandewyn	+240	-	160	-	-	d	-	-	b	b	B	bc		157	539
Maximize System	9	EWR d/s Doring confluence	+143	470	-	-	-	-	-	-	b	b	B	bc	y		
	10	No EWR d/s Doring confluence	+240	470	-	-	-	-	-	-	-	-	-	-	-	259	422
	11	Meet EWR throughout system	+240	470	-	-	-	d	D	D	b	b	B	bc	y	51	640

⁸ If EWR are set to "-" these requirements will not be actively supplied, however the volume contributed toward the EWR will be monitored. If a lower case letter is used no additional schemes were introduced upstream of the site to help meet the EWR.

5. SCENARIOS SELECTED FOR CONSIDERATION BY THE ESTUARINE TEAM

The main two criteria for selection of scenarios for presentation to the estuarine team (see Section 2) were that the scenarios be realistic approximations of possible future inflows to the Olifants/Doring estuary and that they cover as wide a range as possible in terms of differences in both the Mean Annual Runoff (MAR), and the distribution of the flows reaching the estuary. After due consideration of the inputs received from those consulted, the following scenarios were selected:

- Scenario 0⁹: Naturalised conditions.
- Scenario 1: Present day conditions, i.e., with no EWR releases.
- Scenario 2: Present day level of development and meeting the EWR for the REC at each of eight EWR sites along the river.
- Scenario 5: Raising Clanwilliam Dam by 15 m and meeting the EWR for the REC at five of the eight EWR sites along the river. The three sites excluded are EWR Site 2, downstream of Bulshoek Barrage, EWR Site 7, downstream of the confluence of the Olifants and Doring Rivers and EWR Site 8 between Clanwilliam Dam and Bulshoek Barrage.
- Scenario 17: Raising Clanwilliam Dam by 15 m, plus an abstraction weir at Melkbosrug (Brandewyn option) and meeting the EWR at four of the eight EWR sites along the river. The four sites excluded are EWR Site 2, downstream of Bulshoek Barrage, EWR Site 5 downstream of Oudrif, EWR Site 7, downstream of the confluence of the Olifants and Doring Rivers and EWR Site 8 between Clanwilliam Dam and Bulshoek Barrage.
- Scenario 10: Raising Clanwilliam Dam by 15 m, plus a dam at Melkboom or Melkbosrug on the Doring River and not meeting any of the EWRs.

In addition, depending on the time available at the Estuary Workshop, the Estuarine Team Leaders agreed to try and consider an additional scenario, namely:

- Scenario 7: Raising Clanwilliam Dam by 15 m and meeting the EWR for the REC at all eight EWR sites along the river.

An additional scenario (Scenario 16) was considered, but resulted in flows to the estuary that were very similar to those achieved from Scenario 5, and it was decided to rather replace it with Scenario 7, as above.

- Scenario 16: Raising Clanwilliam Dam by 15 m, plus additional development of farm dams in the Kouebokkeveld and meeting the EWR at five of the eight EWR sites along the river. The three sites excluded are EWR Site 2, downstream of Bulshoek Barrage, EWR Site 7, downstream of the confluence of the Olifants and Doring Rivers and EWR Site 8, between Clanwilliam Dam and the Bulshoek Barrage.

The Flow Duration Curves for each of the scenarios that were selected are repeated in Figure 5.1 – Figure 5.7 in a larger format than those presented in Appendix E.

⁹ Scenarios 0 and 1 MUST form part of the considerations of the estuarine team as it is these that provide the benchmarks for assessment of the other scenarios (see Inception Report).

File 1 : NAT-164.MON, NAT-164.mon
File 2 : PD-164.MON, PD-164.mon
File 3 : ,

Plot Date : 28 Apr 05, 10:32
Common Period : 20/10 - 59/12

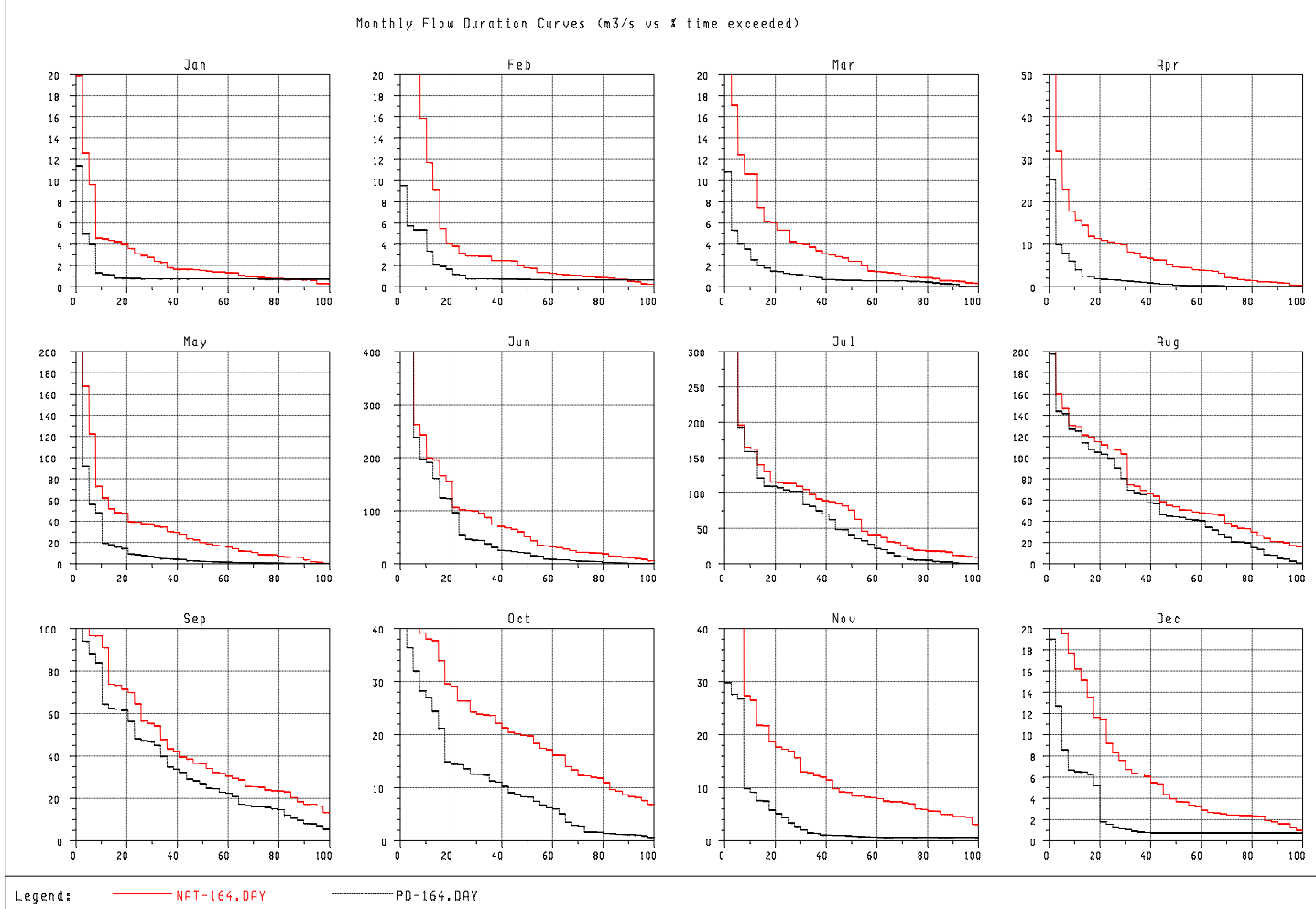


Figure 5.1 Flow duration curves for Scenarios 0 and 1: Naturalized and present day with no EWRs.

File 1 : NAT-164.DA2, NAT-164.day
File 2 : PD-164.DA2, PD-164.day
File 3 : 2-164.DA2, 2-164.day

Plot Date : 11 Jun 05, 12:36
Common Period : 50/10 - 89/12

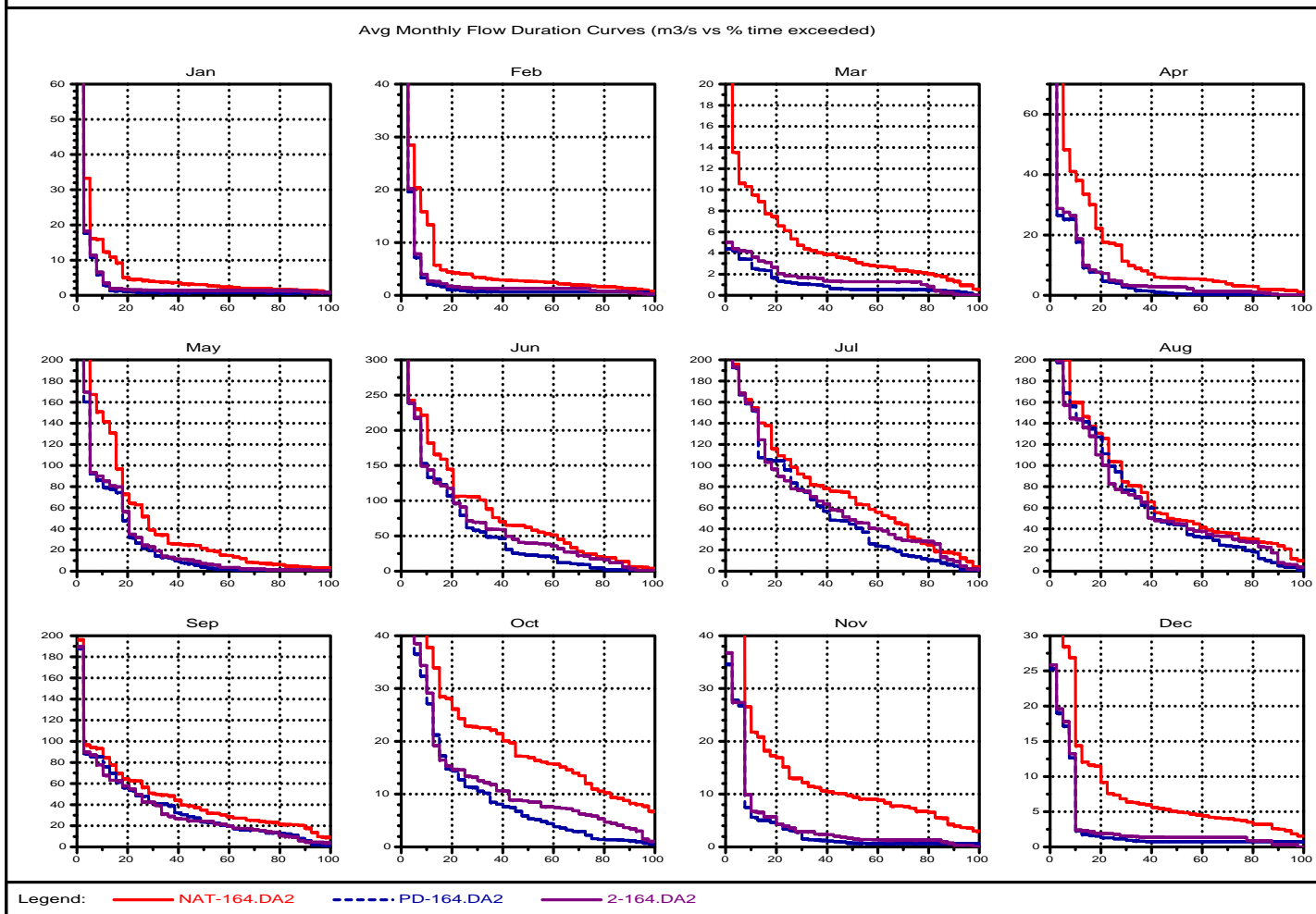


Figure 5.2 Flow duration curves for Scenario 2: Present day level of development and meeting the EWRs for the REC at each of eight EWR sites along the river.

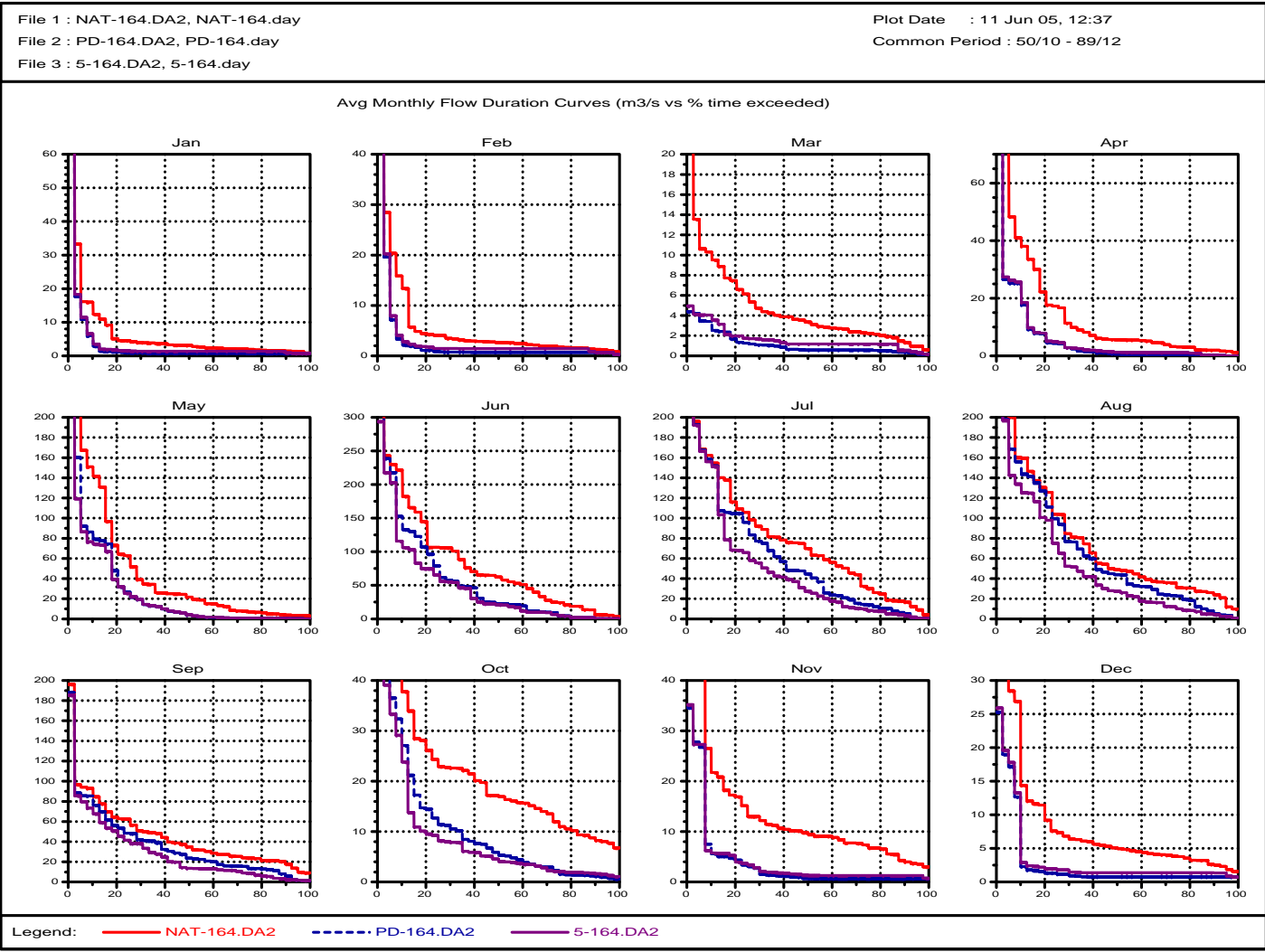


Figure 5.3 Flow duration curves for Scenario 5: Raising Clanwilliam Dam by 15 m and not meeting the EWR for EWR Sites 2, 7 and 8.

File 1 : NAT-164.DA2, NAT-164.day
 File 2 : PD-164.DA2, PD-164.day
 File 3 : 17-164.DA2, 17-164.day

Plot Date : 11 Jun 05, 12:34
 Common Period : 50/10 - 89/12

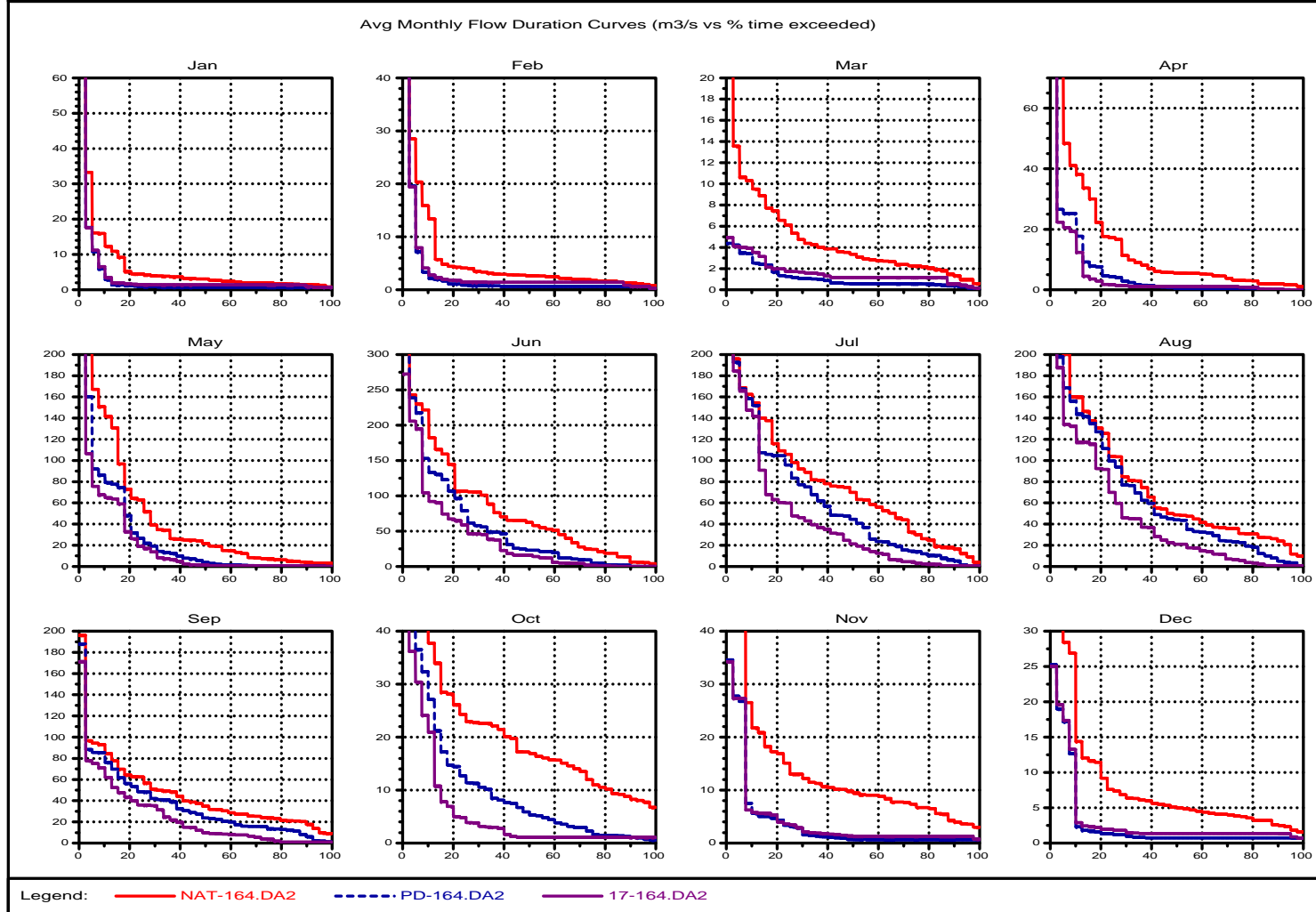


Figure 5.4 Flow duration curves for Scenario 17: Raising Clanwilliam Dam by 15 m, plus an off-channel dam on the Brandewyn River with no EWRs supplied at EWR Sites 2, 5, 7 and 8.

File 1 : NAT-164.DA2, NAT-164.day
File 2 : PD-164.DA2, PD-164.day
File 3 : 10-164.DA2, 10-164.day

Plot Date : 11 Jun 05, 12:20
Common Period : 50/10 - 89/12

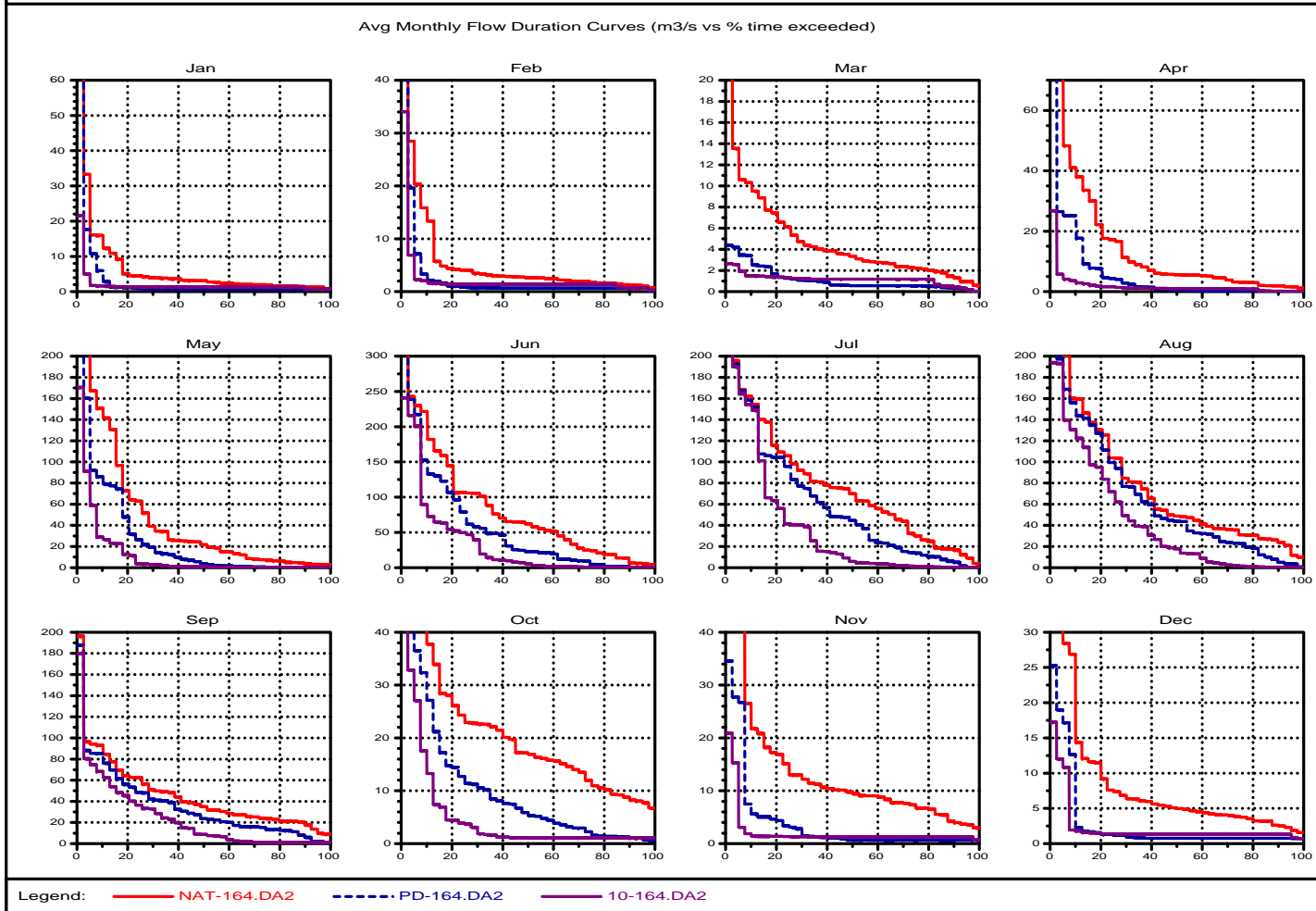


Figure 5.5 Flow duration curves for Scenario 10: Raising Clanwilliam Dam by 15 m, plus a dam at Melkbosrug on the Doring River and no EWRs.

File 1 : NAT-164.DA2, NAT-164.day
File 2 : PD-164.DA2, PD-164.day
File 3 : 7-164.DA2, 7-164.day

Plot Date : 11 Jun 05, 12:38
Common Period : 50/10 - 89/12

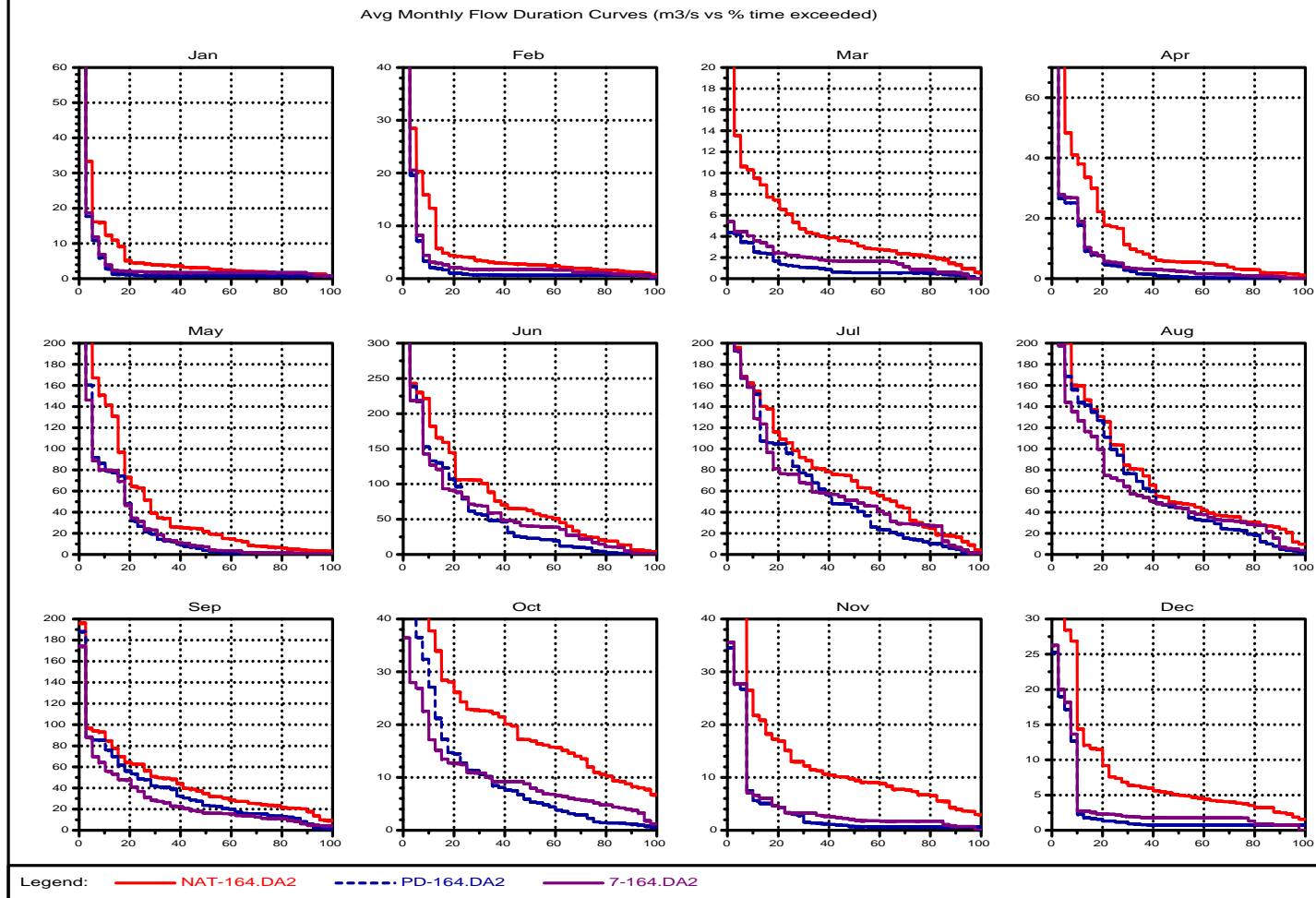


Figure 5.6 Flow duration curves for Scenario 7: Raising Clanwilliam Dam by 15 m and meeting the EWRs for the REC at all eight EWR sites along the river.

File 1 : NAT-164.DA2, NAT-164.day
 File 2 : PD-164.DA2, PD-164.day
 File 3 : 16-164.DA2, 16-164.day

Plot Date : 11 Jun 05, 12:32
 Common Period : 50/10 - 89/12

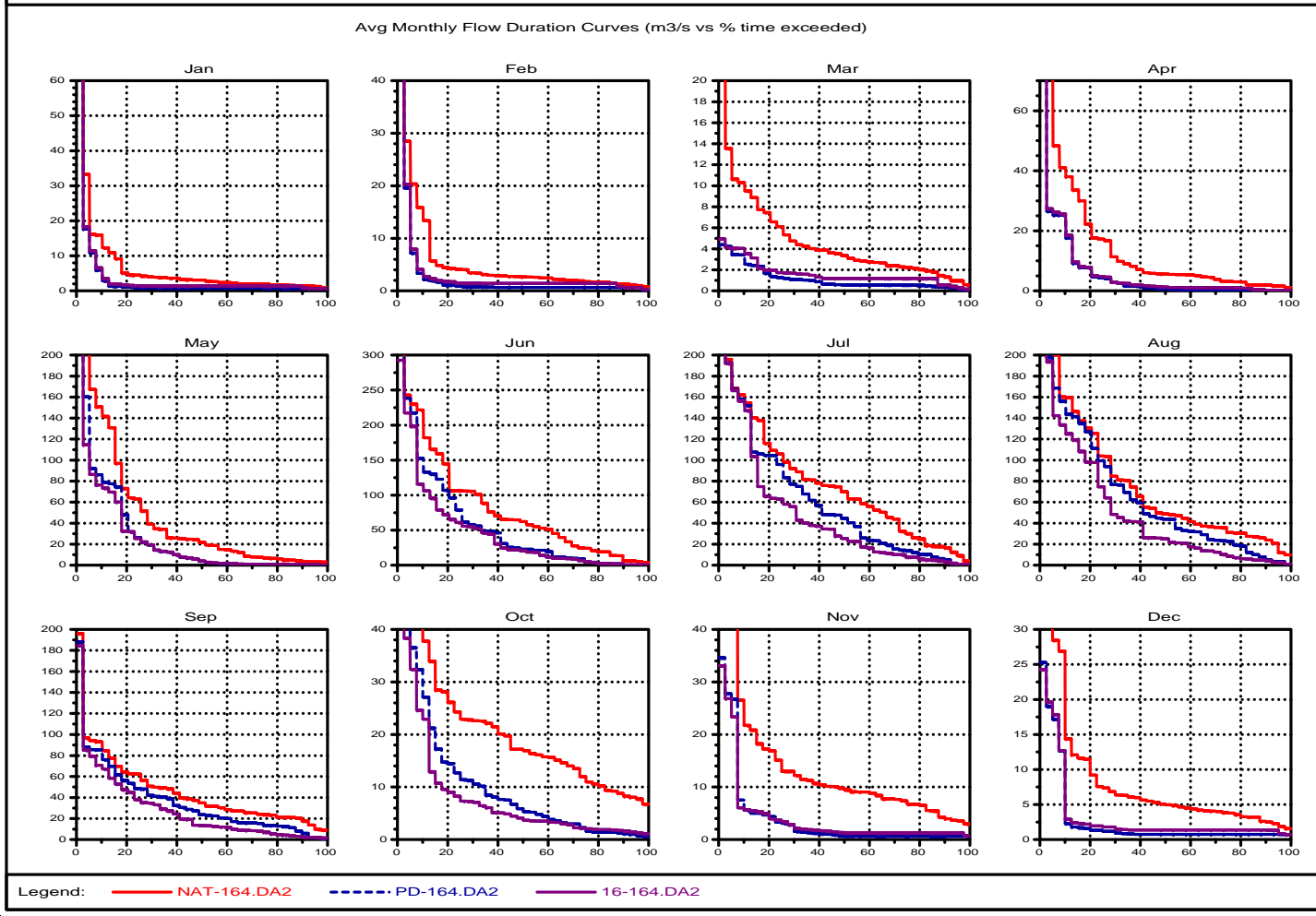


Figure 5.7 Flow duration curves for Scenario 16: Raising Clanwilliam Dam by 15 m plus additional development of farm dams in the Kouebokkeveld and not satisfying the EWR flow requirements at EWR Sites 2 (downstream of Bulshoek Barrage), 7 (downstream of the Olifants/Doring confluence) and 8 (between Clanwilliam Dam and Bulshoek Barrage).

6. RECOMMENDATIONS

6.1 IMPROVED FLOW GAUGING AT LUTZVILLE

In the short term, additional lowflow readings are necessary for the 2005/6 summer period at the causeway downstream of Lutzville. In the longer term, an improved low flow weir should be constructed to monitor inflows into the estuary.

6.2 IMPROVED MODELLING OF EWRS IN THE WRYM

As suggested in Section 3.3, the WRYM needs a mechanism to 'remember' having made a flood release in a particular season to avoid repeating the same release in subsequent months. This could be achieved by ensuring that the flood releases during a particular season (as opposed to a particular month) do not exceed a certain value.

7. REFERENCES

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- Provincial Government Western Cape: Department of Agriculture. 2004. Agricultural development plan and economic analysis (Volume 1 Draft 2.2) – Western Cape Olifants/Doring Irrigation Study (WODRIS). Prepared by J. Howcroft, D. Blanks, M. Copeland, J. Laubscher and N. Vink. September 2004

APPENDIX A: DETAILED EWR COMPONENT SUMMARY

Location & Category	COMPONENT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	% Nat MAR	MAR		
																Natural	Present day	
1D	MAINTENANCE																	
	Low flows	8.8	2.3	0.3	0.3	0.2	0.3	1.6	5.4	11.7	16.1	16.1	10.4	73	22%			
	Flood (class 1)	4.95	6.6	3.3				3.3	3.3	6.6			4.95	33	10%			
	Flood (class 2)										6.5			6.5	2%			
	Flood (class 3)											12.4		12.4	4%			
	Intra-annual totals	13.8	8.9	3.6	0.3	0.2	0.3	4.9	8.7	18.3	22.6	28.5	15.3	125	38%			
	Inter-annual floods													45	14%			
	DROUGHT																	
	Low flows (no floods)	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	4.8	4.5	6.0	3.8	21	6%			
	Total flows from record	7.1	3.4	1.7	0.66	0.2	0.6	2.6	5.3	25.1	40.8	25.7	15.3	129	39%	331	274	
2D	MAINTENANCE																	
	Low flows	4.0	2.6	2.7	2.7	2.4	2.7	2.6	2.7	4.4	8.0	9.6	8.0	52	10%			
	Flood (class 1)	5								5		5		15	3%			
	Flood (class 2)									6	6	6		18	3%			
	Flood (class 3)										12	12		24	5%			
	Flood (class 4)									30	30	30		90	17%			
	Intra-annual totals	9.0	2.6	2.7	2.7	2.4	2.7	2.6	2.7	45.4	56.0	62.6	8.0	199	38%			
	Inter-annual floods													?				
	DROUGHT																	
	Low flows (no floods)	1.0	0.0	0.0	2.7	1.1	0.0	0.0	0.4	1.9	3.2	8.6	8.3	27				
Total flows from record	Not available for this site.															519	?	
3B	MAINTENANCE																	
	Capping flows																	
	Low flows	0.19	0.16	0.11	0.11	0.05	0.05	0.05	0.05	0.10	0.24	0.24	0.31	1.66	22%			
	Flood (class 1)	0.03	0.05					0.05		0.05			0.02	0.20	3%			
	Flood (class 2)								0.11	0.11			0.11	0.33	4%			
	Flood (class 3)										0.22	0.22		0.44	6%			
	Flood (class 4)										0.33	0.33		0.66	9%			
	Intra-annual totals	0.2	0.2	0.1	0.1	0.0	0.1	0.1	0.2	0.3	0.8	0.8	0.4	3.3	43%			
	Inter-annual floods													1.1	14%			
	DROUGHT																	
Low flows (no floods)	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					
Total flows from record	0.2	0.2	0.1	0.11	0.1	0.1	0.07	0.15	0.32	0.93	1.05	0.64	4.06	53%	7.7	7.3		
3C	MAINTENANCE																	
	Low flows	0.13	0.11	0.07	0.07	0.03	0.04	0.04	0.04	0.07	0.17	0.17	0.22	1.15	15%			
	Flood (class 1)	0.03		0.05				0.05					0.025	0.15	2%			
	Flood (class 2)										0.11	0.11		0.22	3%			
	Intra-annual totals	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.3	0.3	0.2	1.5	20%			
	Inter-annual floods													0.59	8%			
	DROUGHT																	
	Low flows (no floods)	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.03	0.03	0.03	0.03	0.1	2%			
	Total flows from record	0.2	0.1	0.1	0.08	0.1	0.1	0.06	0.15	0.18	0.19	0.66	0.38	2.17	28%	7.7	7.3	
	4B	MAINTENANCE																
Capping flows		-	2.59	2.68	2.68	2.44	2.68	0										
Low flows		5.4	0.1	0.0	0.0	0.0	0.0	0.1	1.3	7.8	16.1	16.1	15.6	62	15%			
Flood (class 1)		6.4	3.2					3.2	3.2				3.2	19	5%			
Flood (class 2)										11			11	22	5%			
Flood (class 3)											20.2	20.2		40	10%			
Flood (class 4)												40		40	10%			
Intra-annual totals		11.8	3.3	0.0	0.0	0.0	0.0	3.3	4.5	18.8	36.3	76.3	29.8	184	44%			
Flood Class 5: 1:2 year														40	10%			
Inter-annual floods														55	13%			
DROUGHT																		
Low flows (no floods)	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.8	0.2	3.6	1%				
Total flows from record	6.8	3.9	1.3	6.28	2	0.9	13.2	25.2	39.32	39.1	36.7	24.7	199	47%	420	320		
4C	MAINTENANCE																	
	Capping flows	-	2.6	2.7	2.7	2.4	2.7	0.0	-									
	Low flows from adjusting B category (no floods)	2.4	0.1	0.0	0.0	0.0	0.0	0.1	1.3	5.2	5.9	5.9	5.7	27	6%			
	Flood (class 1)	6.4	3.2					3.2	3.2				3.2	19	5%			
	Flood (class 2)										11	11		22	5%			

Location & Category	COMPONENT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	% Nat MAR	MAR		
																Natural	Present day	
	Flood (class 3)											20.2		20	5%			
	Intra-annual totals	8.8	3.3	0.0	0.0	0.0	0.0	3.3	4.5	5.2	16.9	37.1	8.9	88	21%			
	Inter-annual floods													50	12%			
	DROUGHT																	
	Low flows from adjusting B category (no floods)	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.8	0.2	4	1%			
	Total flows from record														120	29%	420	320
	5B MAINTENANCE																	
	Capping flows	-	2.6	2.7	2.7	2.4	2.7	0	-						N/a			
	Low flows from adjusting B category (no floods)	6.1	0.1	0.0	0.0	0.0	0.0	0.1	2.2	13.0	22.2	21.4	15.6	81	16%			
	Flood (class 1)	8	4					4	4				4	24	5%			
Flood (class 2)									15		15		30	6%				
Flood (class 3)									27		27		54	11%				
Flood (class 4)										59			59	12%				
Intra-annual totals	14.1	4.1	0.0	0.0	0.0	0.0	4.1	6.2	55.0	81.2	63.4	19.6	248	48%				
Inter-annual floods													65	13%				
DROUGHT																		
Low flows (no floods)	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.5	1					
Total flows from record	6.7	1.9	1	18.2	24	52	47.7	44.9	21.1	8.9	4.3	3.2	234	46%	511	401		
5C MAINTENANCE																		
Capping flows	-	2.6	2.7	2.7	2.4	2.7	0	-						N/a				
Low flows (no floods)	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.3	0.3	4.4	5.1	4.2	15	3%				
Flood (class 1)	4	4					4	4				4	20	4%				
Flood (class 2)									15				15	3%				
Flood (class 3)									-				0	0%				
Flood (class 4)										59			59	12%				
Intra-annual totals	4.1	4.1	0.0	0.0	0.0	0.0	4.1	4.3	15.3	63.4	5.1	8.2	109	21%				
Inter-annual floods													61	12%				
DROUGHT																		
Low flows (no floods)	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.5	1	0.3%				
Total flows from record	4.9	2.7	2.6	5.74*	1.7	1	16.4	19.6	11.13*	32.1	22.1	13.8	134	26%	511	401		
6BC MAINTENANCE																		
Capping flows																		
Low flows (no floods)	1.9	0.5	0.1	0.0	0.0	0.1	0.2	0.6	2.7	5.4	8.0	5.8	25	18%				
Flood (class 1)	1						1	1	2			2	7	5%				
Flood (class 2)										2	2		4	3%				
Flood (class 3)									4		4		8	6%				
Flood (class 4)										11	11		22	16%				
Intra-annual totals	2.9	0.5	0.1	0.0	0.0	0.1	1.2	1.6	8.7	18.4	25.0	7.8	66	48%				
Inter-annual floods													16	12%				
DROUGHT																		
Low flows (no floods)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.1	1.4	3	2%				
Total flows from record	2.7	2.1	0.7	0.3	0.1	0.3	0.76	5.76	8.713	13.1	17.7	11.2	63	46%	138	104		
6C MAINTENANCE																		
Capping flows																		
Low flows (no floods)	0.5	0.5	0.1	0.0	0.0	0.1	0.2	0.1	0.6	1.7	2.0	1.8	8	5%				
Flood (class 1)	1					1	1	1	2			2	8	6%				
Flood (class 2)									2	2	2		6	4%				
Flood (class 3)										4	4		8	6%				
Flood (class 4)											11		11	8%				
Intra-annual totals	1.5	0.5	0.1	0.0	0.0	1.1	1.2	1.1	4.6	7.7	19.0	3.8	41	29%				
Inter-annual floods													16	12%				
DROUGHT																		
Low flows (no floods)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.1	1.4	3	2%				
Total flows from record															138	104		

*Discrepancies relate to flood events occurring in some months and not in others.

APPENDIX C: DRAWDOWN OF DAMS AND ANNUAL SUPPLY FOR EACH SCENARIO

Present day infrastructure

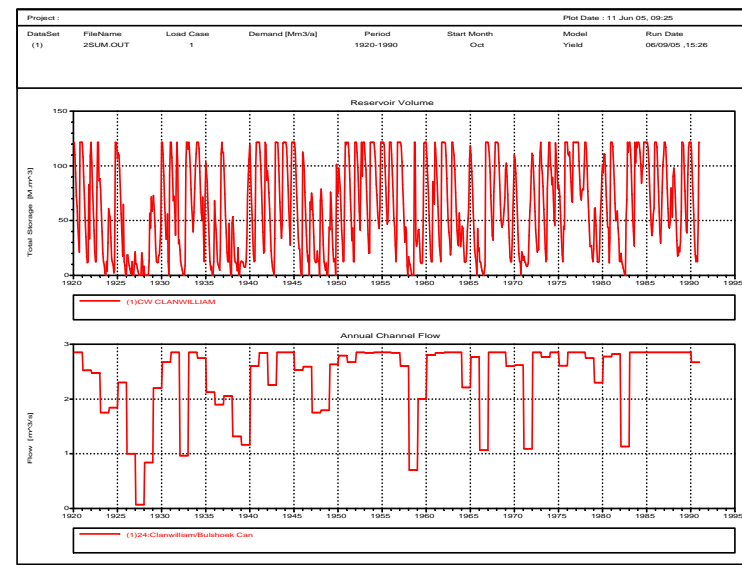
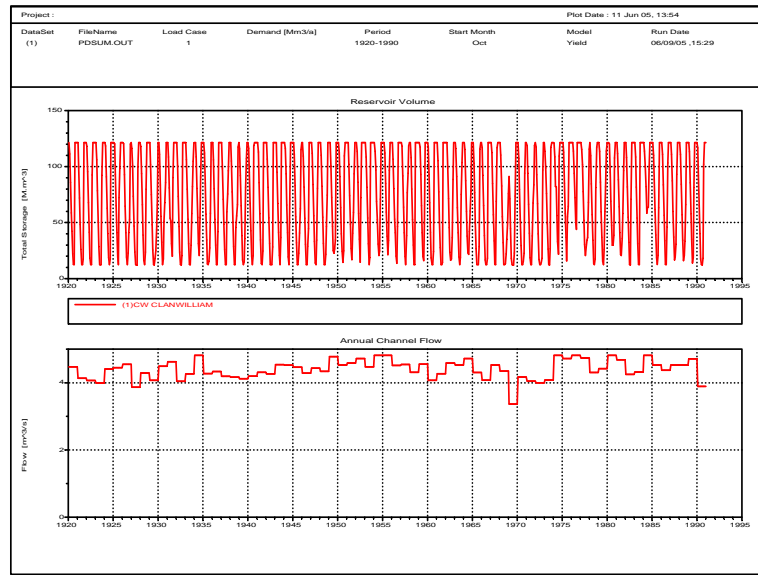


Figure C.1 : Present day without EWR releases (top left)

Figure C.2 : Scenario 2 - existing Clanwilliam Dam with EWR releases (top right).

Raising Clanwilliam Dam

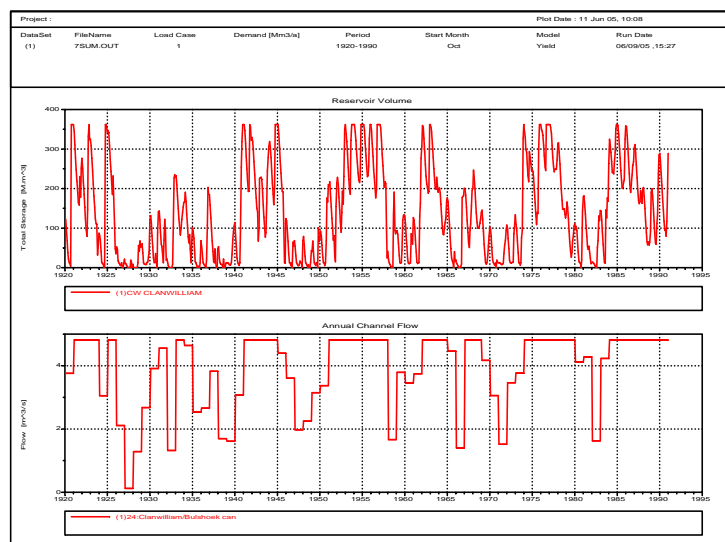
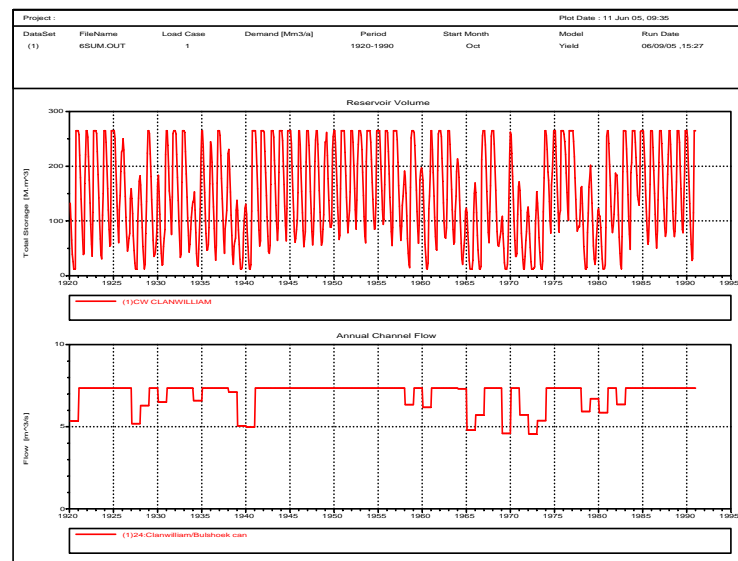
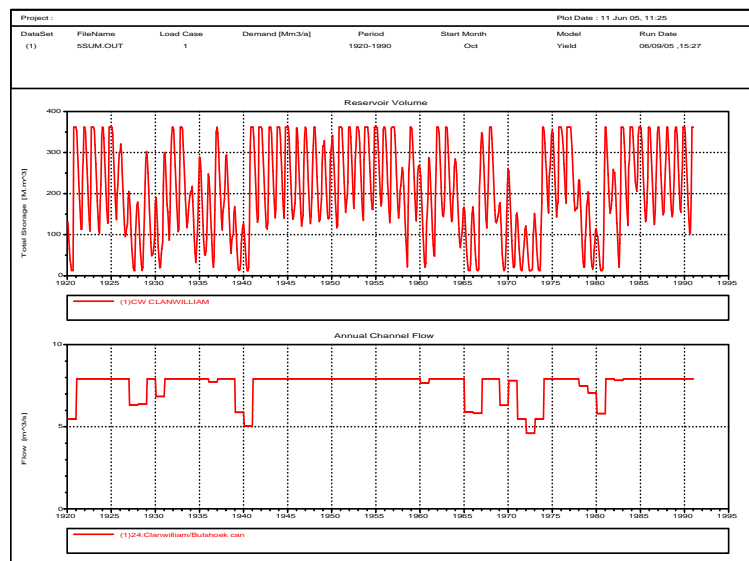


Figure C.3 : Scenario 5 - Raising Clanwilliam Dam by 15 metres without EWR releases (top left)
 Figure C.4 : Scenario 6 - Raising Clanwilliam Dam by 10 metres without EWR releases (top right)
 Figure C.5 : Scenario 7 - Raising Clanwilliam Dam by 15 metres with EWR releases (bottom left).

Schemes damming Doring Headwaters

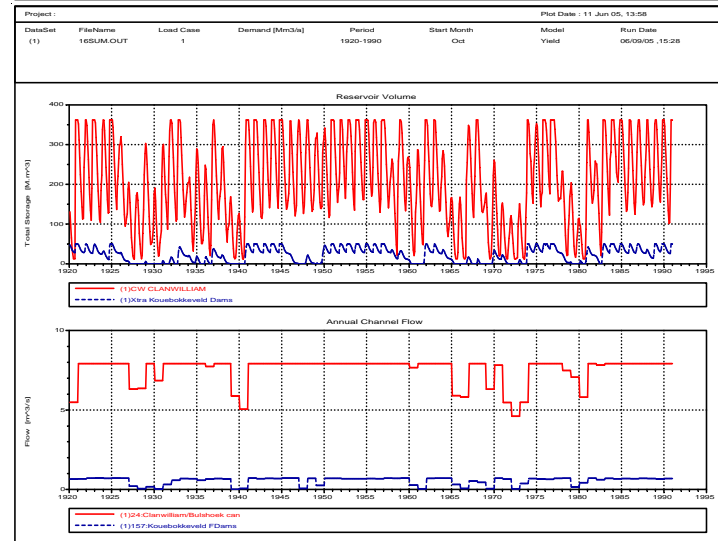
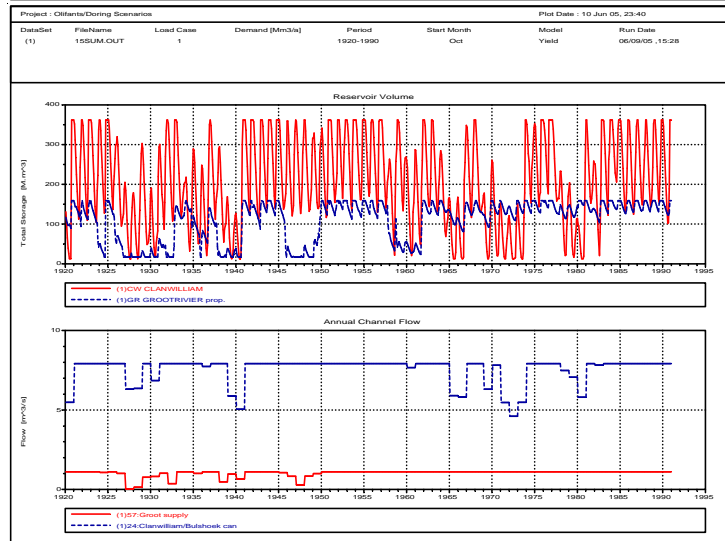
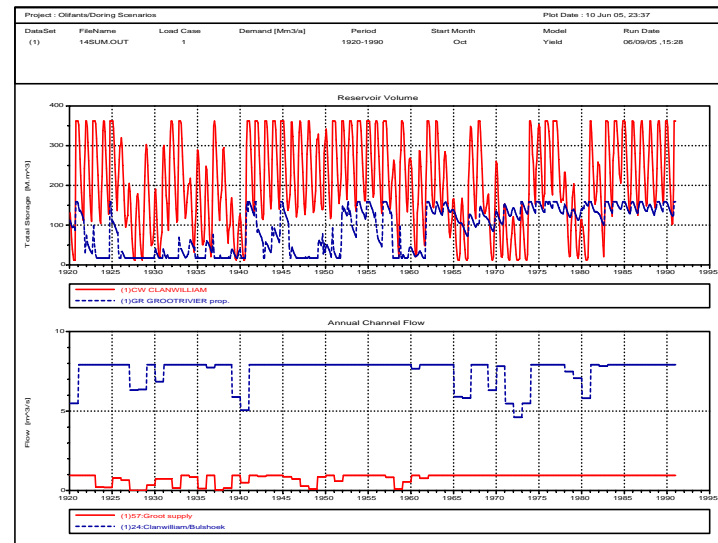
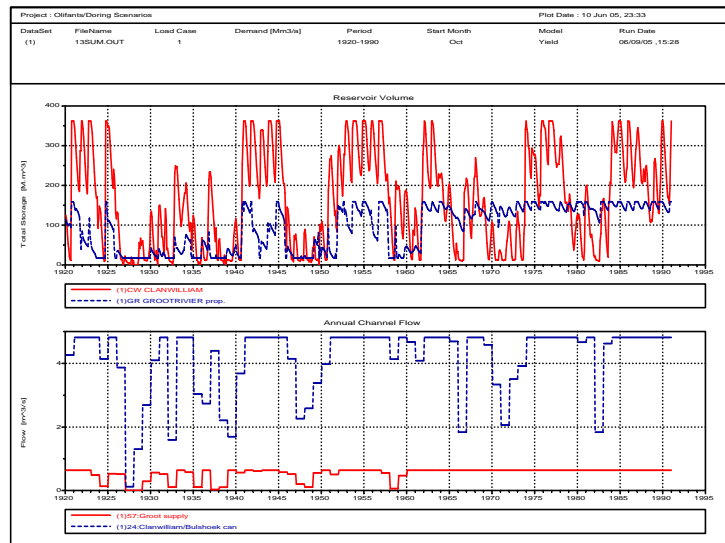


Figure C.6 : Scenario 13 –Groot River Dam supplying EWRs downstream of Clanwilliam Dam and on the Doring River (top left)

Figure C.7 : Scenario 14 –Groot River Dam supplying EWRs on the Doring River (top right)

Figure C.8 : Scenario 15 –Groot River Dam supplying reduced EWRs on the Doring River (bottom left)

Figure C.9 : Scenario 15 –Additional off-channel farm dams in the Kouebokkeveld supplying reduced EWRs on the Doring River (bottom right).

Intermediate development of Doring

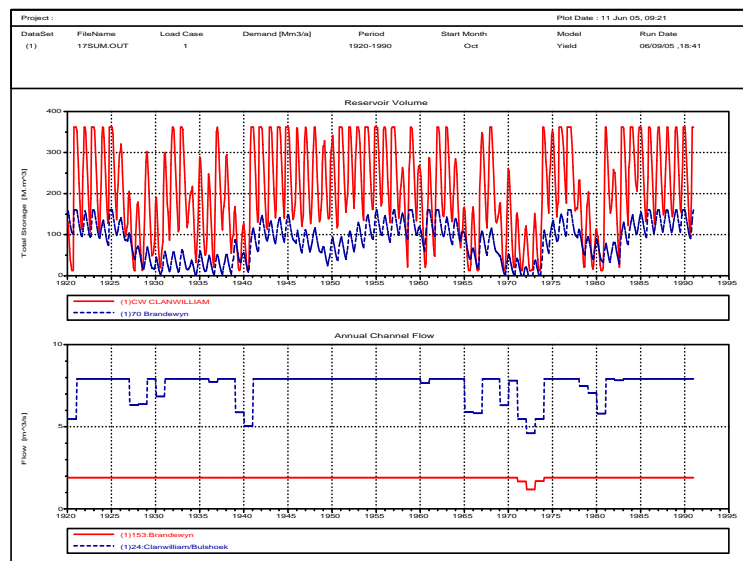
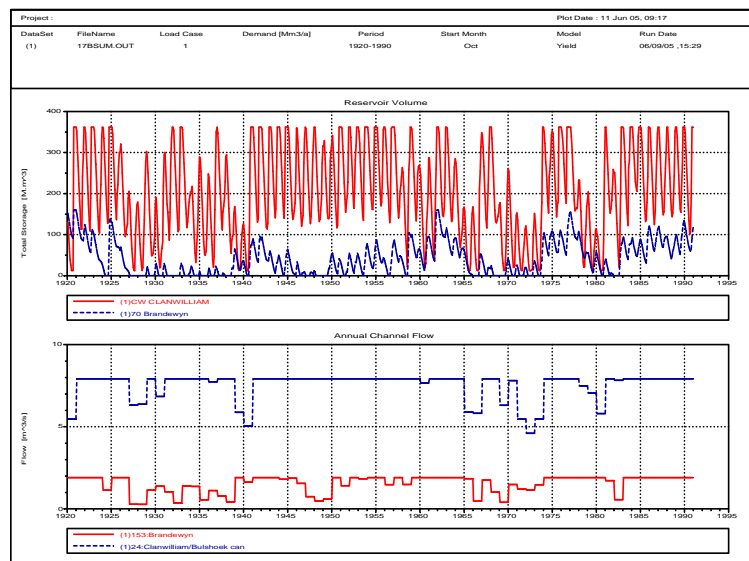


Figure C.10 : Scenario 17 – Off channel Brandewyn Dam not supplying EWR (top left)

Figure C.11 : Scenario 17B - – Off channel Brandewyn Dam only diverting when EWR supplied (top right).

Maximum regulation of Olifants and Doring Rivers

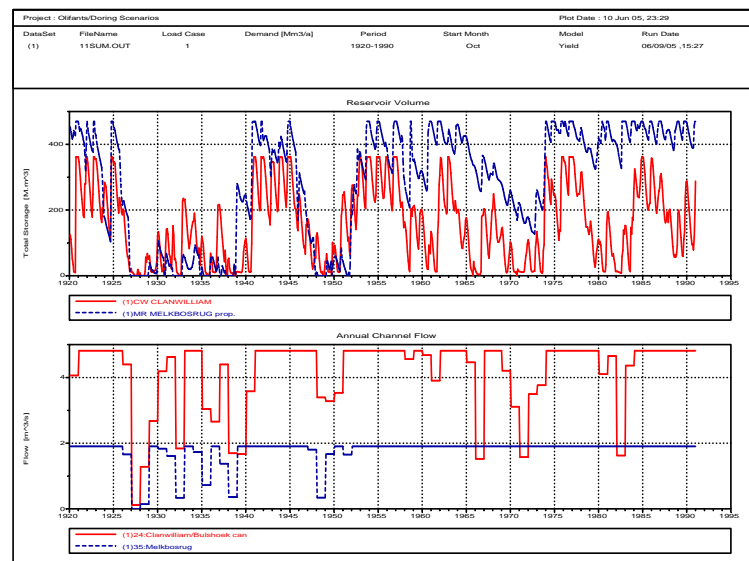
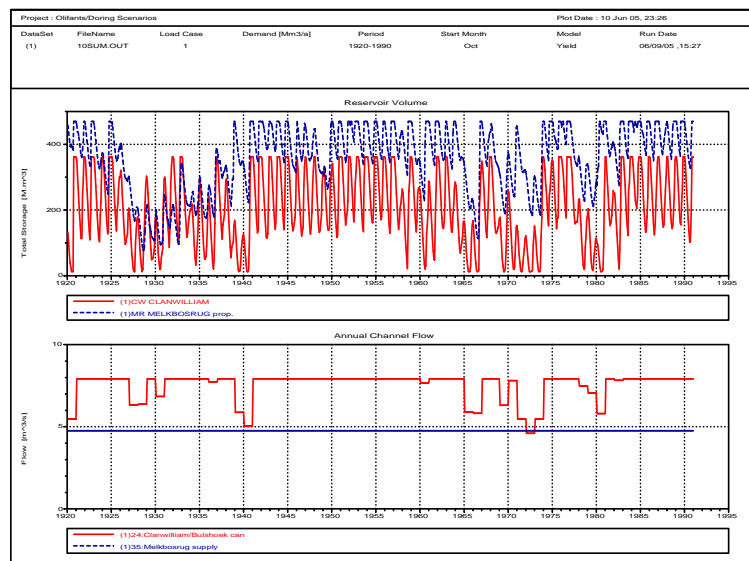


Figure C.12 : Scenario 10 – Clanwilliam Dam raised 15m and Melkbosrug Dam without EWRs (top left)

Figure C.13 : Scenario 11 – Clanwilliam Dam raised 15m and Melkbosrug Dam supplying EWRs (top right)

APPENDIX D: OPERATION OF CLANWILLIAM DAM

From: "Van Heerden Francois (CLW)" <VHeerdF@dwaf.gov.za>
To: Erik VanDerBerg <Erik.VanDerBerg@shands.co.za>
Date: 06/05/2005 15:40:39
Subject: RE: CLANWILLIAM DAM RAISING STUDY: Info on Bulshoek Barrage

The initial and 5-yearly Dam Safety Reports (which NS have) do have some information. Part of it is about flood hydrology at Bulshoek Barrage. I think there is also an Operation and Maintenance report in terms of the Dam Safety Regulations. These reports ought to be available in the Dam Safety Office (A. Chemaly), Dr C Oosthuizen's office and hard copies in W-Cape Regional Office with A Parker (file no's 510/D1 or 530/D1) and Worcester Office (E. Weidemann, or lately, D. Oosthuizen in the Bellville Office).

There is also a "Strukturplan" which was done by the West Coast District Municipality, and has to do with development and control in the dam basin and water surface and focus more on recreational activities. Hard copies also available in abovementioned files 510/D1 or 530/D1. There is a "Bulshoekdam Oewereienaarsvereniging" who is involved with control of these activities and who needs to be informed when, for instance the water level of the dam is involved. There are a number of recreational businesses (holiday houses, caravan parks, etc.), which depends on income from these activities. Power boating and skiing is very popular and for that reason a high water level in the dam is desirable (maximum depth at the dam wall is only 5,53 m (gauge plate reading)).

Flood releases (crest gates) at Bulshoek Barrage depend directly on what happens at Clanwilliam Dam and also floods from the Jan Dissels River. It does happen that a flood occurs in the Jan Dissels River while there are no releases from Clanwilliam Dam (when Clanwilliam Dam is not filled up). It is of importance that the water level in Bulshoek Barrage is not too low (not lower than 4.8 m is suggested) when incoming floods occurs, because of silting up of the dam basin by sand washed in with high flow rates. A considerable amount of silting up already did happen because of this.

Water releases, other than floods, at Bulshoek are dictated by the irrigation demand of the Government Water Scheme downstream of Bulshoek and is controlled by the Lower Olifants River WUA (LORWUA). Maximum releases into the canal is about 7 to 8 m³/s during the peak summer months. During winter months maintenance work is done on the canal system and for that reason the canal is closed for periods of 14 days at a time. This "dry periods" normally starts at the beginning of May each year, but when there are water restrictions, it starts earlier depending on the severity of the restrictions and the canal is then closed for longer periods and flows for shorter periods. Information about these releases is available at LORWUA (and some summaries at De Wet Oosthuizen's Office).

During years of no or very little water restrictions the water level during the irrigation season is kept fairly constant at a level of in the region of 5,0 m to almost full capacity level. When there are water restrictions the dam is operated at a level of 4,8 to 5,1 m, otherwise spills over the crest gates could occur during high southerly wind events. The dam cannot be operated at too low water levels during the peak demand season, because at some stage not enough water can then be released into the canal.

During winter months, especially at the beginning of the raining season, the dam is operated at a much lower level to be able to "catch" runoff from the Jan Dissels River (when Clanwilliam Dam is not filled yet) and to provide storage space for unused water releases from Clanwilliam Dam, which were released for irrigation farmers between Clanwilliam and Bulshoek, pumping water directly from the Olifants River,

especially when the canal at Bulshoek is closed as well. During such events the dam is operated at a water level of about 3,8 to 4.0 m, especially when there are water restrictions - when no restrictions: it is operated at higher levels. At levels of 3,8 to 4.0 m, it impacts severely on recreational activities in the dam and also to some extent on irrigation and other pump abstraction points in the dam basin.

Clanwilliam Dam serves as the main reservoir and water is released from there to Bulshoek - this is also done via LORWUA's requests. LORWUA basically controls all releases (other than floods at Clanwilliam Dam) from Clanwilliam Dam and Bulshoek Barrage and the water level of the Bulshoek Barrage. LORWUA is also responsible for operation (and eventually maintenance) of Bulshoek Barrage wall, the canal sluices and crest gates during floods.

The operation and maintenance of Clanwilliam Dam is still the responsibility of DWAF (De Wet Oosthuizen).

Clanwilliam Dam and Bulshoek Barrage basins fall within the recently established Clanwilliam WUAs area of responsibility, but they are not yet involved in the operation and maintenance of the scheme. Bulshoek Barrage wall and everything downstream, falls within the area of responsibility of LORWUA. We envisage that there will be close co-operation between the two WUAs in future.

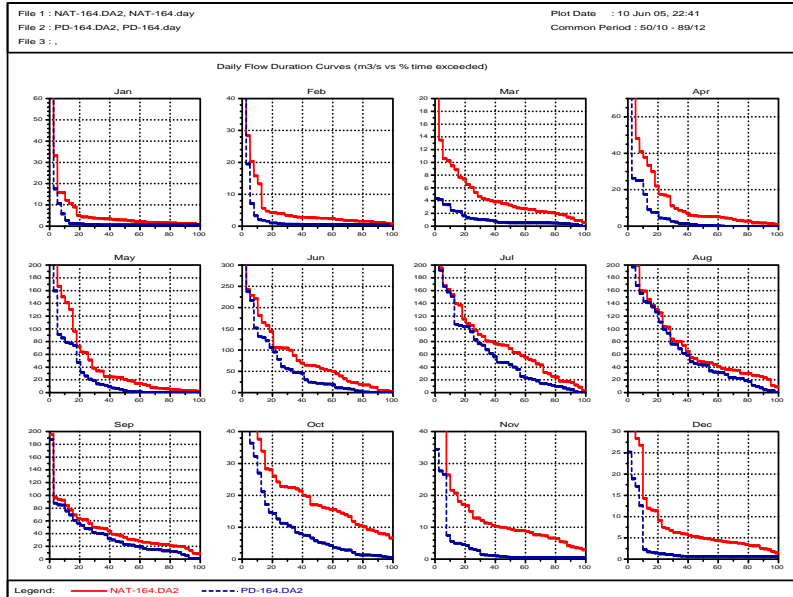
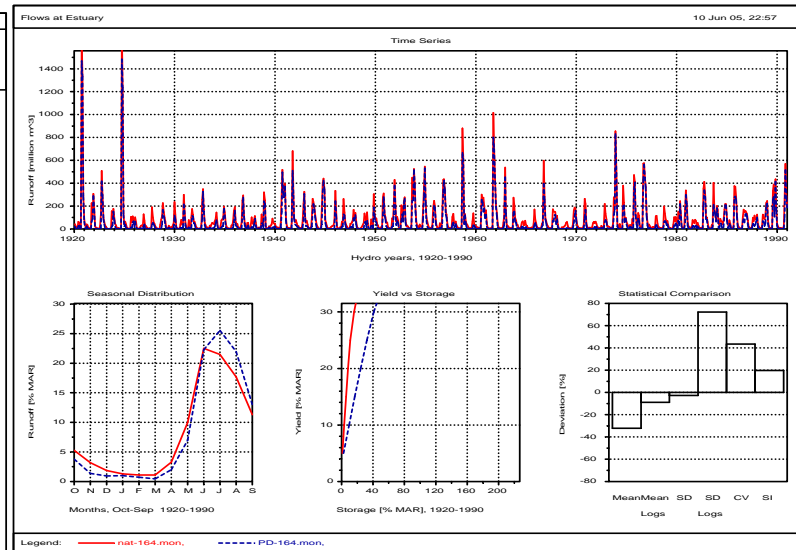
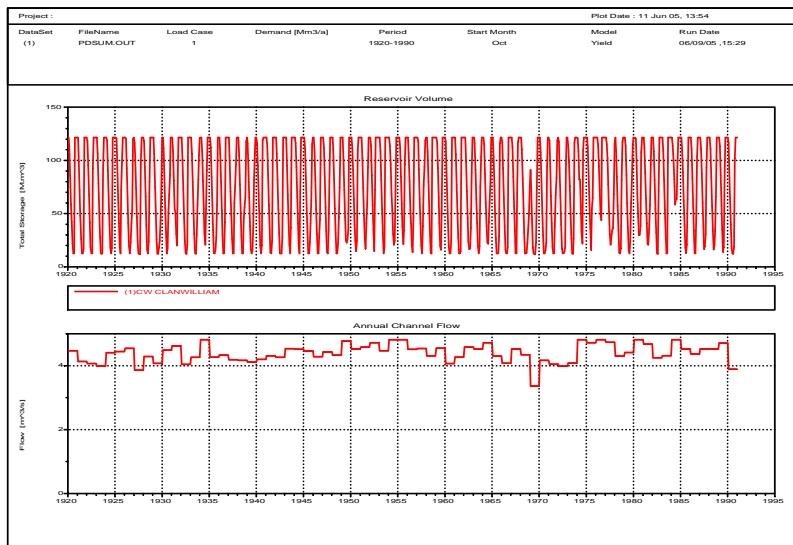
Total leakage water from Bulshoek was at some stage (26 Jan 94) estimated to be 1200 l/s of which it was estimated that the leakage through the foundation alone was only about 700 l/s, the rest was from excessive leakage from the crest gates at the time and leakage from the canal. Thereafter some work was done in the foundation by DWAF: Worcester, with the effect that the leakage was much less, for some time (contact E Weidemann for details). The leakage however gradually increased again and on 11 Apr 02 it was estimated to be about 500 l/s. There after DWAF: Construction did some major repair work (new concrete apron) to stabilize the foundation which unfortunately did not better the situation much, because the leakage is estimated to be about the same still. Some grout work still needs to be done, maybe next year and that will hopefully make a difference. In the mean time LORWUA, at their own costs, recently installed pumps downstream of the dam wall, pumping leakage water back into either the canal or the dam. (For details contact LORWUA: J Matthee).

A comprehensive Reserve determination study is currently in progress. Information of an estimated desktop Reserve requirement is however attached for your information. Please contact Toni Belcher about this, if necessary.

Francois van Heerden

APPENDIX E: SCENARIO PLOTS OF STORAGE TRAJECTORIES AND WATER SUPPLY; ESTUARY FLOW STATISTICS AND FLOW DURATION CURVES

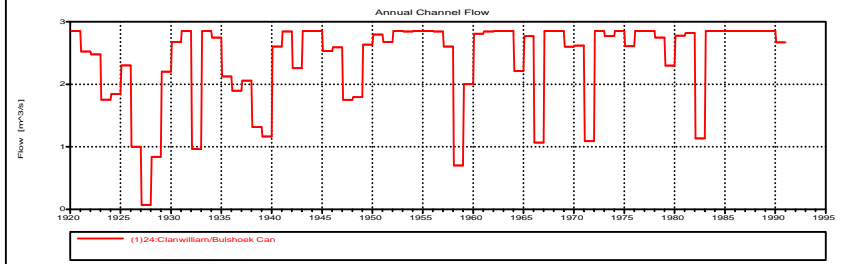
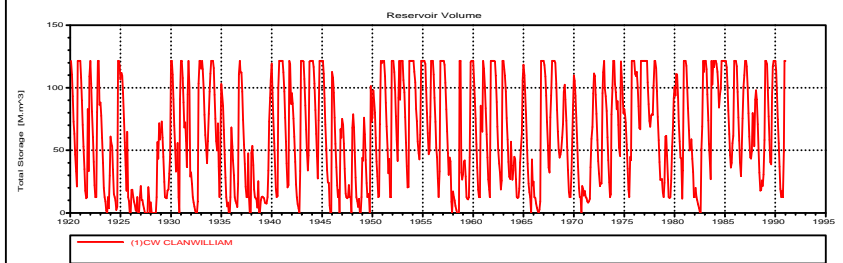
NATURAL AND PRESENT DAY SCENARIOS



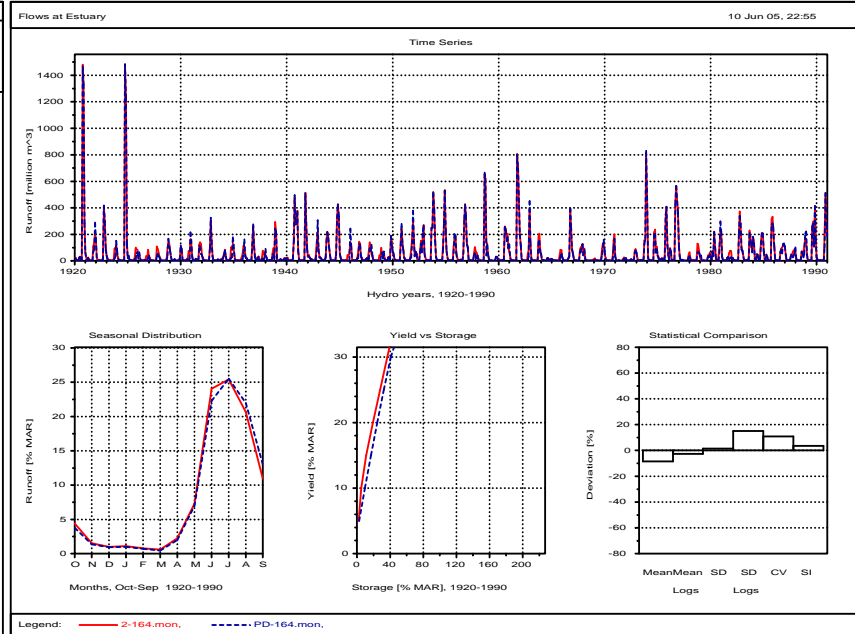
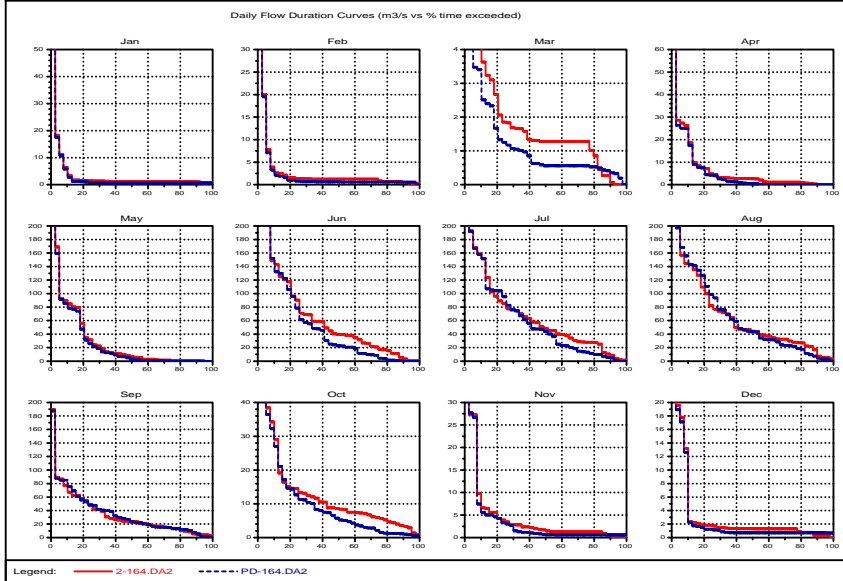
- Key to the plots provided for each scenario:
- Top left : storage trajectories
 - Top Right : Statistics of the flow at the estuary
 - Bottom Left : Flow duration curves – usually comparing the scenario with the natural and present day flows

SCENARIO 2: PRESENT DAY PLUS EWR RELEASES

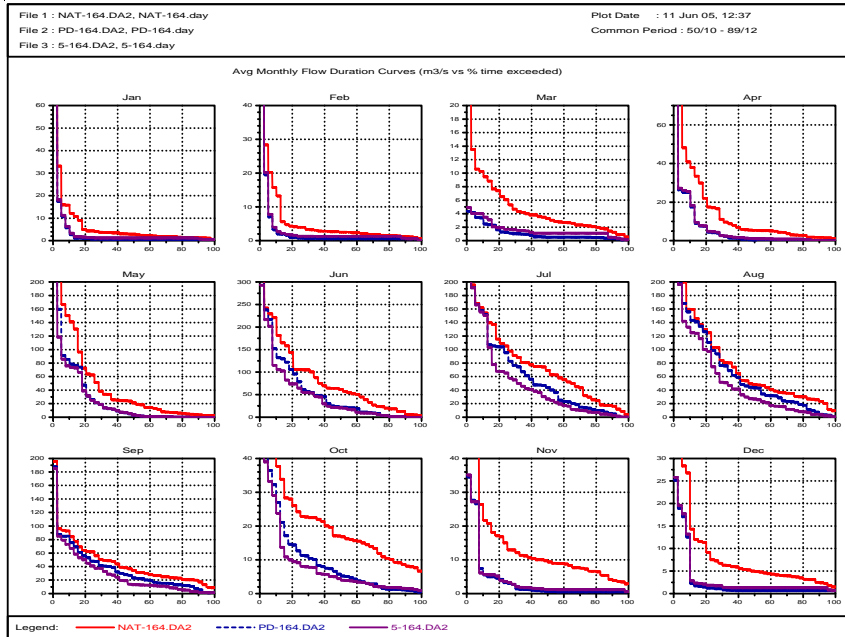
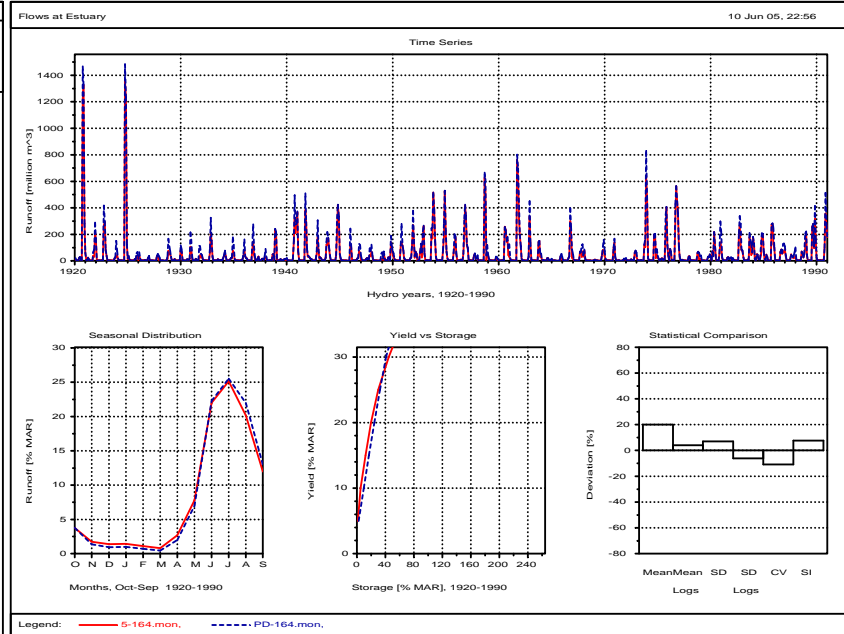
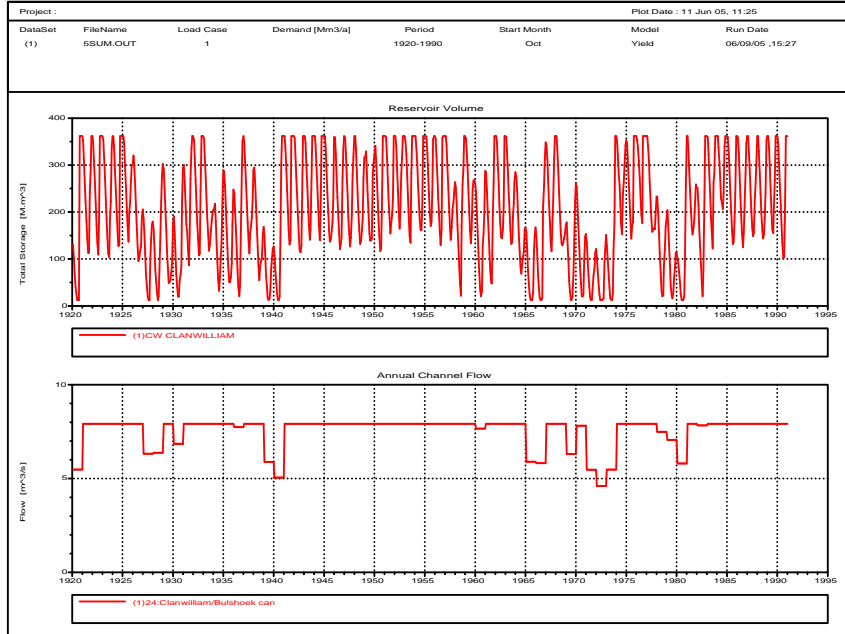
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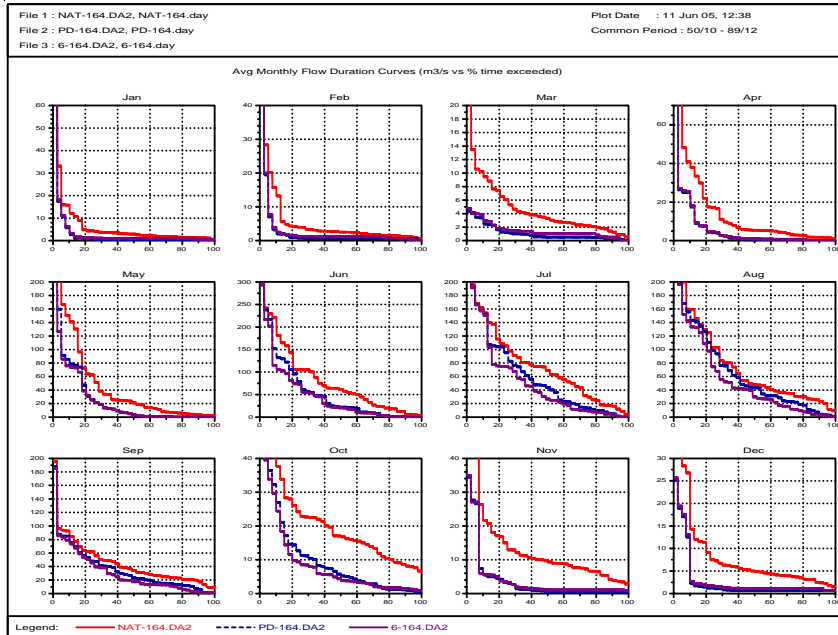
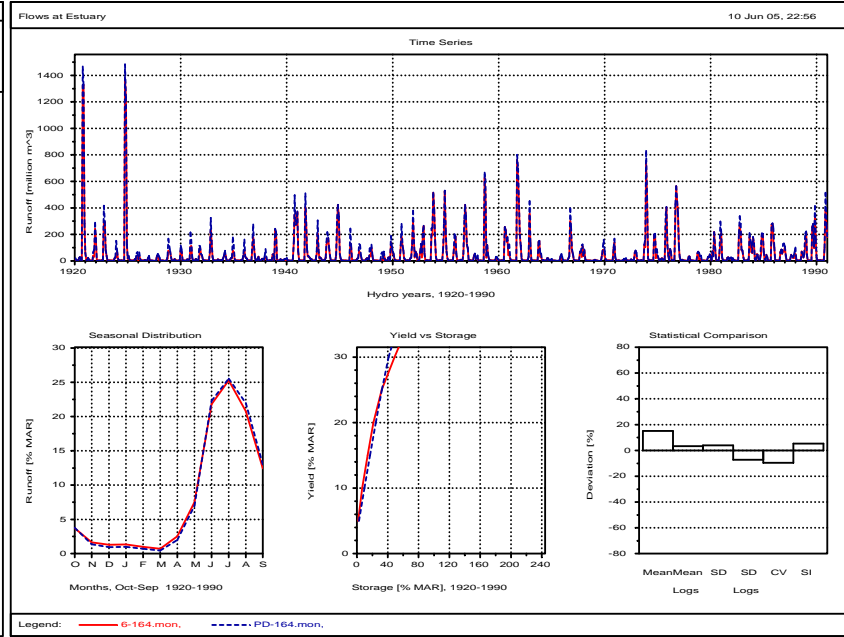
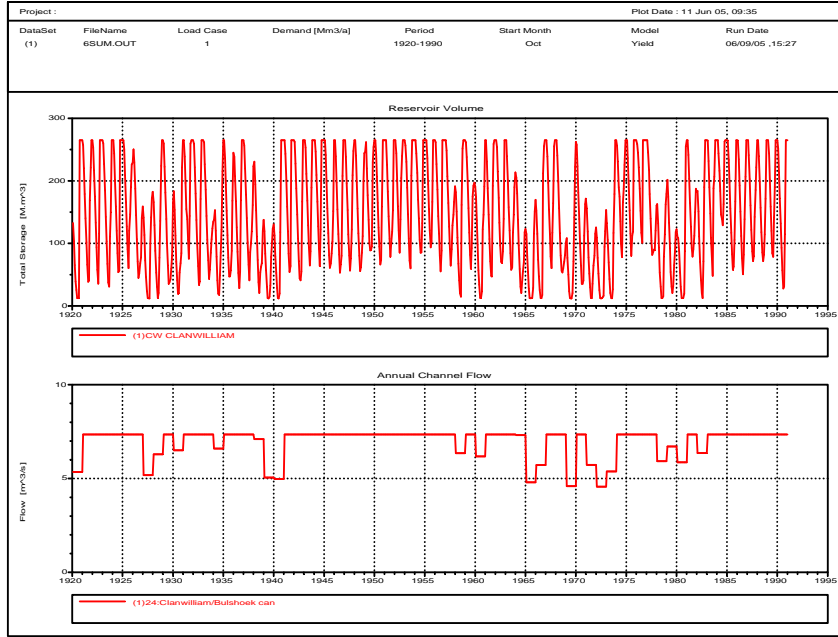
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File 2 :	PD-164.DA2, PD-164.day	Common Period :	50/10 - 89/12
File 3 :	.		



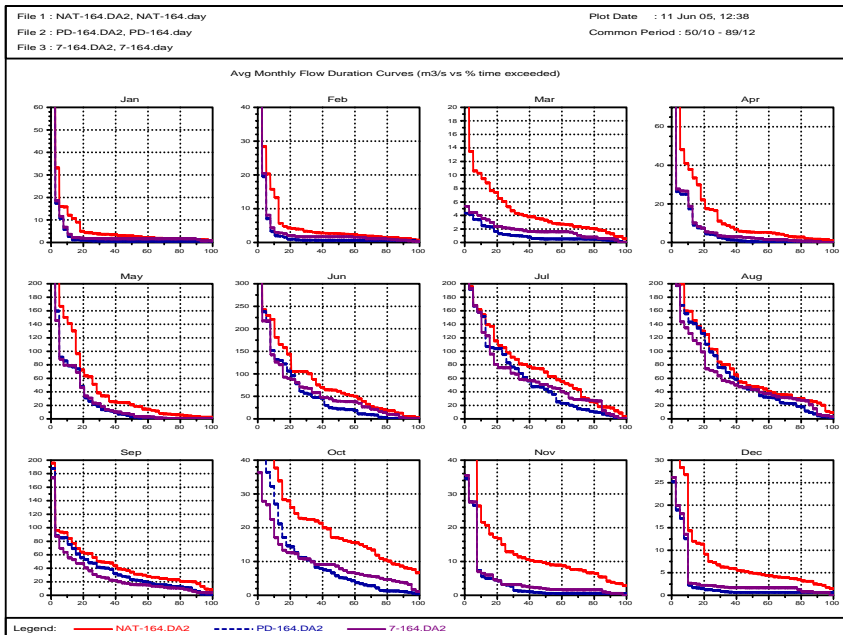
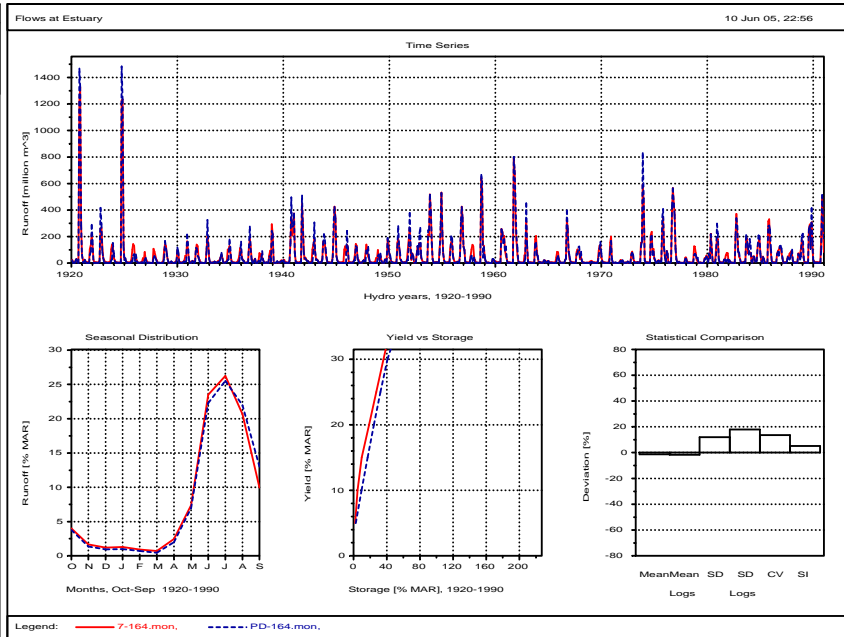
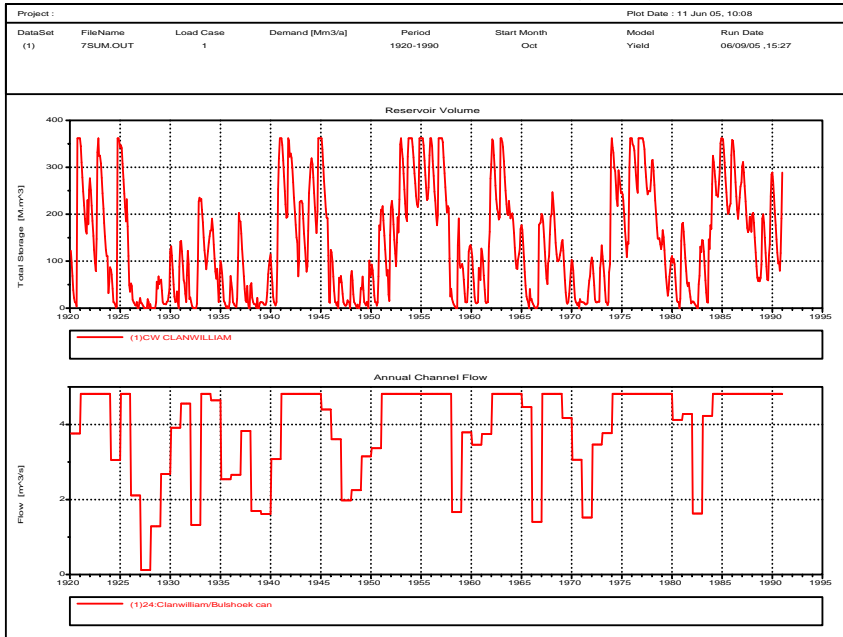
SCENARIO 5: RAISE CLANWILLIAM DAM (15 M) WITHOUT EWR RELEASES DOWNSTREAM OF CLANWILLIAM DAM



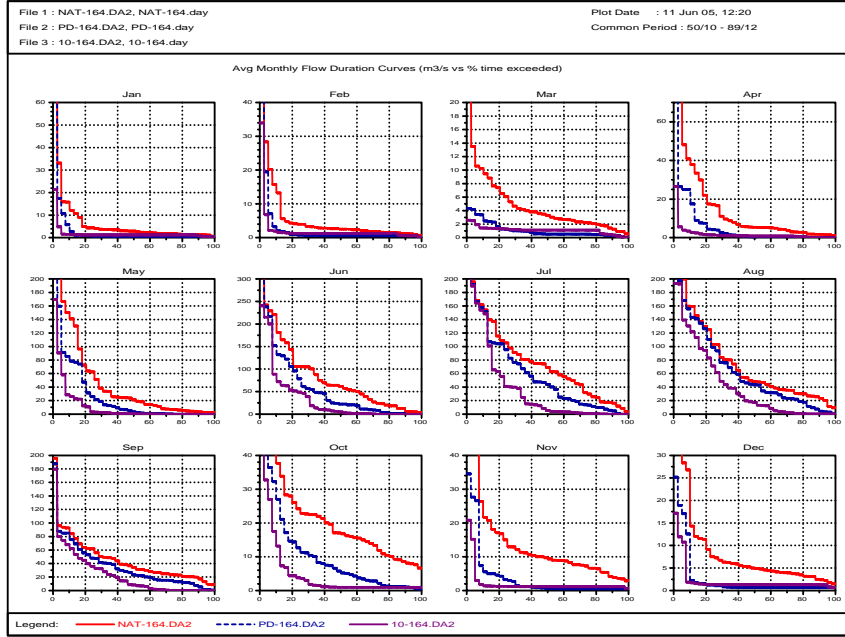
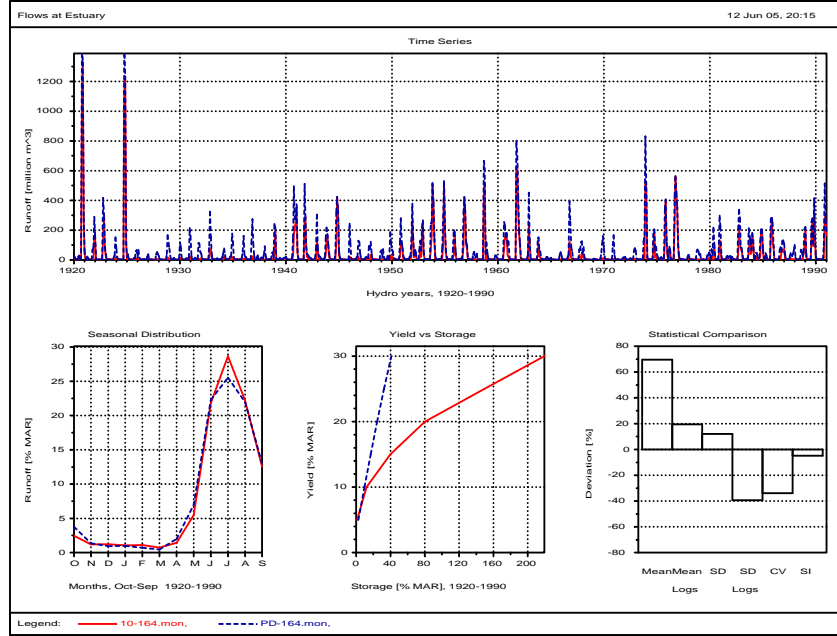
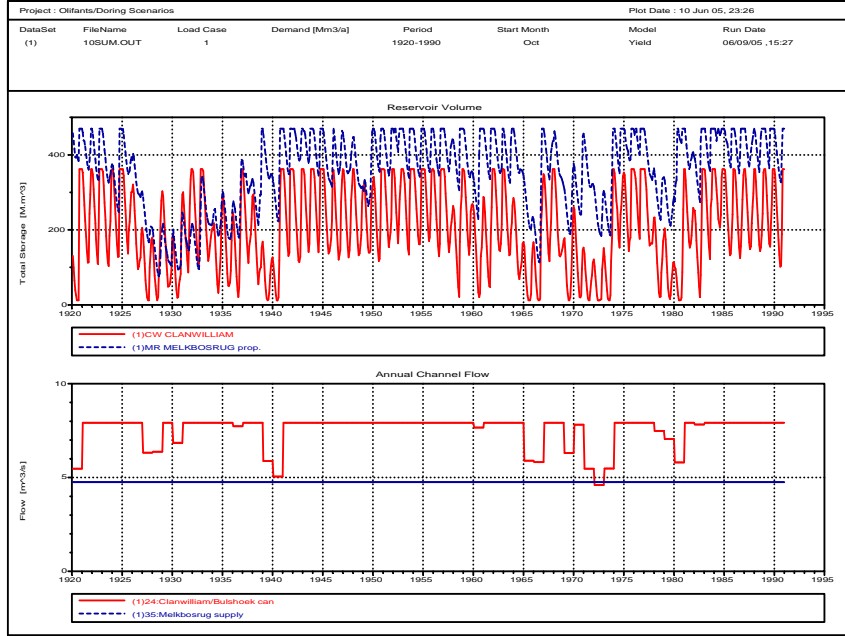
SCENARIO 6: RAISE CLANWILLIAM DAM (10 M) WITHOUT EWR RELEASES DOWNSTREAM OF CLANWILLIAM DAM



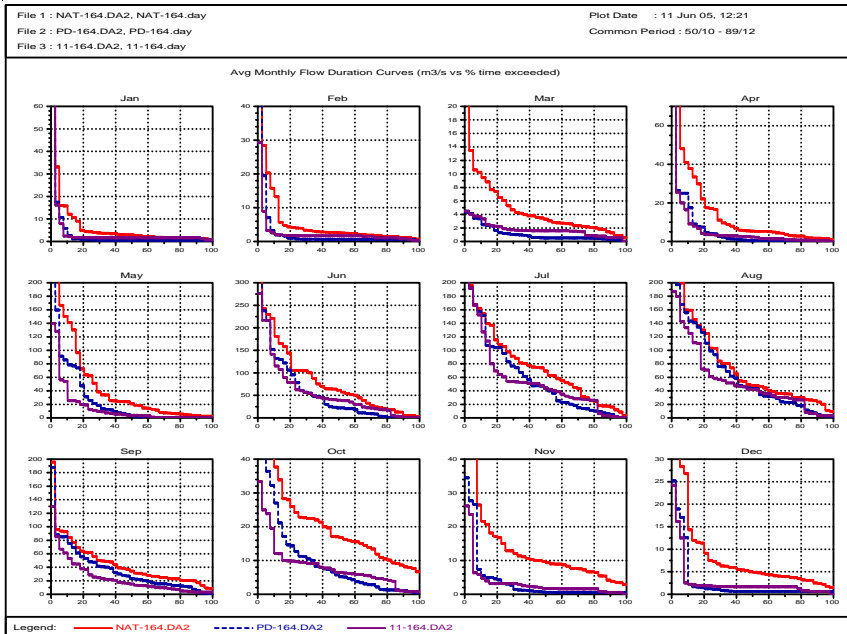
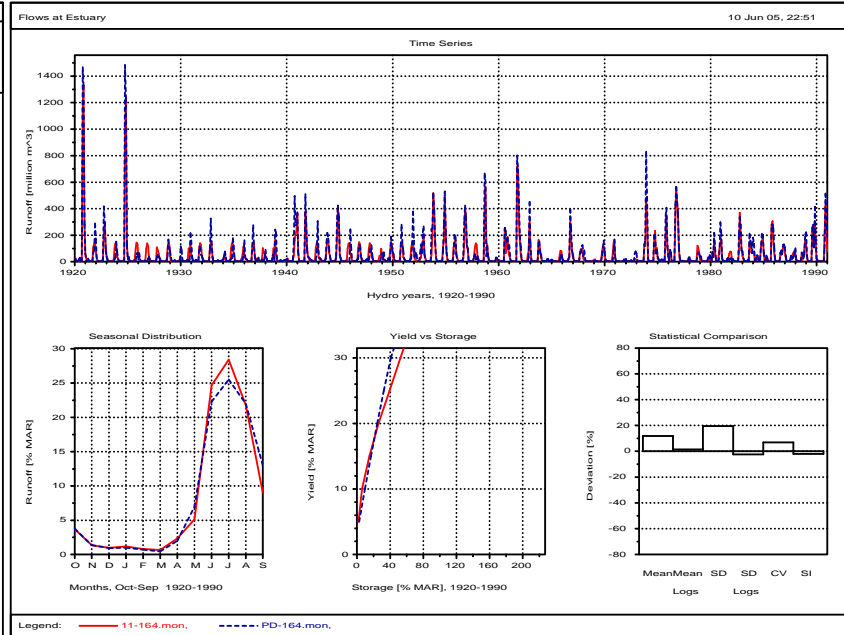
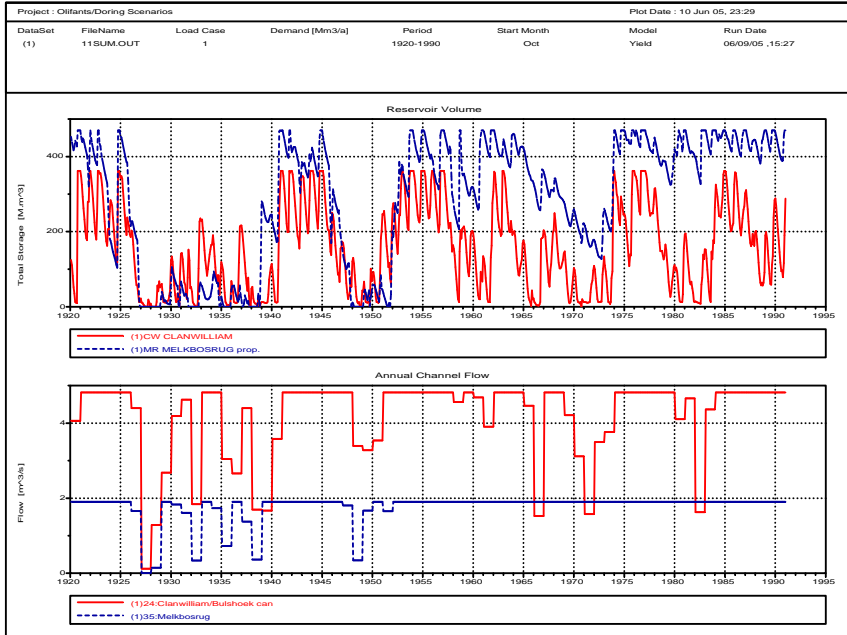
SCENARIO 7: RAISE CLANWILLIAM DAM (15 M) AND RELEASE EWRS



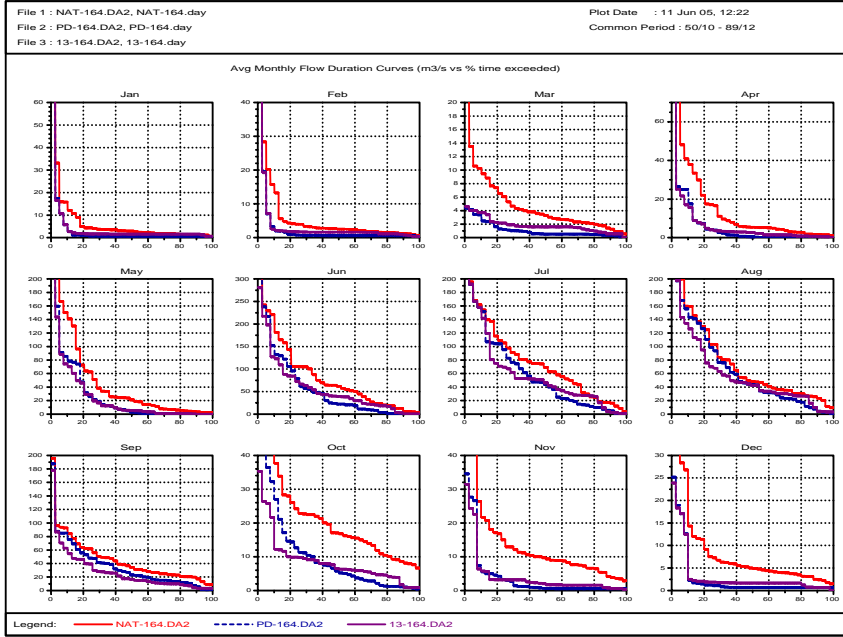
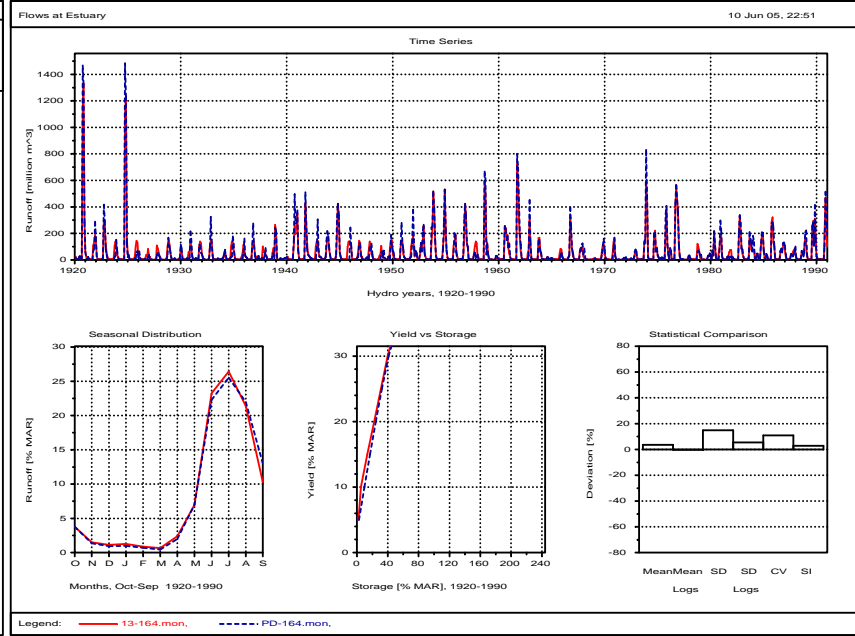
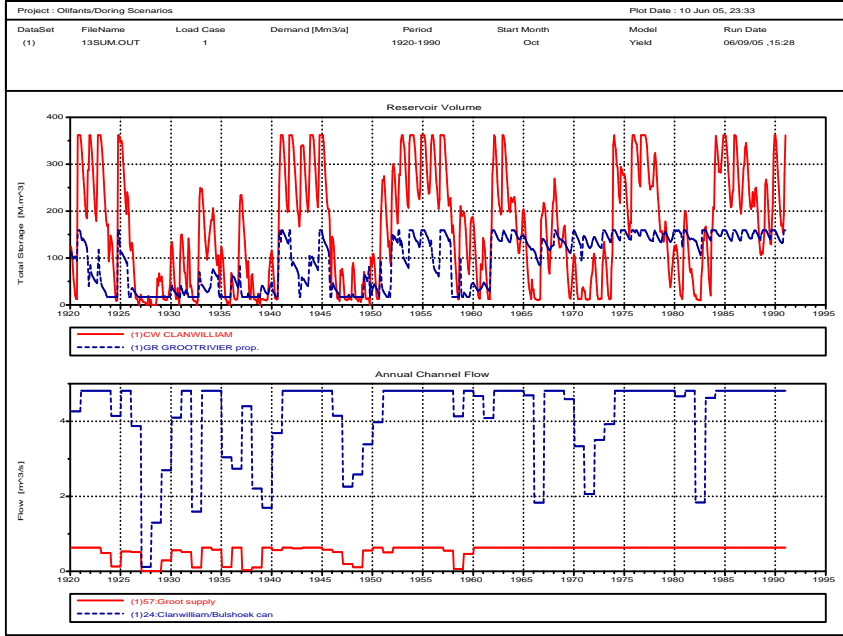
SCENARIO 10: CLANWILLIAM DAM (15 M) AND MELKBOSRUG DAM (470 MCM) ON THE DORING RIVER – NO EWRS



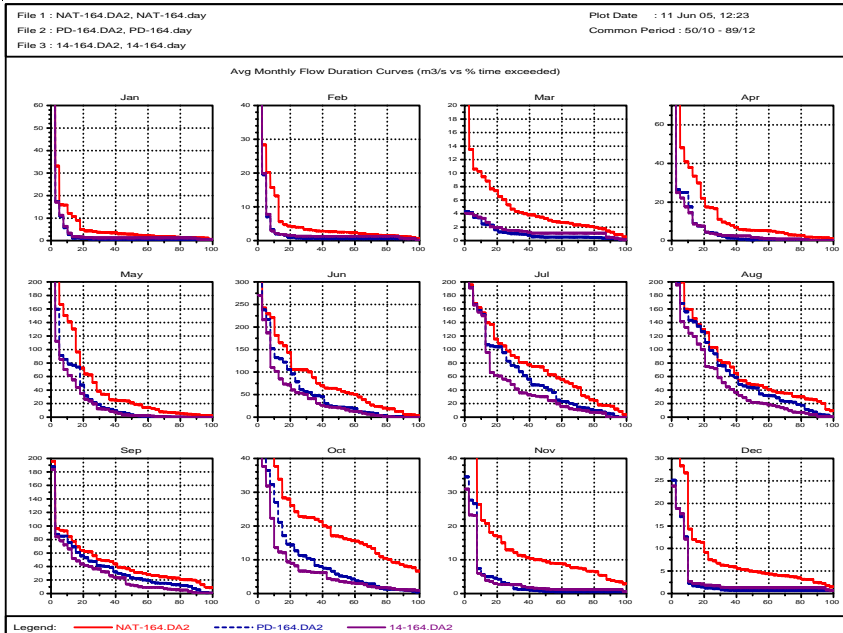
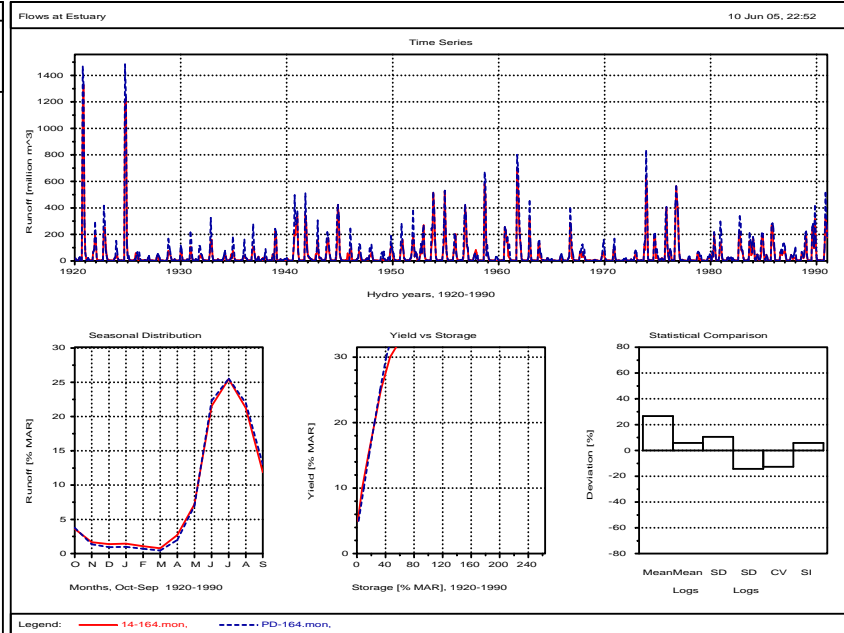
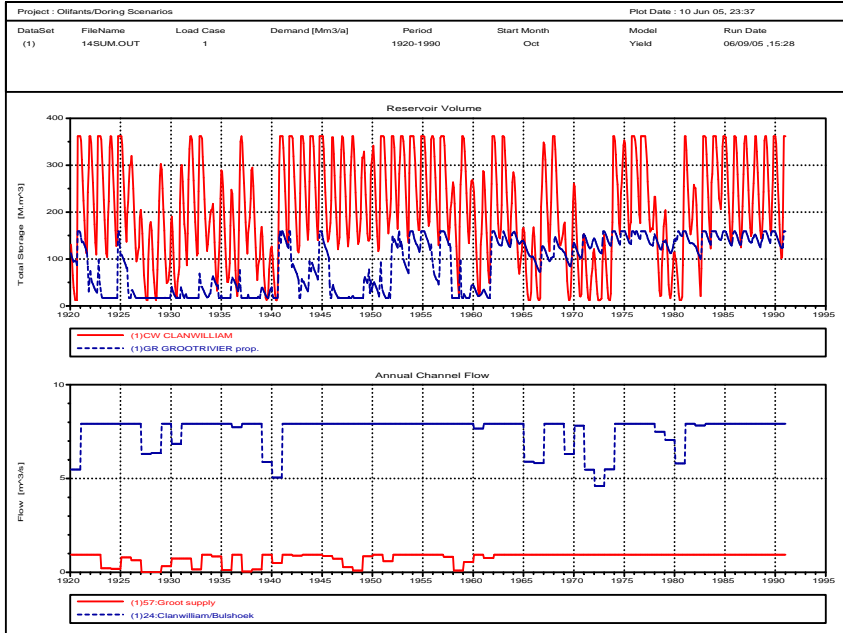
SCENARIO 11: CLANWILLIAM DAM (15 M) AND MELKBOSRUG DAM (470 MCM) AND RELEASE EWRS



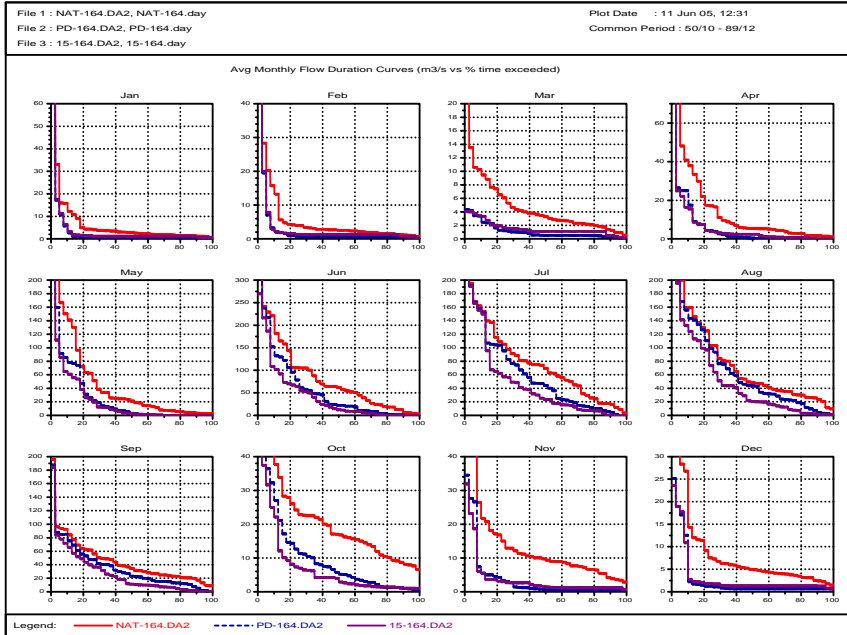
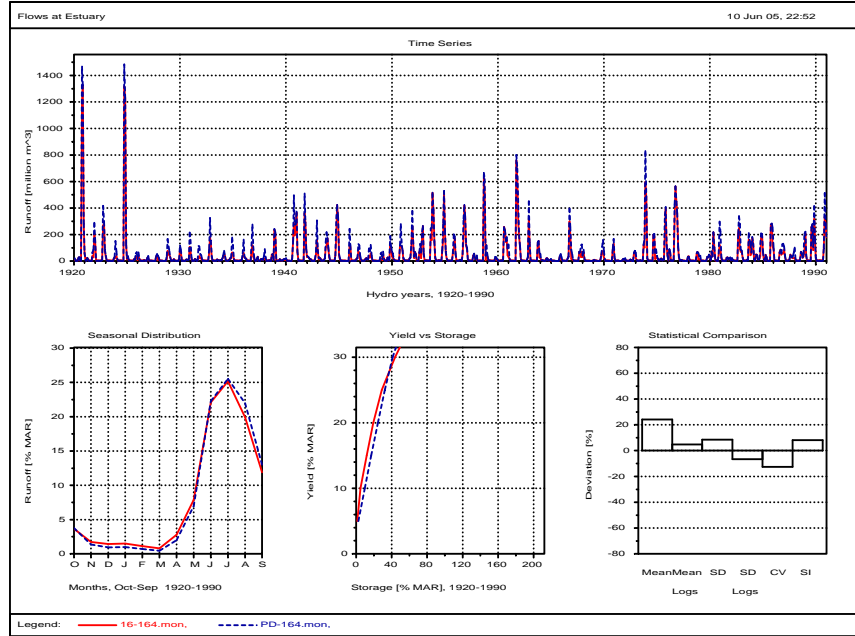
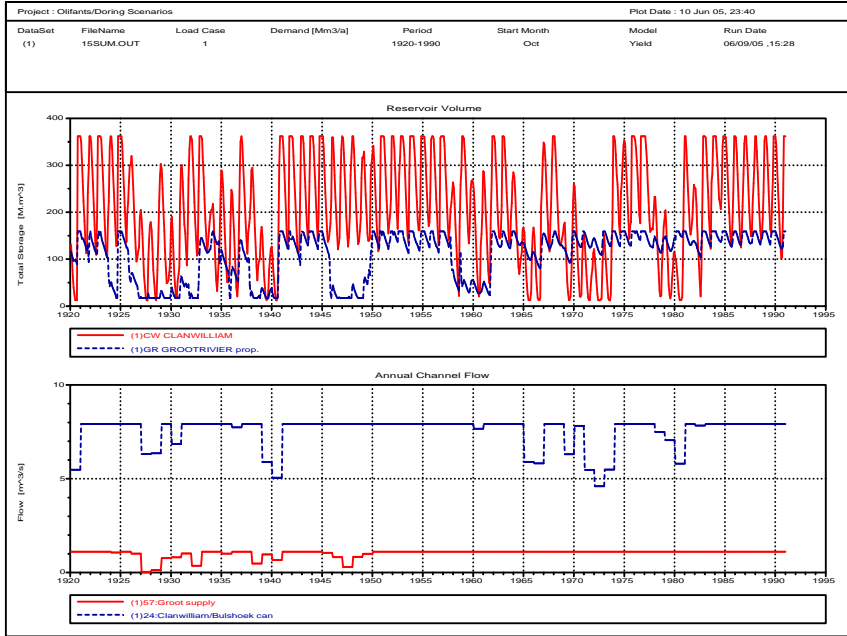
SCENARIO 13: CLANWILLIAM DAM (15 M) AND GROOT DAM AND RELEASE EWRs DOWNSTREAM OF CLANWILLIAM DAM AND THE OLIFANTS/DORING CONFLUENCE



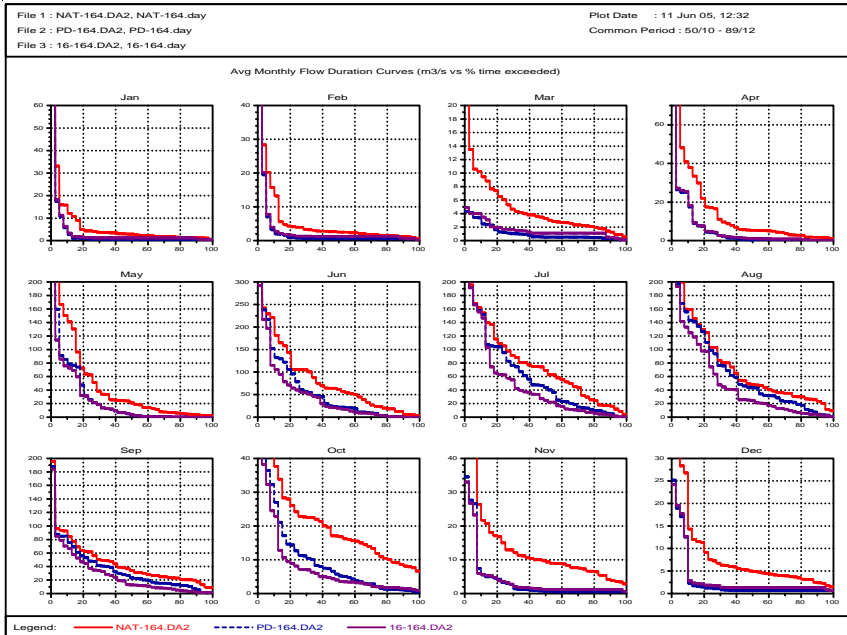
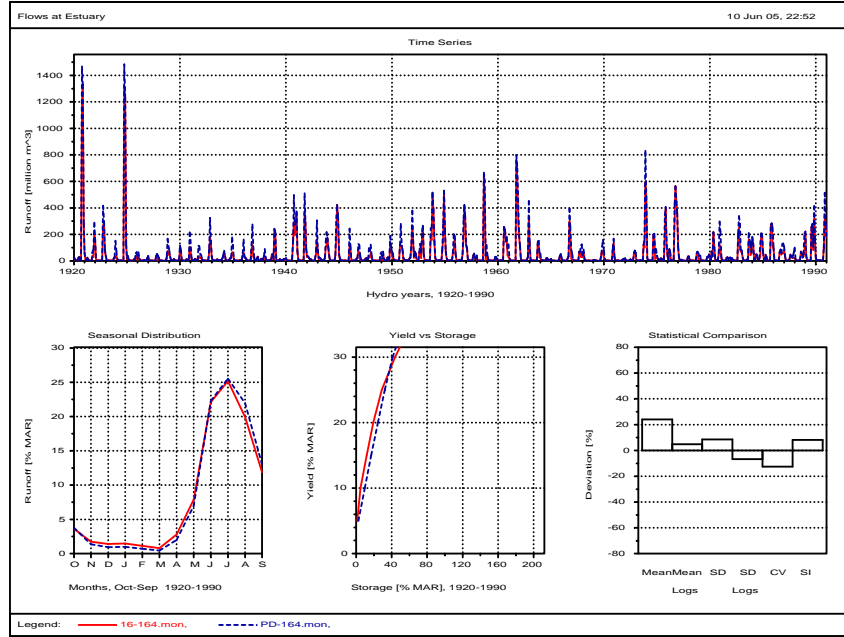
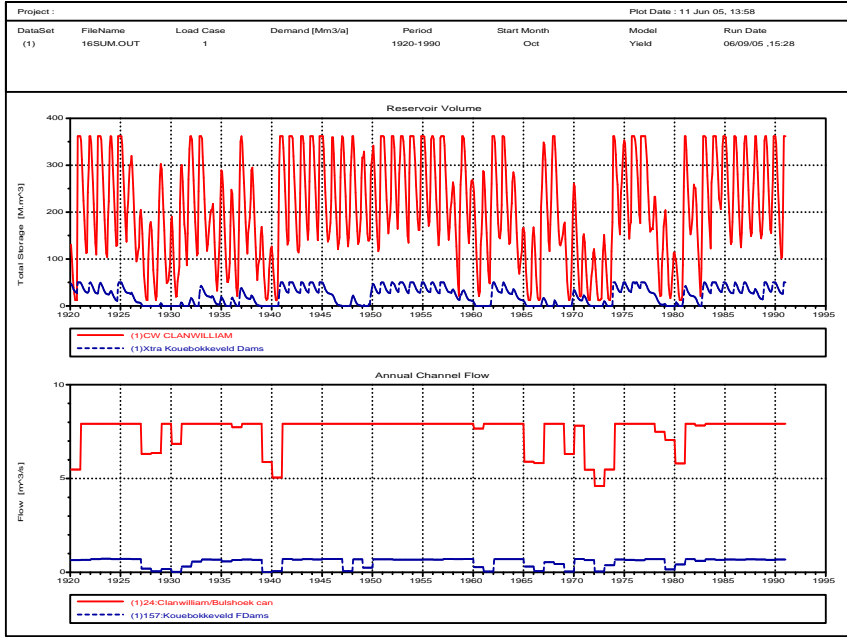
SCENARIO 14: CLANWILLIAM DAM (15 M) AND GROOT RIVER DAM - NO EWRs DOWNSTREAM OF CLANWILLIAM DAM AND THE OLIFANTS/DORING CONFLUENCE



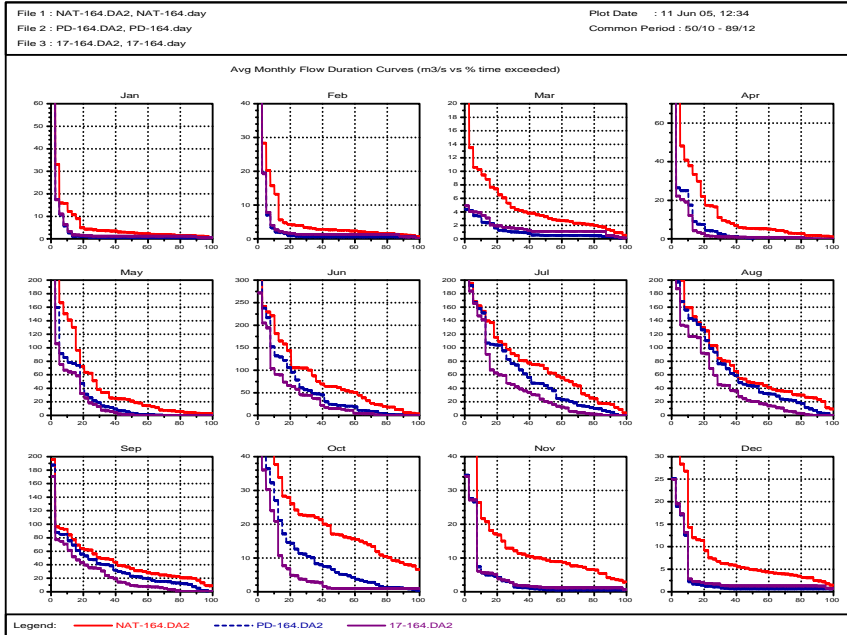
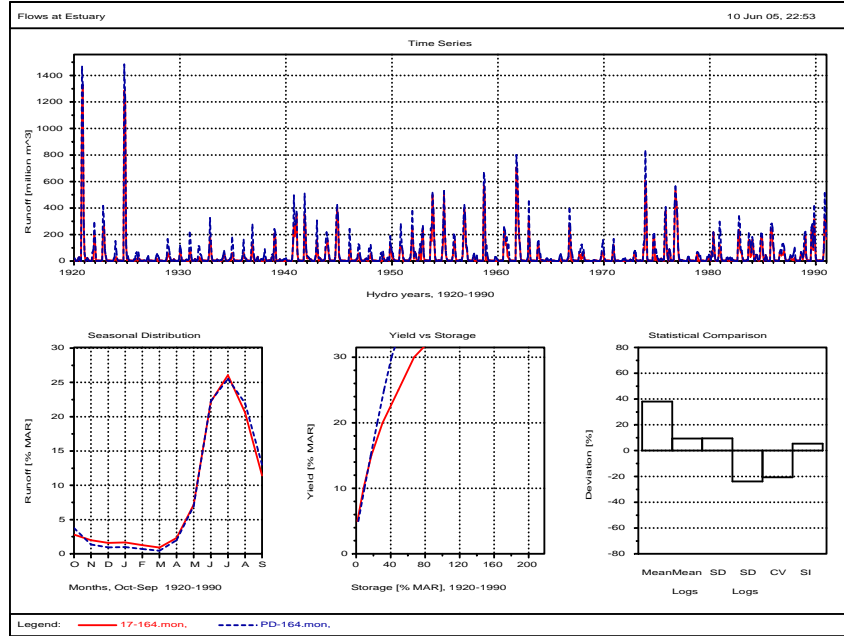
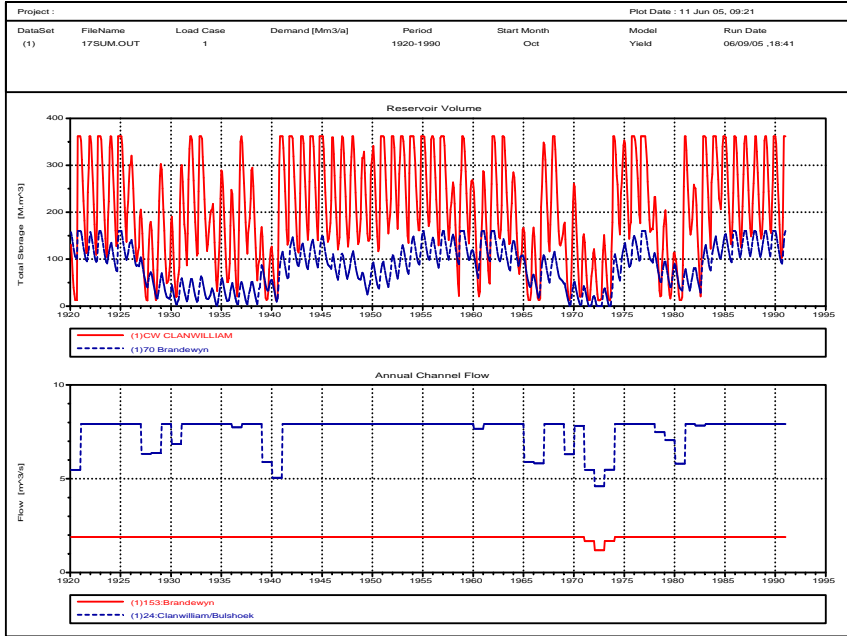
SCENARIO 15: CLANWILLIAM DAM (15 M) AND GROOT RIVER DAM WITH REDUCED EWR ON THE DORING RIVER



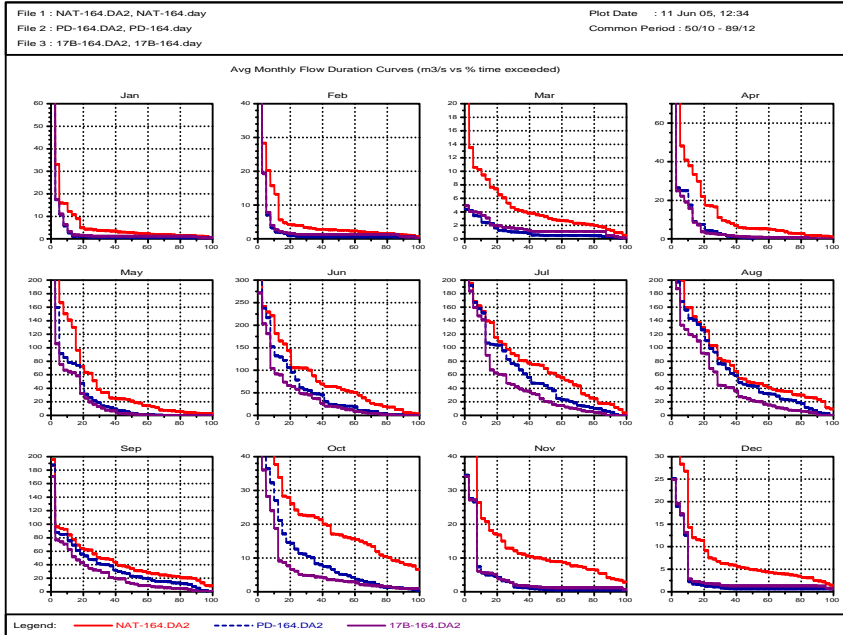
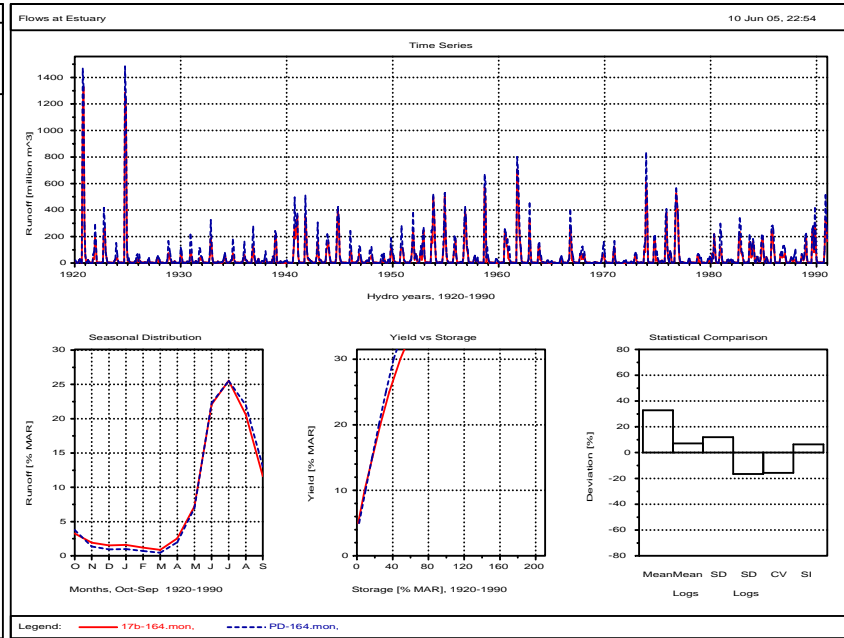
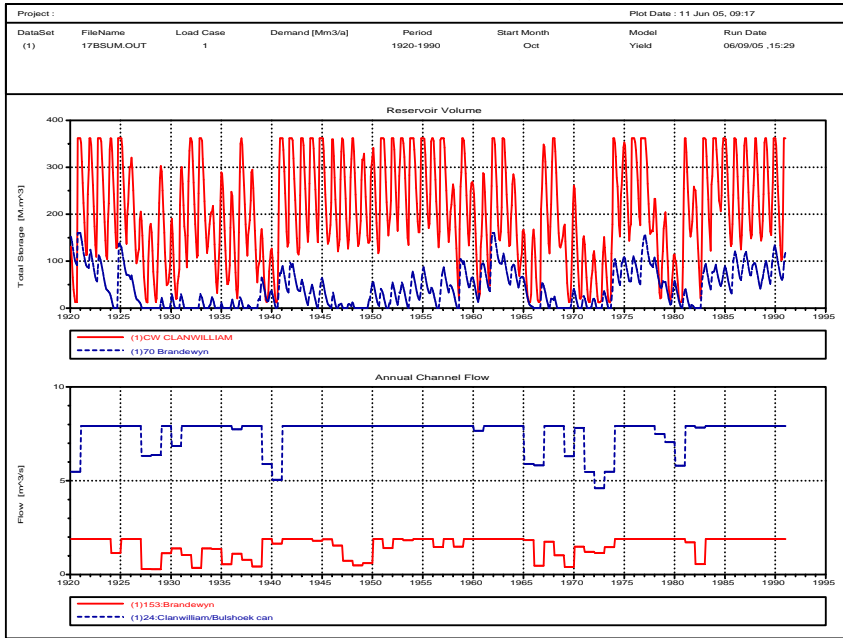
SCENARIO 16: CLANWILLIAM DAM (15 M) AND 50 MCM DAM IN THE KOUEBOKKEVELD INTERCEPTING 30% OF WINTER FLOWS AND REDUCED EWRS ON THE DORING RIVER



SCENARIO 17: CLANWILLIAM DAM (15 M) AND BRANDEWYN SCHEME [160 MCM]



SCENARIO 17B: CLANWILLIAM DAM (15 M) AND BRANDEWYN SCHEME [160 MCM]



APPENDIX F: WRYM SYSTEM DIAGRAM FOR THE PRESENT DAY SITUATION

Other scenarios used the configuration but switched on dams, increased “pulls” of EWR channels and activated the necessary diversion channels where necessary.

See Electronic PDF file included on the CD in the sleeve.