



**Department of Water Affairs  
Directorate: Options Analysis**

**PRE-FEASIBILITY AND FEASIBILITY STUDIES FOR AUGMENTATION  
OF THE WESTERN CAPE WATER SUPPLY SYSTEM BY MEANS OF  
FURTHER SURFACE WATER DEVELOPMENTS**

**REPORT No.3 – VOLUME 2  
Breede-Berg (Michell's Pass) Water Transfer Scheme**

**APPENDIX No.5**

**Scheme Operation and Yield Analyses with Ecological Flow  
Requirements for the Breede-Berg (Michell's Pass) Water Transfer  
Scheme**



**December 2012**

## STUDY REPORT LIST

REPORT No	REPORT TITLE	VOLUME No.	DWA REPORT No.	VOLUME TITLE
1	ECOLOGICAL WATER REQUIREMENT ASSESSMENTS	Vol 1	PWMA19 G10/00/2413/1	<b>Riverine Environmental Water Requirements</b>
				Appendix 1: EWR data for the Breede River
				Appendix 2: EWR data for the Palmiet River
				Appendix 3: EWR data for the Berg River
				Appendix 4: Task 3.1: Rapid Reserve assessments (quantity) for the Steenbras, Pombers and Kromme Rivers
				Appendix 5: Habitat Integrity Report – Breede River
		Vol 2	PWMA19 G10/00/2413/2	<b>Rapid Determination of the Environmental Water Requirements of the Palmiet River Estuary</b>
				Appendix A: Summary of data available for the RDM investigations undertaken during 2007 and 2008
				Appendix B: Summary of baseline data requirements and the long-term monitoring programme
				Appendix C: Abiotic Specialist Report
		Vol 3	PWMA19 G10/00/2413/3	<b>Berg Estuary Environmental Water Requirements</b>
				Appendix A: Available information and data
				Appendix B: Measurement of streamflows in the Lower Berg downstream of Misverstand Dam
				Appendix C: Specialist Report – Physical dynamics and water quality
				Appendix D: Specialist Report – Modelling
				Appendix E: Specialist Report – Microalgae
				Appendix F: Specialist Report – Invertebrates
				Appendix G: Specialist Report – Fish
				Appendix H: Specialist Report – Birds
Appendix I: Specialist Report – The economic value of the Berg River Estuary				
2	PRELIMINARY ASSESSMENT OF OPTIONS		PWMA19 G10/00/2413/4	Appendix 1: Scheme Yield Assessments and Diversion Functions
				Appendix 2: Unit Reference Value Calculation Sheets
				Appendix 3: Yield Analysis and Dam Size Optimization
				Appendix 4: Dam Design Inputs
				Appendix 5: Diversion Weir Layout Drawings
				Appendix 6: Voëlvlei Dam Water Quality Assessment
				Appendix 7: Botanical Considerations
				Appendix 8: Heritage Considerations
				Appendix 9: Agricultural Economic Considerations

**STUDY REPORT LIST (cntd)**

<b>REPORT No</b>	<b>REPORT TITLE</b>	<b>VOLUME No.</b>	<b>DWA REPORT No.</b>	<b>VOLUME TITLE</b>
<b>3</b>	<b>FEASIBILITY STUDIES</b>	<b>Vol 1</b>	PWMA19 G10/00/2413/5	<b>Berg River-Voëlvlei Augmentation Scheme</b>
				Appendix 1: Updating of the Western Cape Water Supply System Analysis for the Berg River-Voëlvlei Augmentation Scheme
				Appendix 2: Configuration, Calibration and Application of the CE-QUAL-W2 model to Voëlvlei Dam for the Berg River-Voëlvlei Augmentation Scheme
				Appendix 3: Monitoring Water Quality During Flood Events in the Middle Berg River (Winter 2011), for the Berg River-Voëlvlei Augmentation Scheme
				Appendix 4: Dispersion Modelling in Voëlvlei Dam from Berg River Water Transfers for the Berg River-Voëlvlei Augmentation Scheme
				Appendix 7 - 12: See list under Volume 2 below
		<b>Vol 2</b>	PWMA19 G10/00/2413/6	<b>Breede-Berg (Michell's Pass) Water Transfer Scheme</b>
				Appendix 5: Scheme Operation and Yield Analyses with Ecological Flow Requirements for the Breede-Berg (Michell's Pass) Water Transfer Scheme
				Appendix 6: Preliminary Design of Papenkuils Pump Station Upgrade and Pre-Feasibility Design of the Boontjies Dam, for the Breede-Berg (Michell's Pass) Water Transfer Scheme
				Appendix 7: Ecological Water Requirements Assessment Summary for the Berg River-Voëlvlei Augmentation Scheme, and the Breede Berg (Michell's Pass) Water Transfer Scheme
				Appendix 8: Geotechnical Investigations for the Berg River-Voëlvlei Augmentation Scheme, and the Breede-Berg (Michell's Pass) Water Transfer Scheme
				Appendix 9: LiDAR Aerial Survey, for the Berg River-Voëlvlei Augmentation Scheme, and the Breede-Berg (Michell's Pass) Water Transfer Scheme
				Appendix 10: Conveyance Infrastructure Design Report, for the Berg River-Voëlvlei Augmentation Scheme, and the Breede-Berg (Michell's Pass) Water Transfer Scheme
				Appendix 11: Diversion Weirs Design for the Berg River-Voëlvlei Augmentation Scheme, and the Breede-Berg (Michell's Pass) Water Transfer Scheme
Appendix 12: Cost Estimates for the Berg River-Voëlvlei Augmentation Scheme, and the Breede-Berg (Michell's Pass) Water Transfer Scheme				
<b>4</b>	<b>RECORD OF IMPLEMENTATION DECISIONS</b>		PWMA19 G10/00/2413/7	

## STUDY REPORT MATRIX DIAGRAM

### PHASE 1: PRE-FEASIBILITY STUDY

#### ECOLOGICAL WATER REQUIREMENT ASSESSMENTS

##### Riverine Environmental Water Requirements

*PWMA19 G10/00/2413/1*

- Data (Electronic format)
- Rapid Reserves (Steenbras, Pombers, Kromme Rivers)
- Habitat Integrity (Breede River)

##### Rapid Determination of the Environmental Water Requirements of the Palmiet River Estuary

*PWMA19 G10/00/2413/2*

- Existing Data Availability
- Baseline Data Requirements and Monitoring Programme
- Abiotic Assessment

##### Berg Estuary Environmental Water Requirements

*PWMA19 G10/00/2413/3*

- Available Information and Data
- Measurement of Streamflows in the Lower Berg
- Physical Dynamics and Water Quality
- Modelling
- Microalgae
- Invertebrates
- Fish
- Birds
- Economic Value of the Estuary



#### PRELIMINARY ASSESSMENT OF OPTIONS

*PWMA19 G10/00/2413/4*

- Scheme Yield Assessments and Diversion Functions
- Unit Reference Value Calculation Sheets
- Yield Analysis and Dam Size Optimization
- Dam Design Inputs
- Diversion Weir Layout Drawings
- Voëlvei Dam Water Quality Assessment
- Botanical Considerations
- Heritage Considerations
- Agricultural Economic Considerations



### PHASE 2: FEASIBILITY STUDIES

#### BERG RIVER VOËLVLEI AUGMENTATION SCHEME

*PWMA19 G10/00/2413/5*

- Update System Analysis
- Berg River CE-Qual Water Quality Modelling
- Berg River Flood Water Quality Modelling
- Dispersion Modelling in Voëlvei Dam
- Ecological Water Requirements Summary
- Geotechnical Investigations
- Aerial Survey
- Conveyance Infrastructure Design
- Diversion Weirs Design
- Cost Estimates

#### BREEDE - BERG (MICHELL'S PASS) WATER TRANSFER SCHEME

*PWMA19 G10/00/2413/6*

- Scheme Operation and Yield Analysis
- Preliminary Design of Papenkuils Pumpstation and Boontjies Dam
- Ecological Water Requirements Summary
- Geotechnical Investigations
- Aerial Survey
- Conveyance Infrastructure Design
- Diversion Weirs Design
- Cost Estimates



### IMPLEMENTATION DECISION SUPPORT

#### RECORD OF IMPLEMENTATION DECISIONS

*PWMA19 G10/00/2413/7*

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## 1. INTRODUCTION

The Yield Model of the Breede River was utilised to assess the impacts of the proposed Michells Pass Scheme on the flows at the IFR sites downstream. The model was also utilised to determine the capacity and the operating rules for upgrading the pumps at Papenkuils to reinstate the existing yield and if possible to comply with the flow requirements of the Preliminary Reserve.

The Papenkuils pump station is currently operated in a step-wise manner. When the stream flow downstream of the pump station reaches 5 m<sup>3</sup>/s an additional 2.5 m<sup>3</sup>/s pump is switched on until the pump station is operating at full capacity. This allows minimum flows of between 2.5 m<sup>3</sup>/s and 5 m<sup>3</sup>/s to bypass the pump station. If the abstraction at Michell's Pass is increased to 5 m<sup>3</sup>/s then the stream flows at Papenkuils further downstream would decrease. This reduction would in turn reduce the volume that could be pumped into the Brandvlei Dam.

It was determined that if the capacity of the Papenkuils pump station capacity is increased from 7m<sup>3</sup>/s to 26 m<sup>3</sup>/s after the proposed BBTS is constructed then the present day yield of Brandvlei Dam would be reinstated and the low flow component of the EWR at Le Chasseur, which is currently met, would also be provided.

This Appendix compares the natural and present day flows with the future flows with the 5 m<sup>3</sup>/s BBTS and a 20 m<sup>3</sup>/s pumping capacity at Papenkuils not the 26 m<sup>3</sup>/s capacity which is now recommended.

## 2. COMPARISON OF MONTHLY FLOW DURATION CURVES AND THE RESERVES

**Figure 1** shows the sites on the Breede River for which the present day and future stream flow sequences with the 5 m<sup>3</sup>/s BBTS scheme and the 20 m<sup>3</sup>/s Papenkuils Pump Station were compared using flow duration plots. The present day flow sequences take account of the existing Artois Canal diversions and the operation of the 7 m<sup>3</sup>/s pumps at Papenkuils. The future flow sequences assume that the BBTS would have a capacity of 5 m<sup>3</sup>/s, that the Boontjies River Dam would be constructed and that the present day summer flows upstream of H1006 would be released downstream. It was assumed that the capacity of the Papenkuils Pump Station would be increased to 20 m<sup>3</sup>/s.

The monthly flow duration curves prepared for each site are listed in **Table 1** which also lists the **Figure** numbers that are grouped in twos as follows:

- The First Figure shows the **Natural Flow (red)**, **Total EWR (green)** and **Present Day MAR (blue)**
- The Second Figure shows the **Total EWR (red)** ((**green**) in First), **Present Day MAR (green)** ((**blue**) in First) and **Future BBTS and Papenkuils (blue)**

The Figures show the following:

- **Figure A2** shows that downstream of the Michell's Pass Diversion the Class D Reserve would be met except during February and March.
- **Figure B2** shows that the future flows at Le Chasseur would be similar to the present day flows with significant excesses to the Class C/D Reserve during the summer months on account of the elevated irrigation releases and shortfalls in the winter months.
- **Figure C2** indicates that the future and present day flows upstream of the Riviersonderend Confluence would also be similar with no summer excesses to the Class C Reserve which would be met except during 3 months of the year.
- **Figure D2** shows that there would be significant shortfalls in the Class B/C Reserve for the reach immediately upstream of the Estuary.

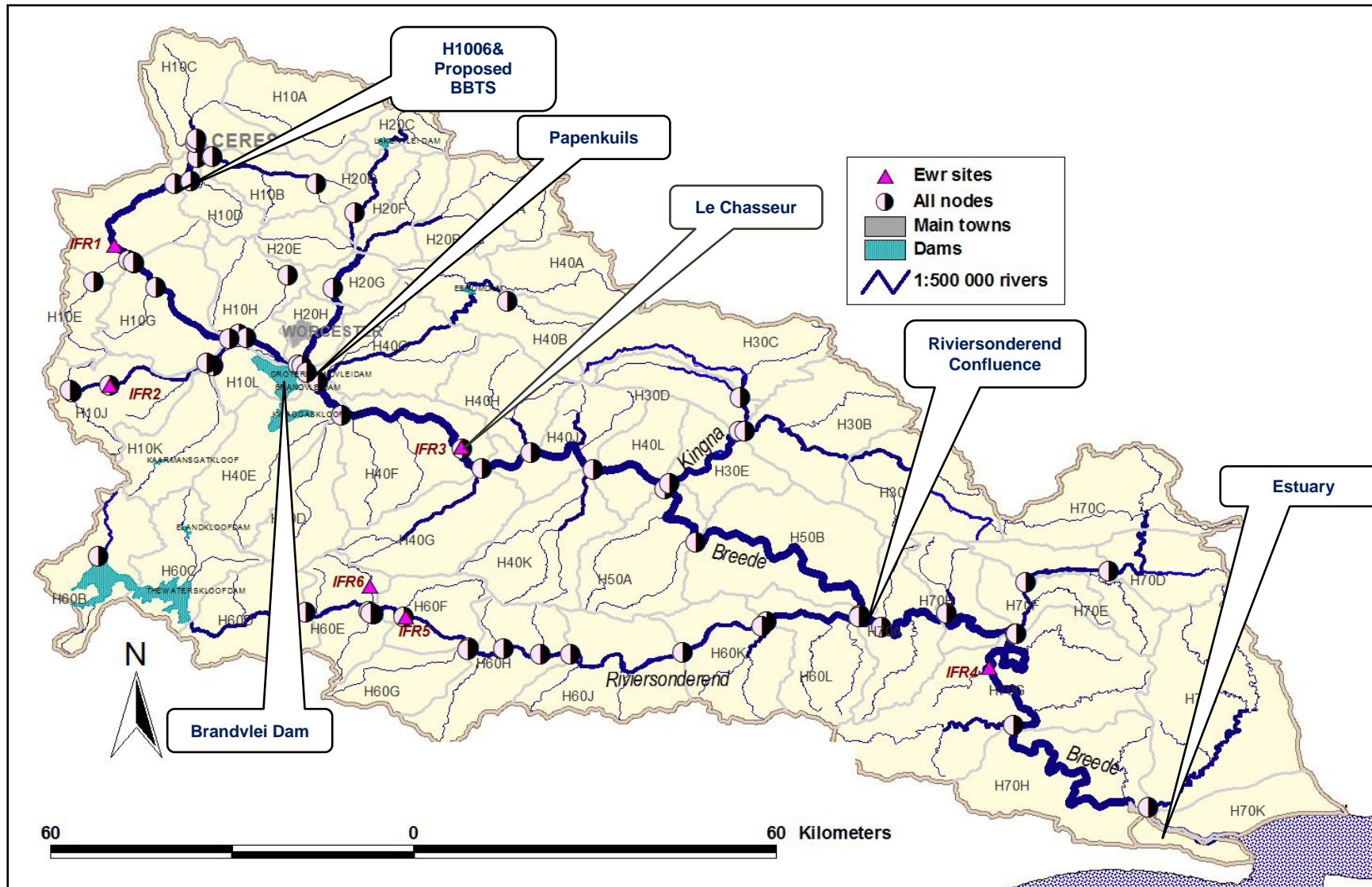


Figure A: Breede River System and Sites where Flow Duration Curves Are Compared

**Table 1: Summary of Stream flows sequences compared using flow duration plots for each month**

Site	Code	Natural	Total EWR	EWR baseflows	Present-day	Future (5m <sup>3</sup> /s Mitchells Pass diversion plus 20 m <sup>3</sup> /s Papekuils pump station into Brandvlei)	Figure
d/s Mitchells pass	vi3	✓(red)	✓(green)		✓(blue)		Figure A1
			✓(red)		✓(green)	✓(blue)	Figure A2
Le Chasseur	vii8	✓(red)	✓(green)		✓(blue)		Figure B1
			✓(red)		✓(green)	✓(blue)	Figure B2
u/s Breede confluence	i2	✓(red)	✓(green)		✓(blue)		Figure C1
			✓(red)		✓(green)	✓(blue)	Figure C2
u/s Estuary	iii4	✓(red)	✓(green)		✓(blue)		Figure D1
			✓(red)		✓(green)	✓(blue)	Figure D2
Estuary	Est	✓(red)	✓(green)		✓(blue)		Figure E1
			✓(red)		✓(green)	✓(blue)	Figure E2



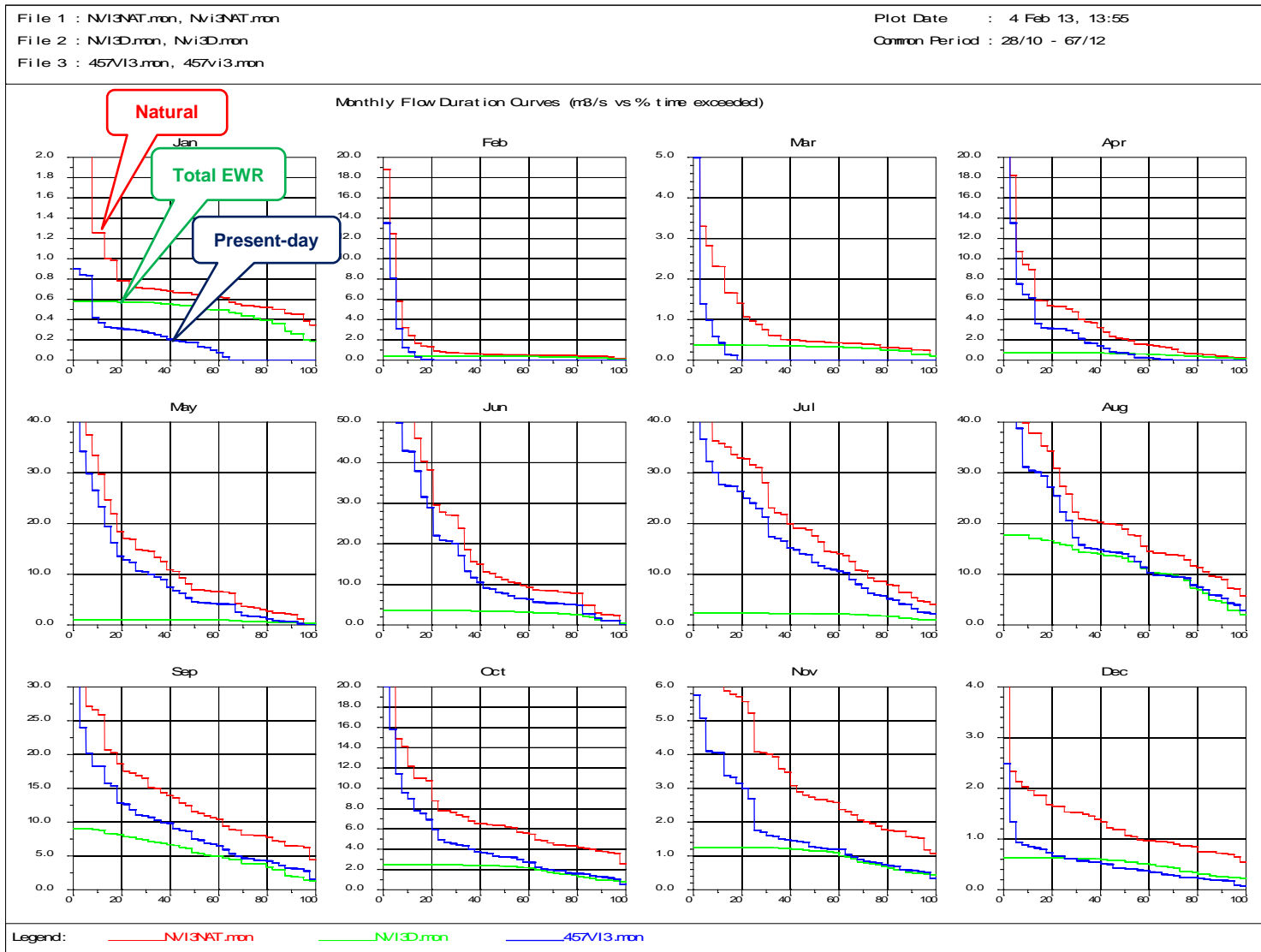


Figure A1: Monthly Flow Duration Plots immediately downstream of Mitchell's Pass (current)

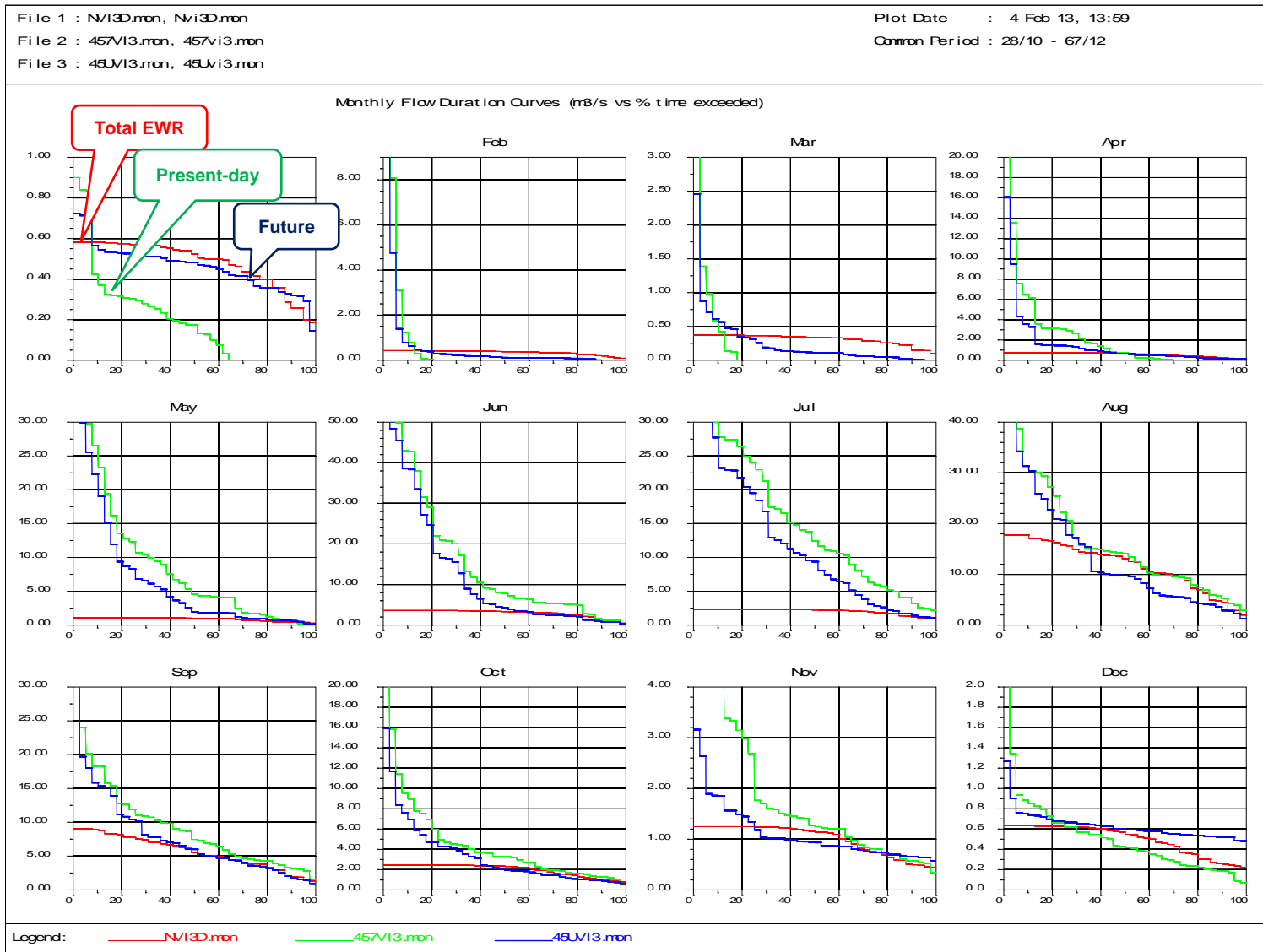


Figure A2: Monthly Flow Duration Plots immediately downstream of Mitchell's Pass (with BBTS and augmented Papekuils)

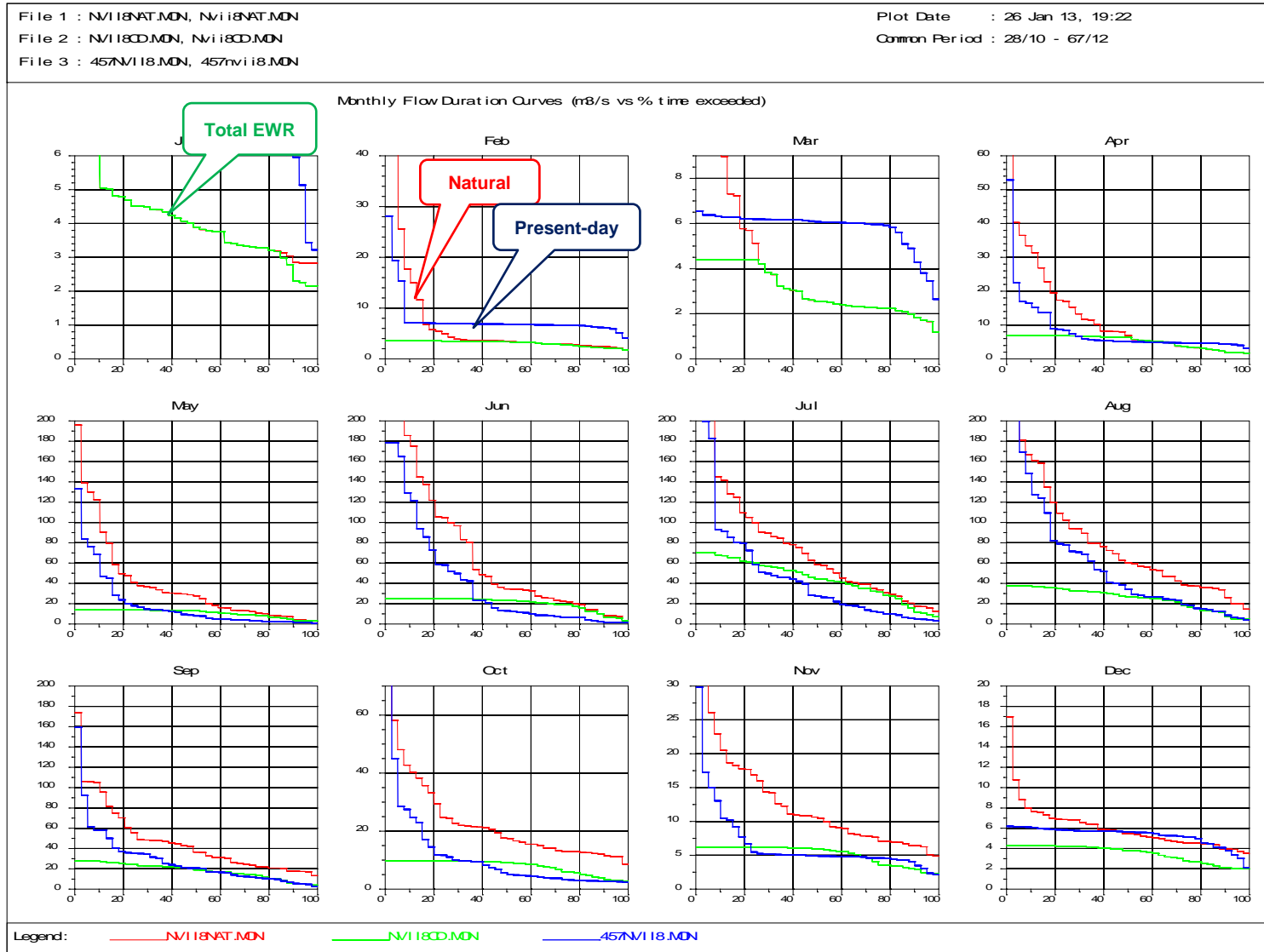


Figure B1: Monthly Flow Duration Plots at Le Chasseur (current)

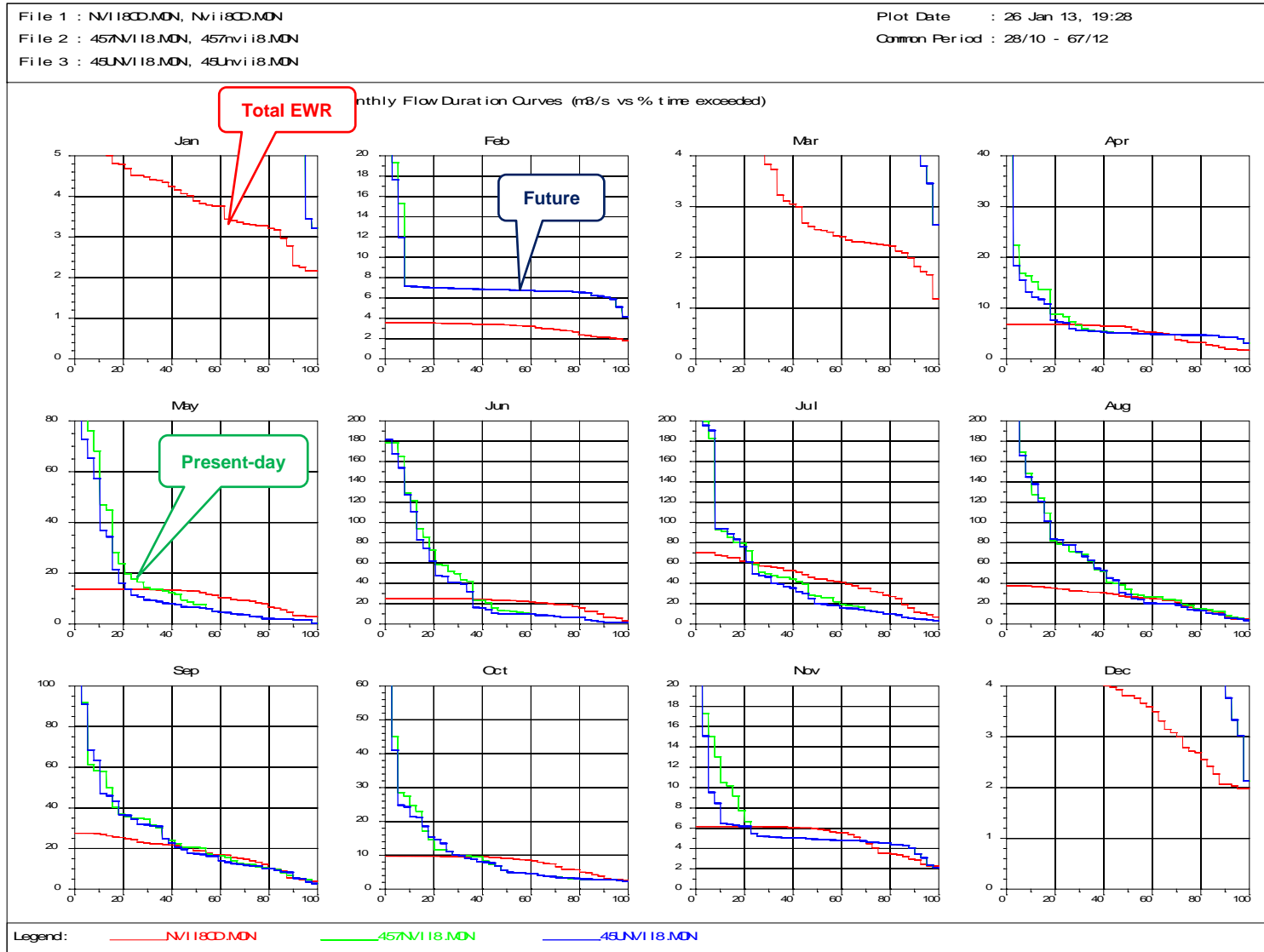


Figure B2: Monthly Flow Duration Plots at Le Chasseur (with BBTS and augmented Papekuils)

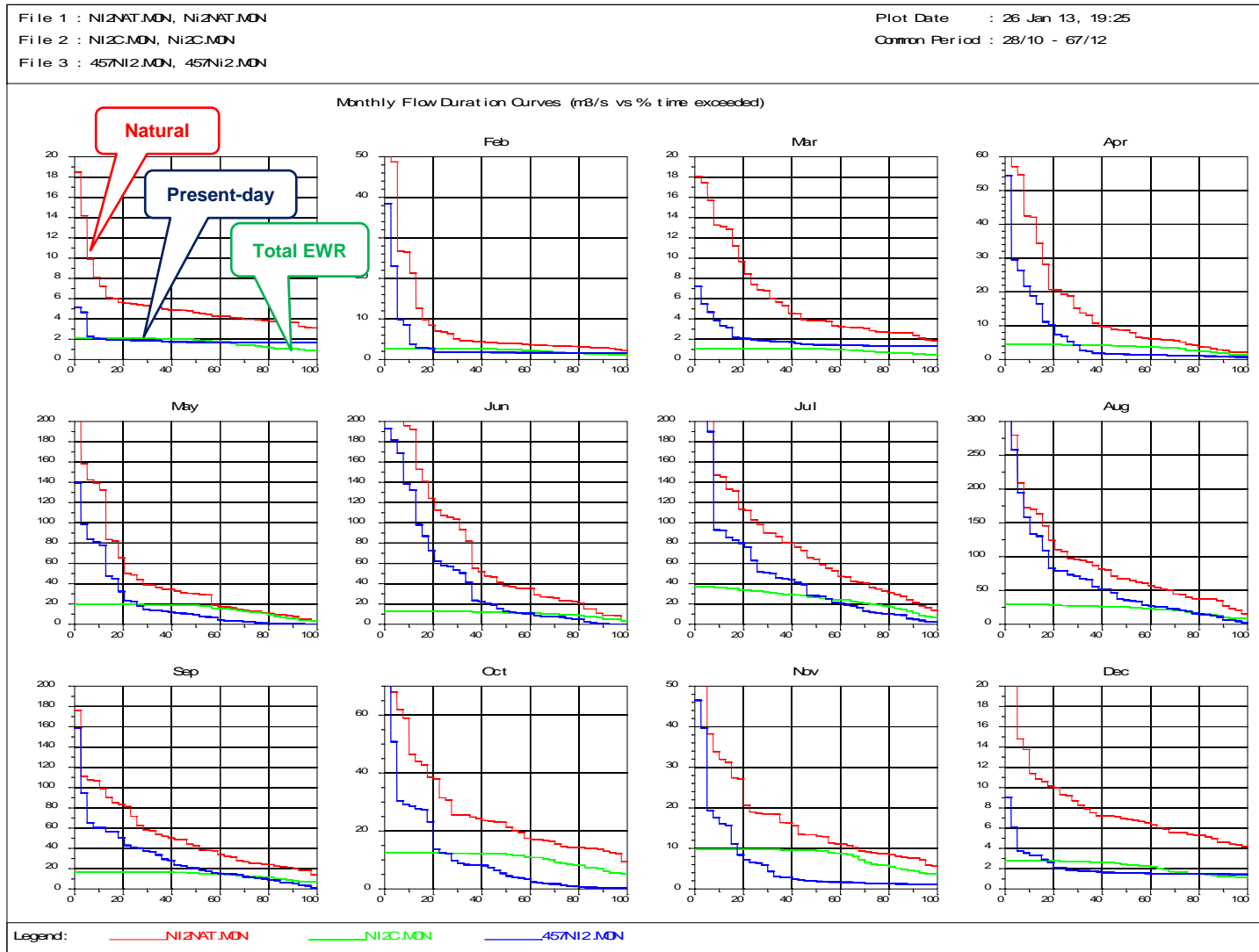


Figure C1: Monthly Flow Duration Plots Upstream of Brede/Riviersonderend Confluence (current)

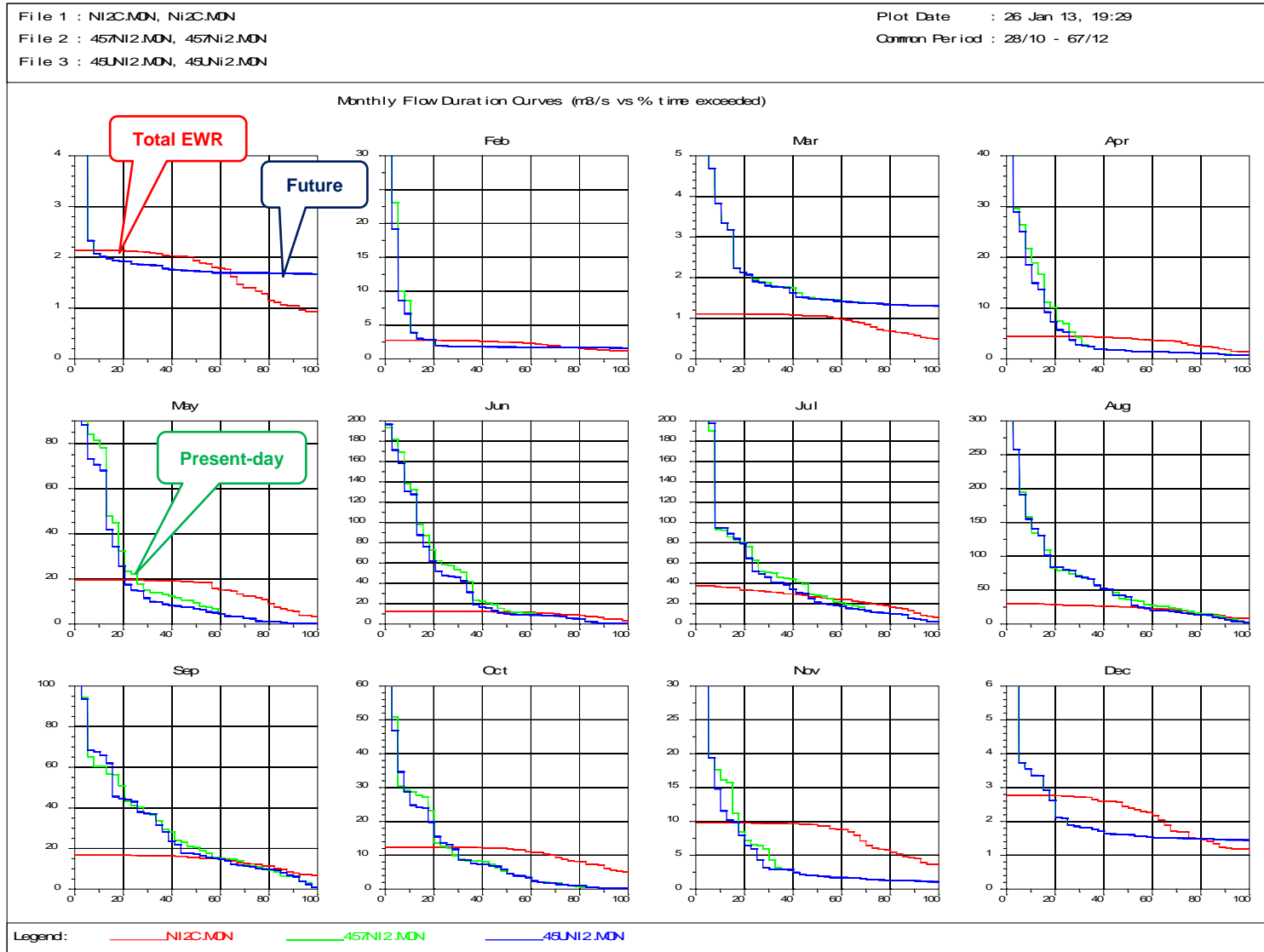


Figure C2: Monthly Flow Duration Plots Upstream of Brede/Riviersonderend Confluence (with BBTS and augmented Papekuils)

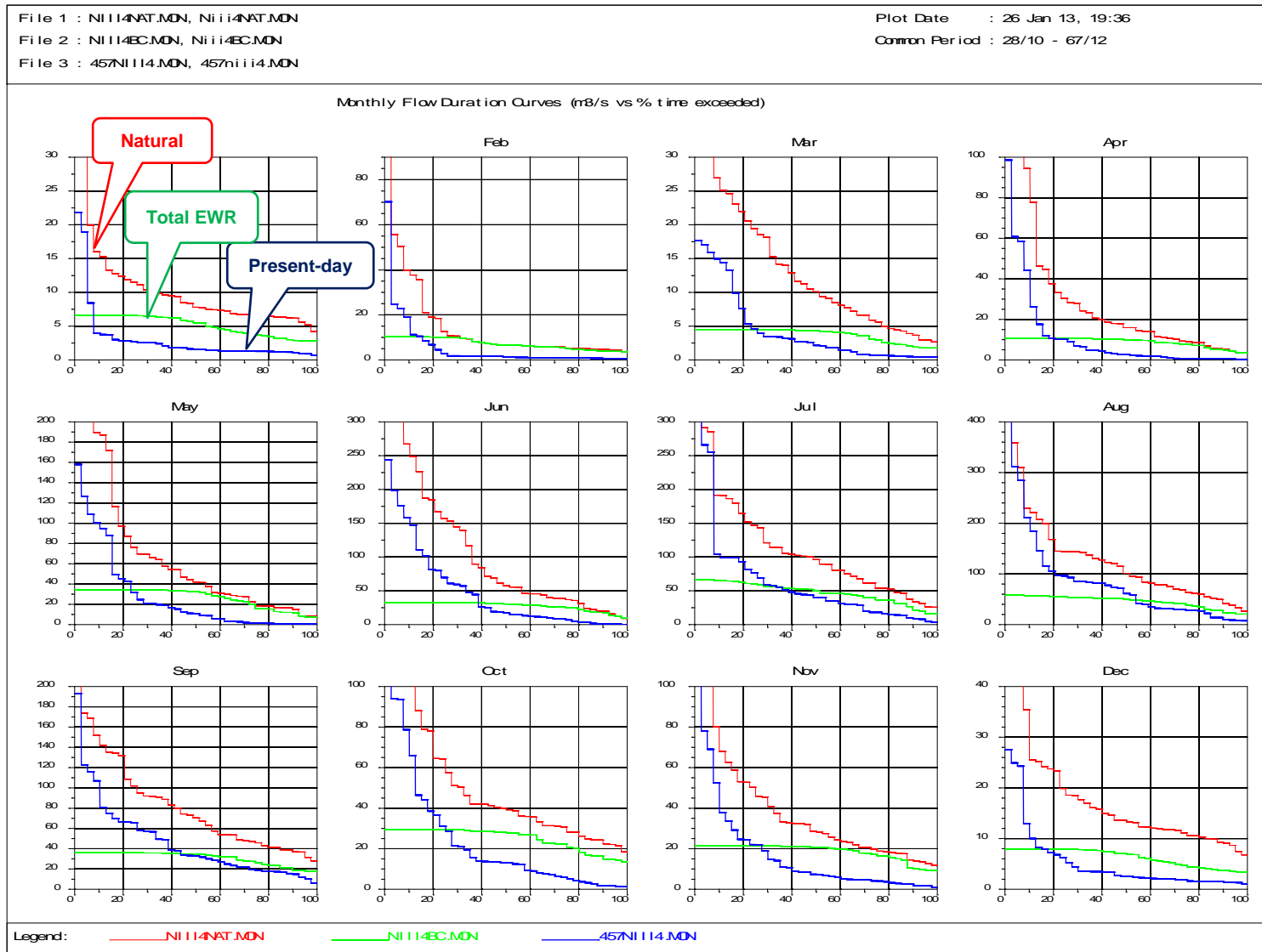


Figure D1: Monthly Flow Duration Plots Upstream of Brede River Estuary (current)

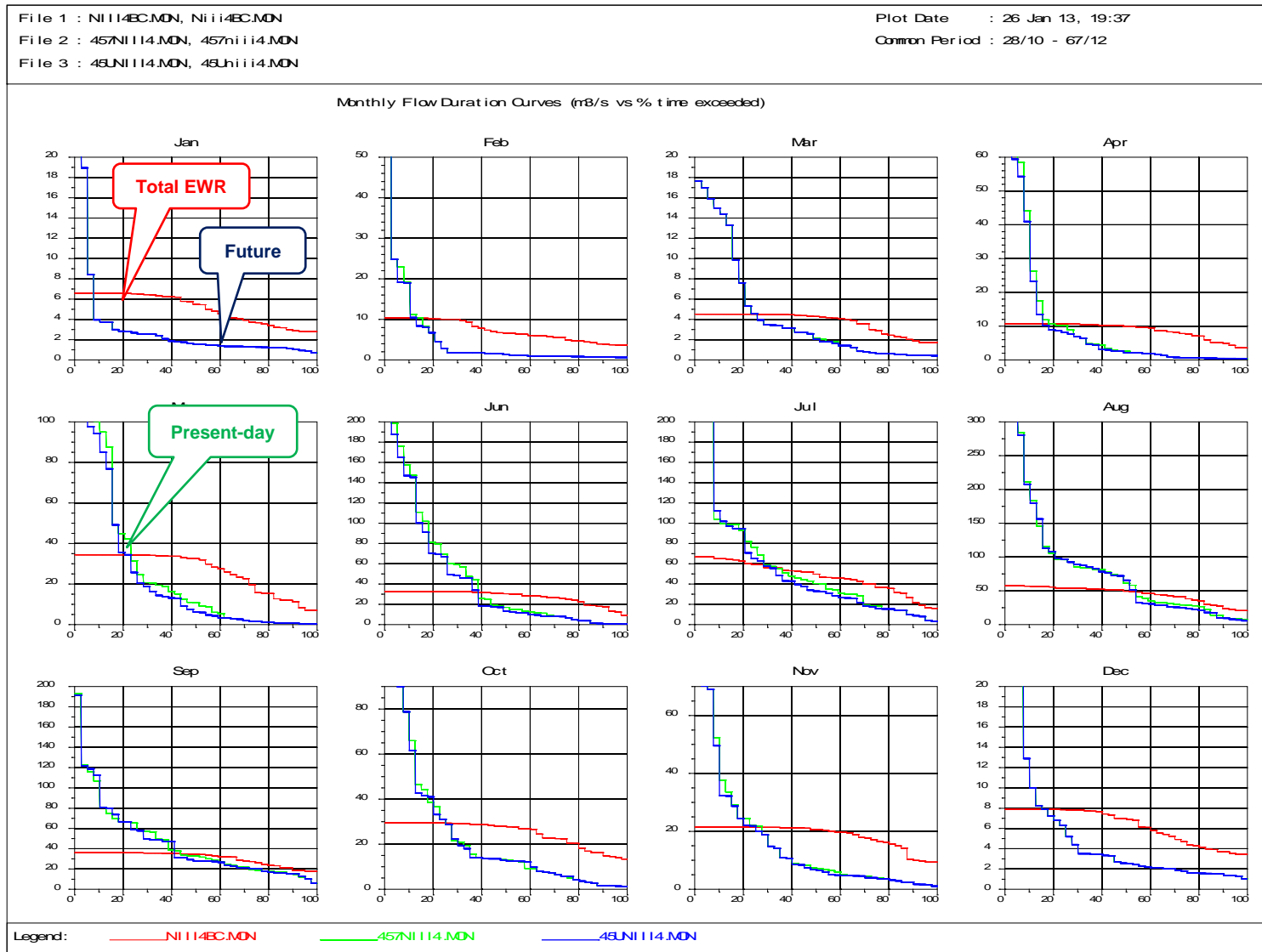


Figure D2: Monthly Flow Duration Plots Upstream of Brede River Estuary (with BBTS and Augmented Papekuils)



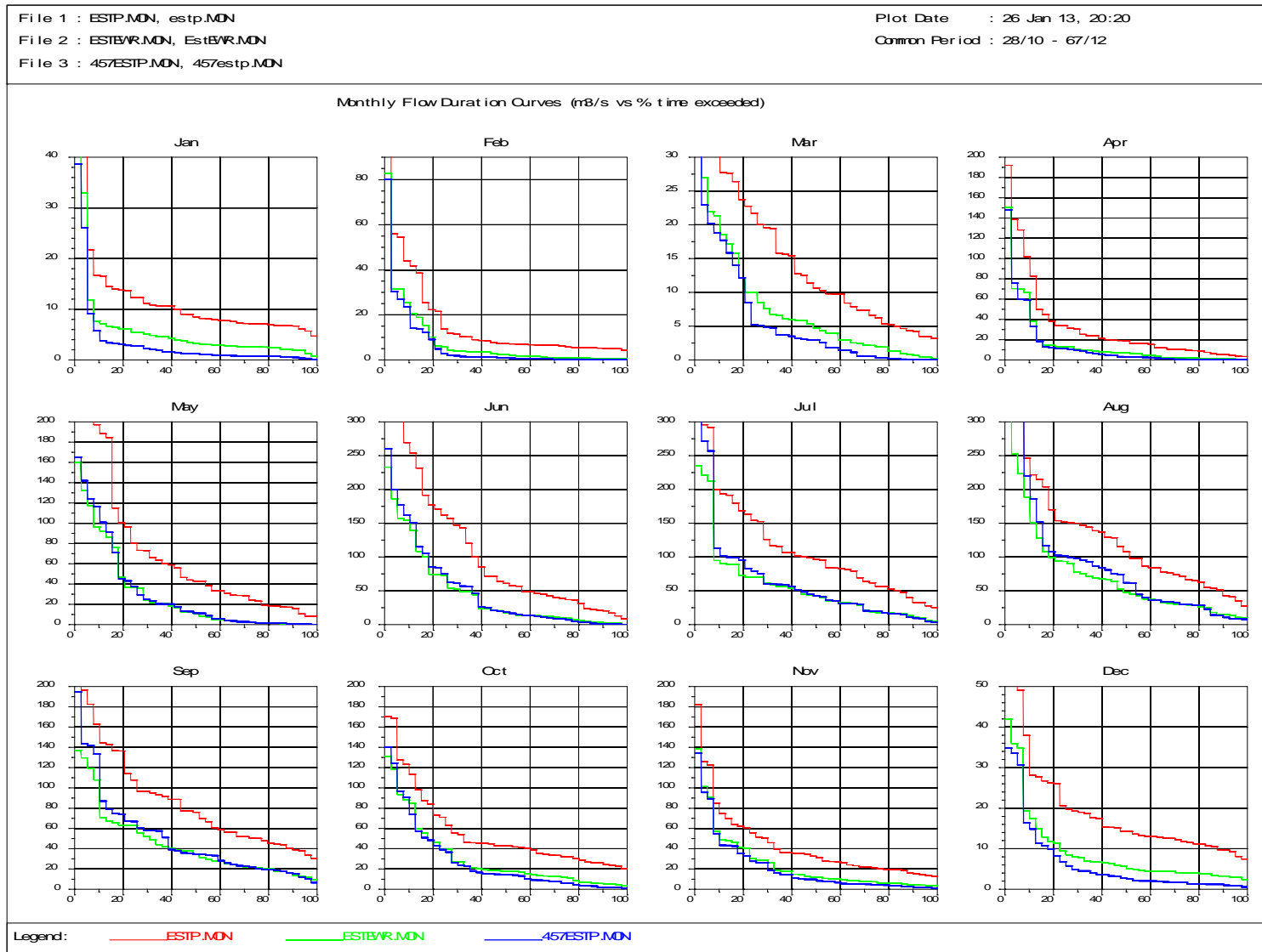


Figure E1: Monthly Flow Duration Plots at Brede River Estuary (current)

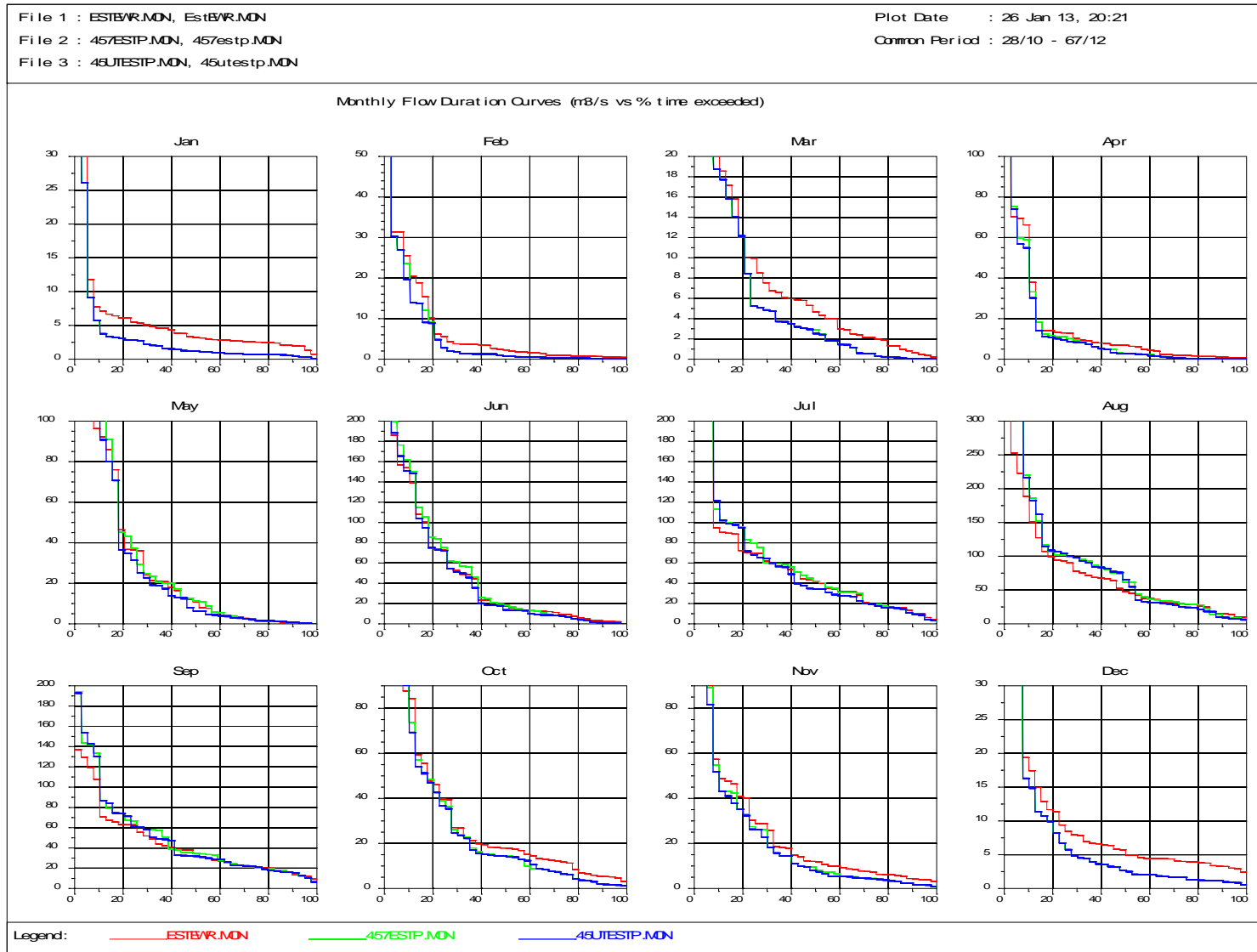


Figure E2: Monthly Flow Duration Plots at Brede River Estuary (with BBTS and Augmented Papankuils)

### 3. COMPARISON OF ANNUAL DURATION CURVES AND THE RESERVES

**Figures A3, B3, C3, D3 and E3** compare the flow annual duration curves with the Reserve requirements at the same sites as described above. These curves show more clearly than the monthly duration curves how the flows with the 5 m<sup>3</sup>/s diversion at Michell's Pass and 20 m<sup>3</sup>/s pumping capacity at Papenkuils comply with the Reserves on an annual basis:

- **Figure A3** shows that downstream of the proposed Michell's Pass diversion the Class D Reserve would be met for 85% of the time.
- **Figure B3** indicates that there would be a slight shortfall in the high Class C/D Reserve at Le Chasseur for about 40% of the time when the higher flows would be lower than the present day flows, however the low flows would exceed the Reserve requirements as do the present day flows.
- **Figure C3** shows a moderate shortfall in the Class C Reserve upstream of the Riviersonderend confluence for about 50% of the time.
- **Figure D3** indicates that the low flow component of the B/C Reserve upstream of the Estuary is currently not met for about 75% of the time and that the proposed interventions would result in a slight deterioration.
- **Figure E3** indicates that the circumstances at the Estuary would be similar to those for the river immediately upstream of the Estuary.

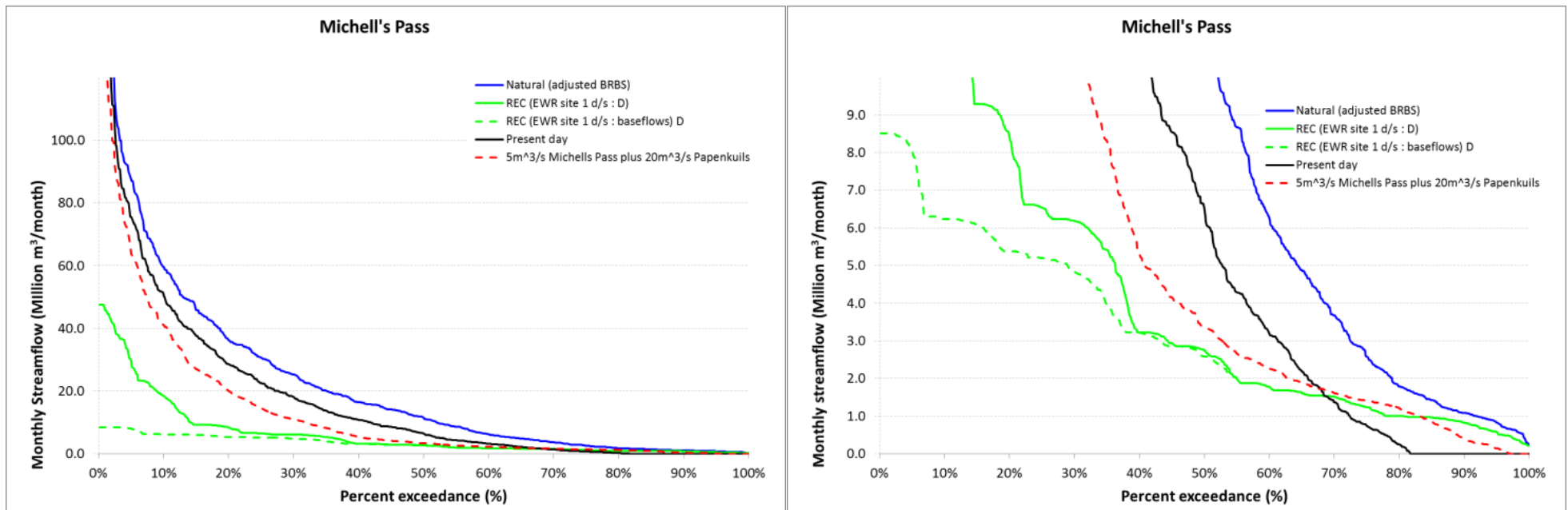


Figure A3: Annual stream flow shortfalls at Michell's Pass relative to total EWR

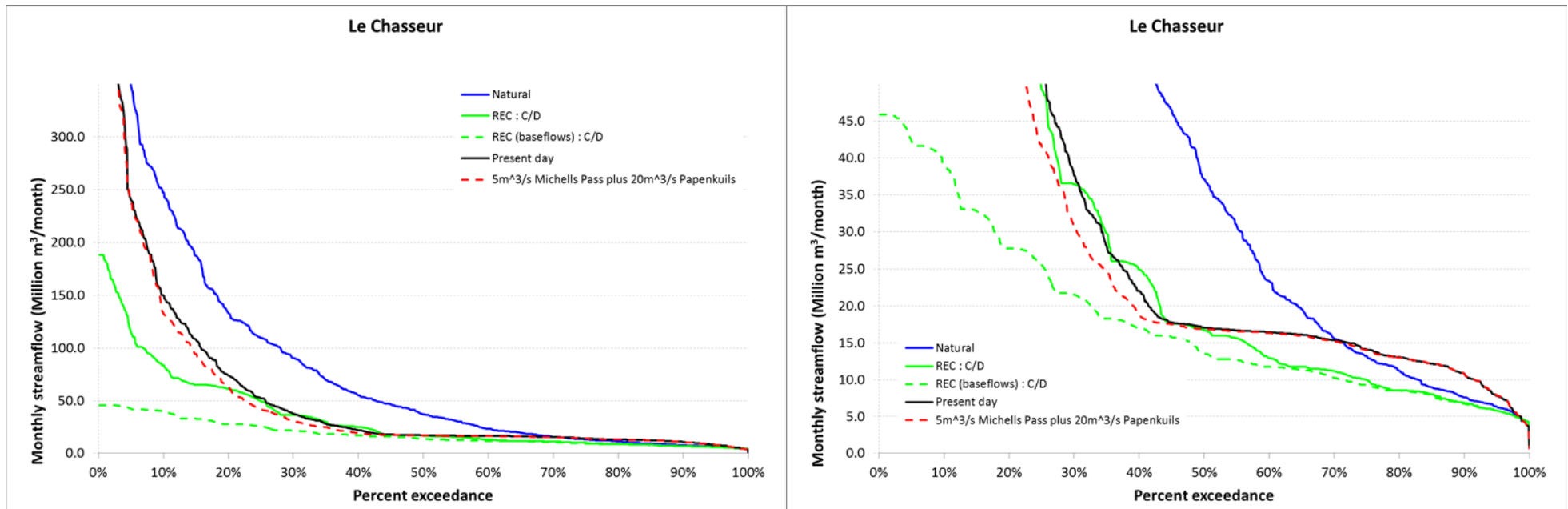


Figure B3: Annual stream flow shortfalls at Le Chasseur relative to total EWR

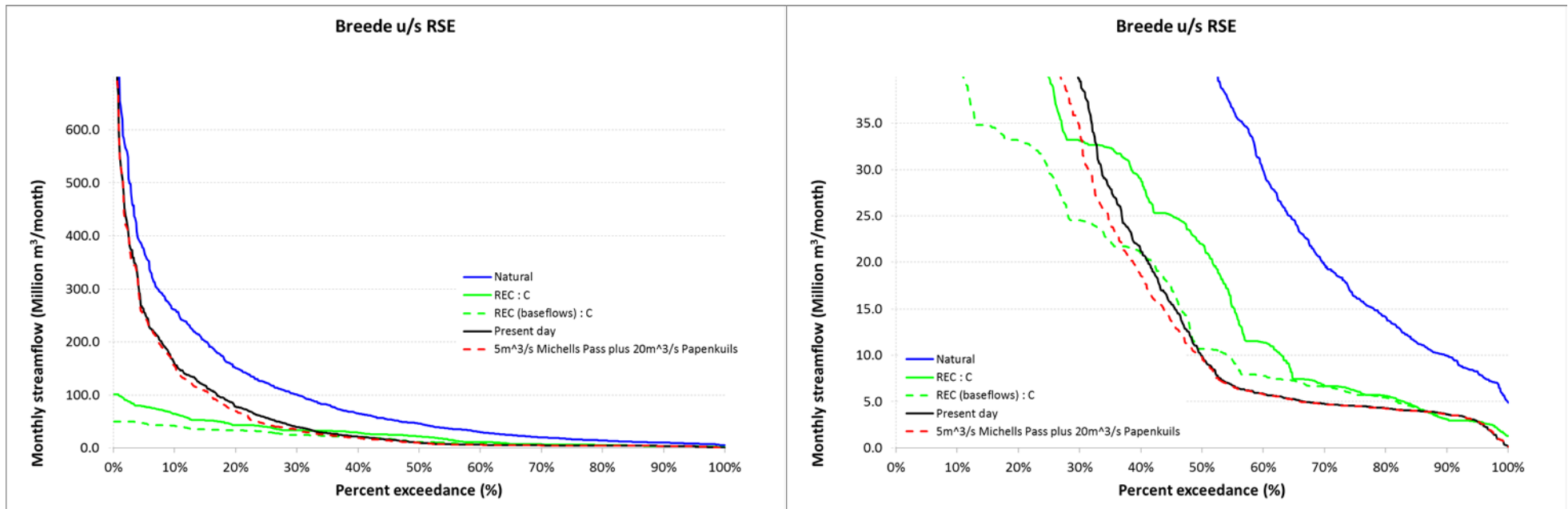


Figure C3: Annual stream flow shortfalls upstream of the Rivieronderend confluence relative to total EWR

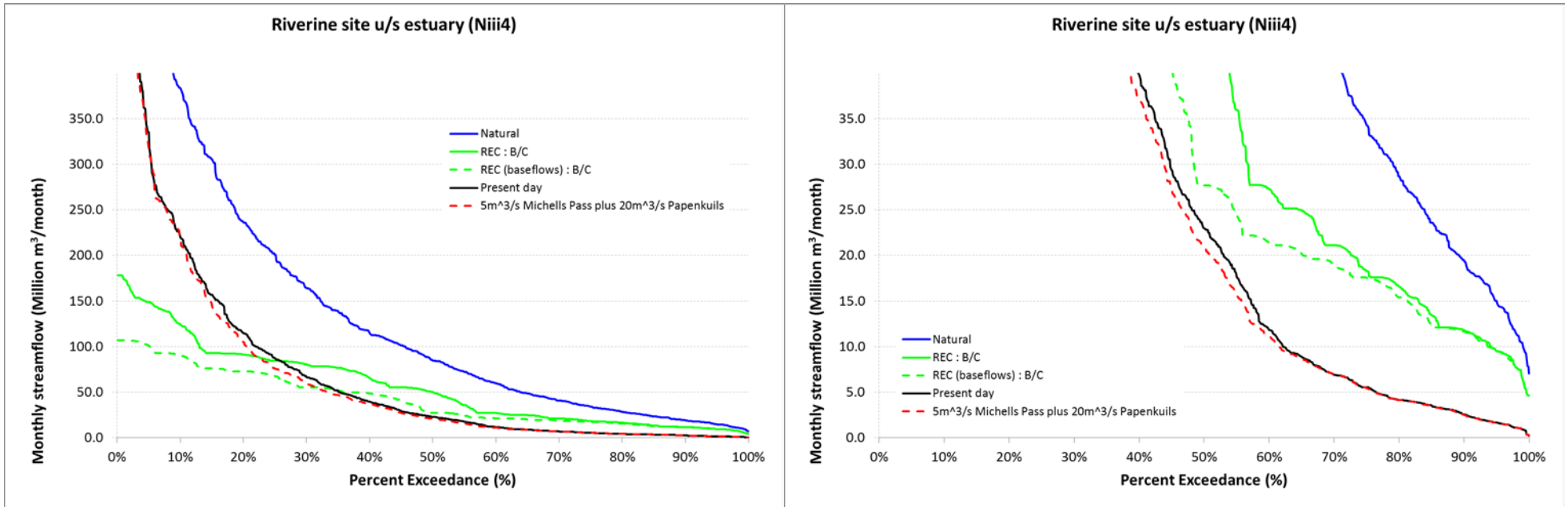


Figure D3: Annual stream flow shortfalls upstream of Estuary relative to total EWR

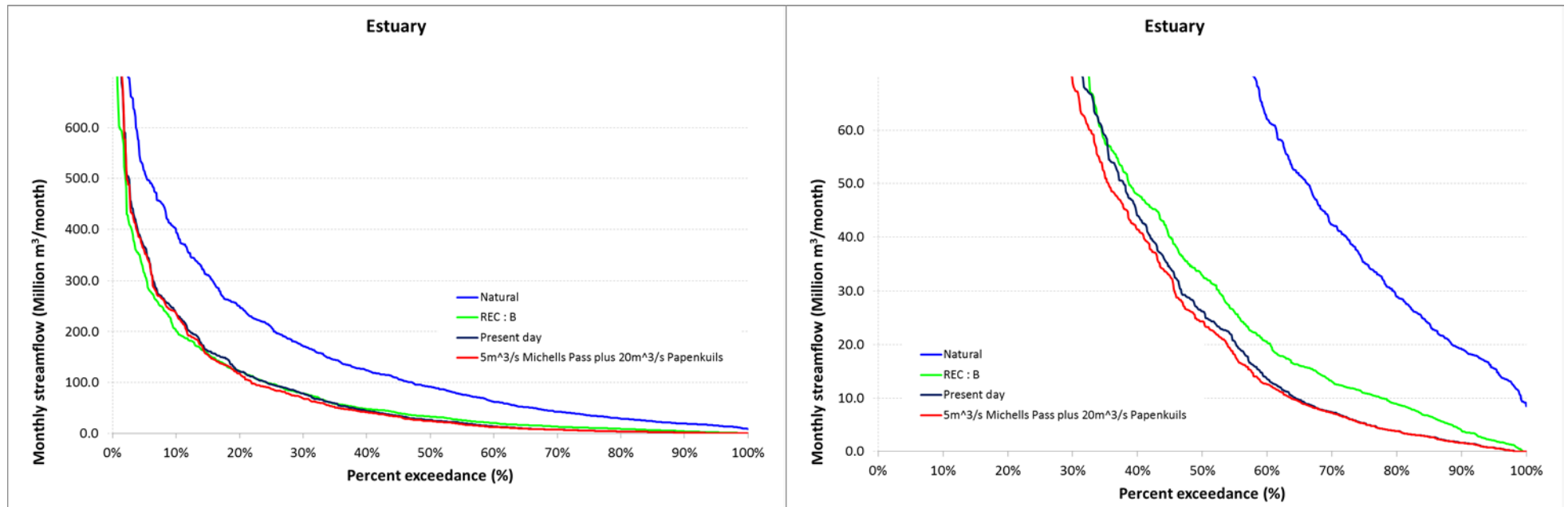


Figure E3: Annual stream flow shortfalls at Estuary relative to total EWR



Figures A4 to D4 show the same information as shown in the Figures above but to a much coarser scale which masks some of the features previously described.

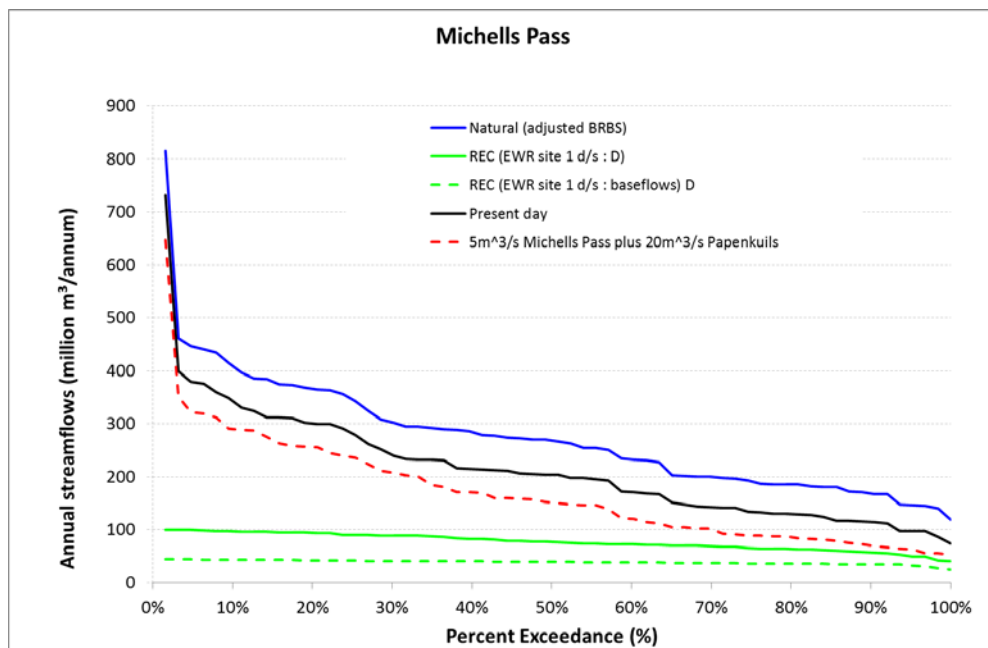


Figure A4: Annual stream flow shortfalls at Michells Pass relative to total EWR

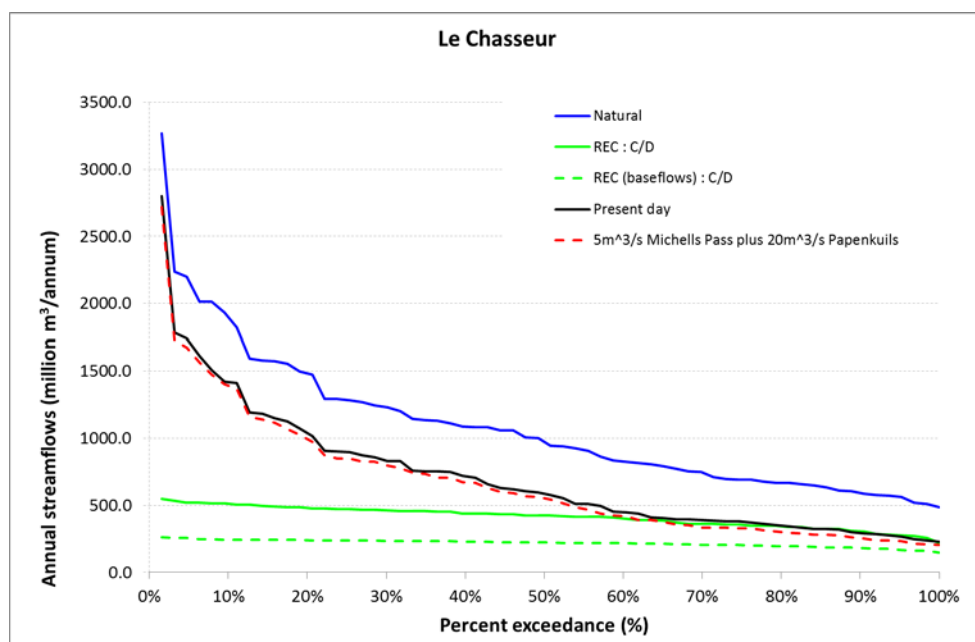
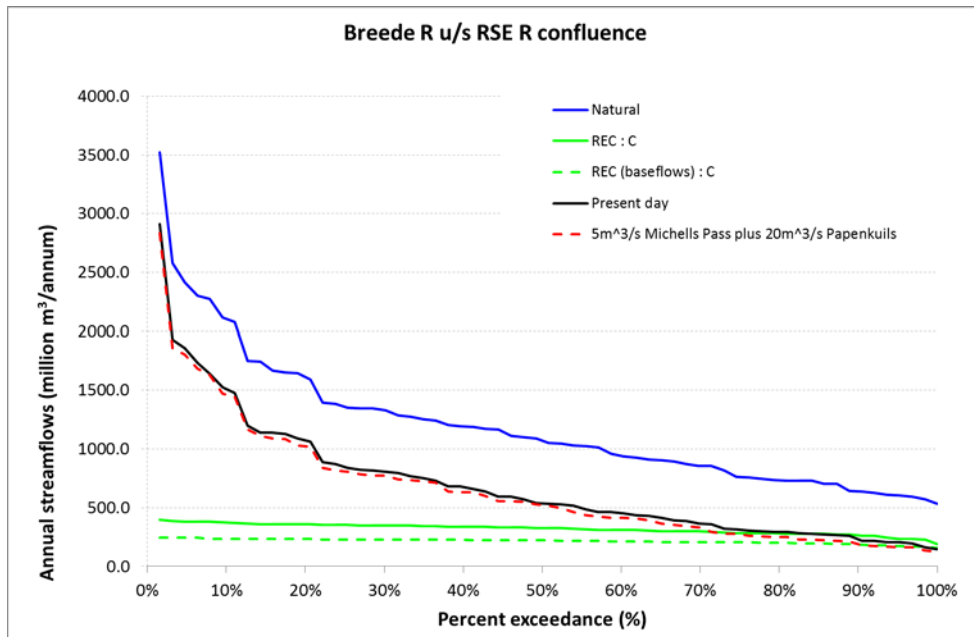
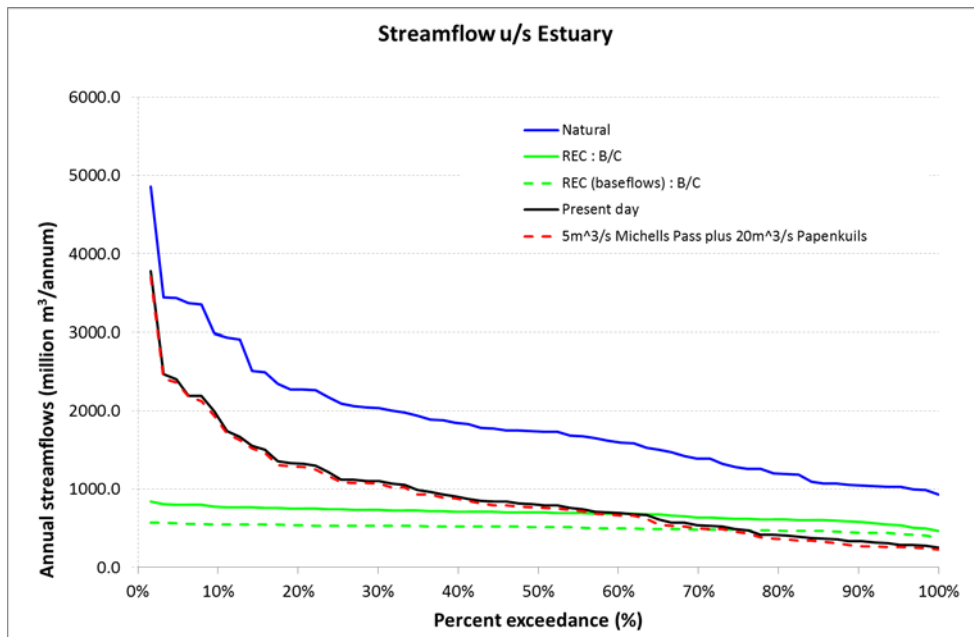


Figure B4: Annual stream flow shortfalls at Le Chasseur relative to total EWR



**Figure C4:** Annual stream flow shortfalls upstream of Rivieronderend Breede confluence relative to total EWR



**Figure D4:** Annual stream flow shortfalls upstream of Estuary relative to total EWR

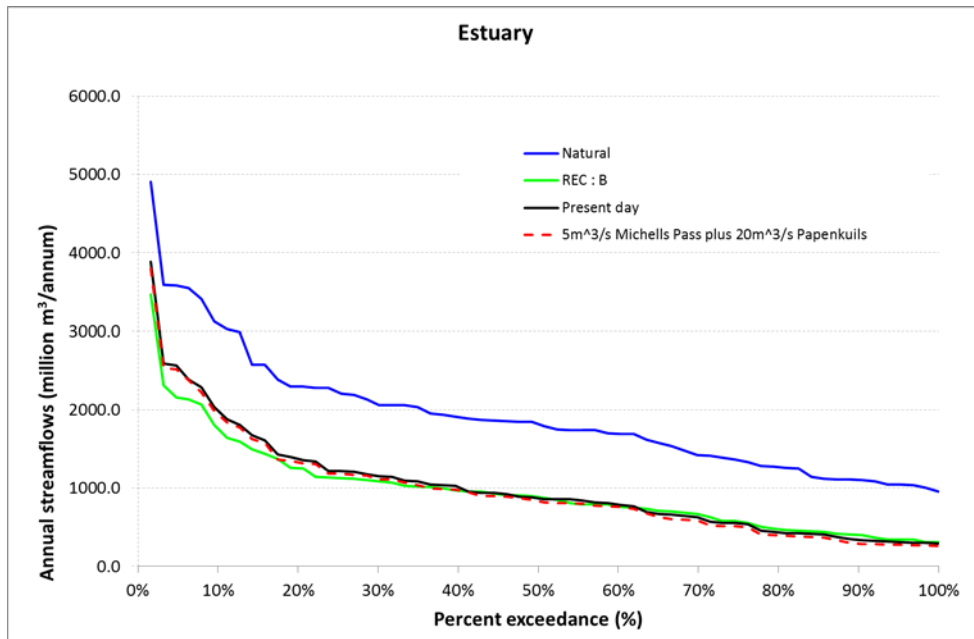


Figure E4: Annual stream flow shortfalls at Estuary relative to total EWR