water affairs

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REPUBLIC OF SOUTH AFRICA

REPORT NO.: P WMA 02/B810/00/0608/5

GROOT LETABA RIVER WATER DEVELOPMENT PROJECT (GLeWaP)

TECHNICAL STUDY MODULE:

Water Resource Analysis

VOLUME 5

MAY 2010

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LIST OF STUDY REPORTS IN GROOT LETABA RIVER WATER DEVELOPMENT PROJECT (BRIDGING STUDIES)

This report forms part of the series of reports, done for the Bridging Study phase of the GLeWaP. All reports for the GLeWaP are listed below.

REPORT NUMBER	REPORT TITLE
P WMA 02/B810/00/0508	**Project Coordination and Management Team**
P WMA 02/B810/00/0508/1	Project Coordination and Management Team: Executive Summary Report: Vol 1
P WMA 02/B810/00/0508/2	Project Coordination and Management Team: Main Report: Vol 2
P WMA 02/B810/00/0508/3	Project Coordination and Management Team: Register of Decisions: Vol 3
P WMA 02/B810/00/0508/4	Project Coordination and Management Team
P WMA 02/B810/00/0508/5	Project Coordination and Management Team
P WMA 02/B810/00/0608	**Technical Study Module**
P WMA 02/B810/00/0608/1	Technical Study Module: Main Report: Vol 1
P WMA 02/B810/00/0608/2	Technical Study Module: Review of Water Requirements: Vol 2
P WMA 02/B810/00/0608/3	Technical Study Module: Groundwater: Vol 3
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P WMA 02/B810/00/1110/1	Technical Study Module: Preliminary Design of Nwamitwa Dam: Vol 6 - Annexure 1: Appendices
P WMA 02/B810/00/1110/2	Technical Study Module: Preliminary Design of Nwamitwa Dam: Vol 6 - Annexure 2: Appendix B (Part 1): Geotechnical Investigations
P WMA 02/B810/00/1110/3	Technical Study Module: Preliminary Design of Nwamitwa Dam: Vol 6 - Annexure 3: Appendix B (Part 2): Geotechnical Investigations
P WMA 02/B810/00/1110/4	Technical Study Module: Preliminary Design of Nwamitwa Dam: Vol 6 - Annexure 4: Appendix H: Drawings
P WMA 02/B810/00/0608/7	Technical Study Module: Preliminary Design of the Raising of Tzaneen Dam: Vol 7
P WMA 02/B810/00/0608/8	Technical Study Module: Bulk Water Distribution Infrastructure: Vol 8
P WMA 02/B810/00/1110/5	Technical Study Module: Bulk Water Distribution Infrastructure: Vol 8 - Annexure 1 : Appendices
P WMA 02/B810/00/0708	**Environmental Management Module**
P WMA 02/B810/00/0708/1	Environmental Management Module: Scoping Report: Vol 1
P WMA 02/B810/00/0708/2	Environmental Management Module: Environmental Impact Assessment Report: Vol 2
P WMA 02/B810/00/0708/3	Environmental Management Module: Environmental Management Programme for Borrow Area 1 on the Farm Laborie 515: Vol 3
P WMA 02/B810/00/0708/4	Environmental Management Module: Environmental Management Programme for Borrow Area 2 on the Farm La Parisa 729 (Gubits Farm): Vol 4
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REPORT DETAILS PAGE

Project name:	***Groot Letaba River Water Development Project***
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PSP

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EXECUTIVE SUMMARY

1. INTRODUCTION

1.1 Background to Project

The catchment of the Groot Letaba River has many and varied land uses with their associated water requirements, for example commercial irrigation, commercial afforestation, tourism, as well as primary requirements by the population in the catchment. The water resources available in the catchment are limited, and considerable pressure has been put on these resources in the past. This situation has been investigated at various levels by the Department of Water Affairs (DWA).

The first major study undertaken for this area was the Letaba River Basin Study in 1985 (DWAF, 1990a), which comprised the collection and analysis of all available data on water availability and use, as well as future water requirements and potential future water resource developments. This was followed by a Pre-feasibility Study (DWAF, 1994), which was completed in 1994. The focus of the Pre-feasibility Study was the complete updating of the hydrology of the Basin. The next study undertaken was the Feasibility Study of the Development and Management Options (DWAF, 1998 a & b), which was completed in 1998.

The Feasibility Study proposed several options for augmenting water supply from the Groot Letaba River. These included some management interventions, as well as the construction of a dam at Nwamitwa and the possible raising of Tzaneen Dam. These options would enable additional water to be allocated to the primary water users, would allow the ecological Reserve to be implemented and could also improve the assurance of supply to the agricultural sector.

This Bridging Study was initiated by the Department of Water Affairs in order to re-assess the recommendations contained in the Feasibility Study in the light of developments that have taken place in the intervening 10 years.

The study area is shown in ***Figure E.1****. It consists of the catchment of the Letaba River, upstream of its confluence with the Klein Letaba River. The catchment falls within the Mopane District Municipality, which is made up of six Local Municipalities. The Local Municipalities within the catchment area are Greater Tzaneen, Greater Letaba, and Greater Giyani. The major town in the study area is Tzaneen, with the urban centre of Polokwane located just outside of the catchment to the west.*

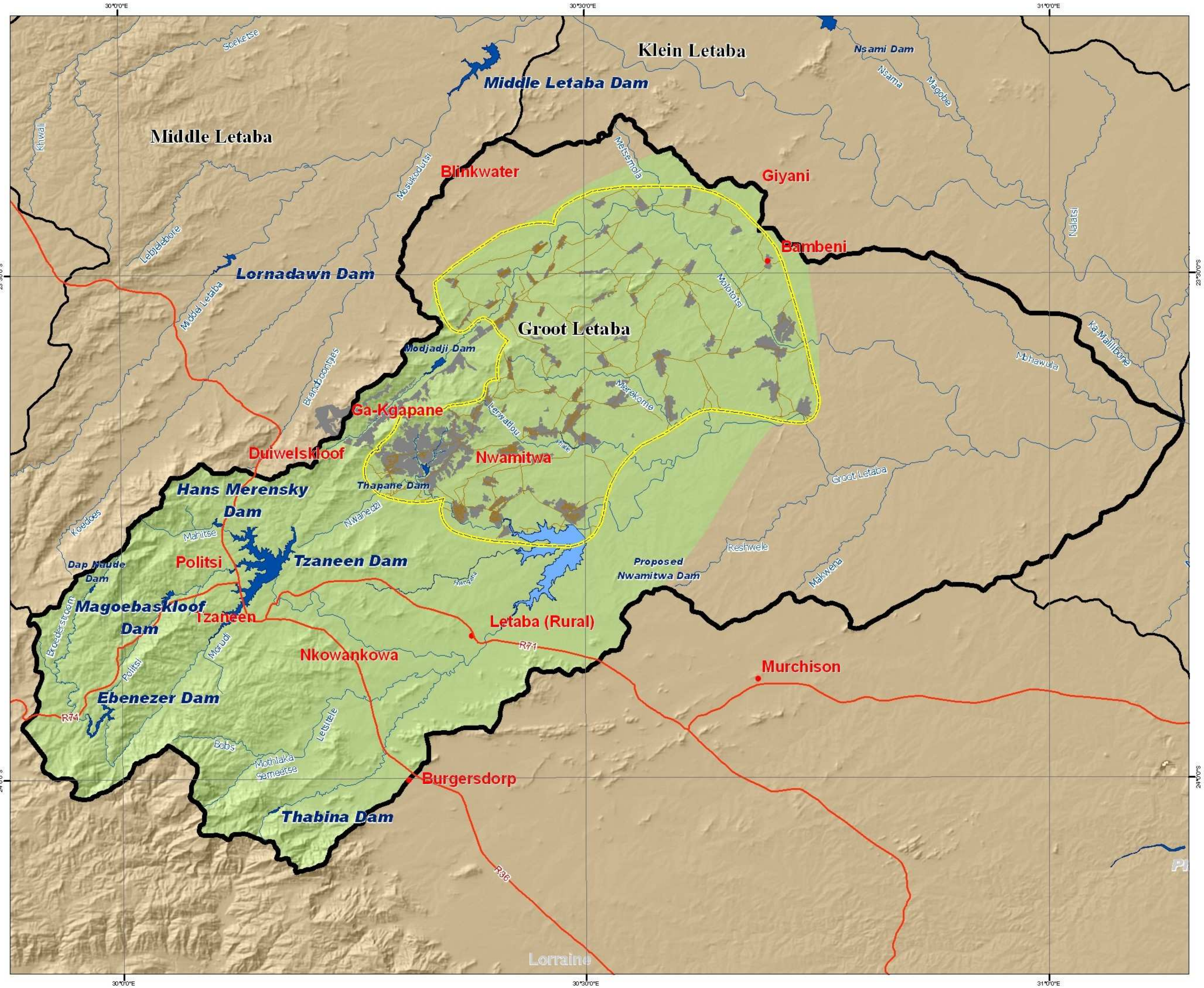
*The site of the proposed Nwamitwa Dam is also shown on **Figure E.1**. The focus of the Feasibility Study was the Groot Letaba Catchment, with the catchments of the other rivers (Middle Letaba, Klein Letaba and Lower Letaba rivers) being included to check that environmental flow requirements into the Kruger National Park were met, and that international agreements regarding flow entering Mozambique were met. This focus was kept for this Bridging Study.*

1.2 SCOPE AND ORGANISATION OF PROJECT

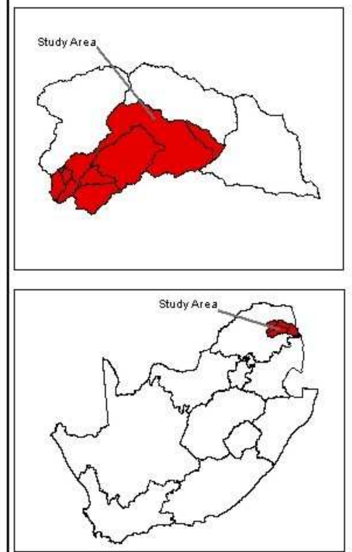
The Department's Directorate: Options Analysis (OA), appointed Aurecon in Association with a number of sub-consultants to undertake this study. The official title of the study is: "The Groot Letaba River Water Development Project : Bridging Studies".

The Bridging Study comprises a number of modules. This report focuses on part of the scope of work for the Technical Study Module (TSM). The tasks comprising the TSM are listed below:

TASK 1: WATER REQUIREMENTS
TASK 2: WATER RESOURCE EVALUATION
TASK 3: PRELIMINARY DESIGN OF NWAMITWA DAM
TASK 4: RAISING OF TZANEEN DAM
TASK 5: BULK WATER DISTRIBUTION INFRASTRUCTURE
TASK 6: IMPLEMENTING PROGRAMME
TASK 7: WATER QUALITY



OVERVIEW MAPS :



LEGEND

- Towns
- National Roads
- Secondary Roads
- Rivers
- Dams
- Villages
- Study Area
- Proposed Supply Area from Nwamitwa Dam

PATH:
s\projects\mxd\Reports\WaterResource Ana\figE1.mxd

SCALE:
0 5 10 15 km
1:380,000

PROJECTION INFORMATION :

COORDINATE SYSTEM :	Transverse Mercator
PROJECTION NAME :	TM31
DATUM :	D_WGS_1984
SPHEROID :	WGS_1984
CENTRAL MERIDIAN :	31

CONSULTANT :

aurecon

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

TITLES :

GROOT LETABA RIVER WATER DEVELOPMENT PROJECT

PROJECT AREA

FIGURE NO. :

E1

1.3 Scope of this Report

This report describes a portion of Task 2: Water Resource Evaluation, namely the Water Resource Analysis. The remainder of Task 2 is reported on in the report entitled Review of Water Requirements (DWA, 2010a).

The primary objective of the Water Resource Evaluation Task was to:

- *Assess the present availability of surface water from the Groot Letaba River system; and*
- *Assess the increase in yield of the proposed new developments, taking account of the flow regime required to maintain the ecological Reserve.*

The first objective is reported on in the report entitled Hydrology*, and the second objective forms the subject of this report.*

*The bulk of the work undertaken for and reported on in this report is contained in **Section 2**. This section describes the complete Water Resources Yield Model (WRYM) network which was configured for the Groot Letaba River System and contains most of the results of the WRYM analysis. The following aspects are reported on:*

- *The approach to the system modelling (**Section 2.3**);*
- *The historic firm yield (HFY) of the proposed Nwamitwa Dam (**Section 2.4**);*
- *Compliance with the Ecological Water Requirement (EWR) (**Section 2.6**);*
- *Results from the Historical Analysis undertaken in the Feasibility Study (**Sections 2.2** and **2.7**);*
- *Water supply from Tzaneen Dam (**Section 2.8**);*
- *Long-term stochastic yield anaylsis (**Section 2.9**); and*
- *Filling times of Nwamitwa Dam (**Section 2.10**).*

***Section 3** contains a description of the impacts of future developments on Massingir Dam. Recommendations regarding operating rules for the proposed Nwamitwa Dam/ Tzaneen Dam system are discussed in **Section 4**. **Section 5** reports briefly on the potential increase in yield that would be obtained from the raising of Dap Naude Dam and Ebenezer Dam.*

*Conclusions are given in **Section 6** and Recommendations, in **Section 7**. **Section 8** contains the references.*

2. WATER RESOURCE ANALYSIS

2.1 INCLUSION OF FRESHETS

During the extension of the stream flow records, it was noticed that the observed freshets (during months with flows somewhat higher than dry season flow) were missing in the simulated streamflows lower down in the Groot Letaba River. These freshets would contribute to increase the yield of Nwamitwa Dam as they would exceed the abstraction capacity of the irrigators, and because they would help recharge the aquatic environment. A re-examination of the Pitman Parameters indicated that modifying these parameters would improve the calibration and that the observed record was plausible. The observed records were used to estimate the magnitude of the freshets which would be about 8 Mm^3/a upstream of the proposed Nwamitwa Dam, 5 Mm^3/a between Nwamitwa Dam and Prieska and about 21 Mm^3/a between Prieska and Letaba Ranch. These freshets (total volume of 34 Mm^3/a) were added to the WRYM simulated flows in order to more closely match the observed flows.

The freshets were not based on a thorough recalibration of the catchments, but on comparing the observed and simulated records at Prieska and Letaba Ranch for dry periods when no spill was likely from Tzaneen Dam (1982-1987, 1991-1995 and 2002-2005), and determining the average annual contribution over each of these periods. These freshets were all assumed to contribute to the high flow EWR requirements downstream of Nwamitwa and the streamflow sequence of the required high flow streamflows was factored until it matched the additional contribution expected from the freshets. The factored high flow sequence was treated as an "additional inflow" into the system.

The supply from the existing Tzaneen Dam is highly dependent on the EWR requirements that are imposed at the downstream EWR sites, and also on how much the river channel losses reduce the delivery of water to the EWR sites.

2.2 LOSSES IN THE SYSTEM

The historical firm yield from Nwamitwa Dam decreases from 18 to 6 Mm^3/a, depending on the factor applied to the losses downstream of the Letaba Ranch. Loss factors of 0, 0.5 (50%) and 1.0 (100%) were assumed for testing sensitivity. Losses were determined between the Letaba Ranch and the Black Heron Weir for dry periods when there were no accruals from the Klein Letaba tributary that enters between the two gauges. However, this approach did not allow for estimation of the losses over the full critical period which would include periods of accruals. It is possible that the actual losses in the system can vary depending on the antecedent river flow and on the operation of the *system. If the antecedent conditions are wet then water may seep out of the sandy river banks into the river channel.*

Determination of Historical Firm Yields

*The current historical firm yield of the proposed Nwamitwa Dam is 14 Mm^3/a (scenario ct77H in **Table E7**). This historical firm yield is based on the following assumptions :*

- *Nwamitwa Dam is constructed to RL479.5 (capacity of 187 Mm^3).*
- *The full Preliminary Reserve Requirement is supplied at EWR Site 3 (Prieska) but only the reduced EWR "Scenario 7" is supplied at EWR sites 4 – 7. ("Scenario 7" as per Preliminary Reserve Determination report (DWAF, 2006b)).*
- *The supply from Tzaneen Dam remains unchanged from present day condiitons.*
- *The current operating rules at Tzaneen Dam remain unchanged from present day conditions.*
- *The average losses over the critical drawdown period are half the observed losses during the low flow period.*
- *A total of about 34 Mm3/a of freshets were added to the WRYM simulation. These will contribute about 8 Mm3/a extra inflow to Nwamitwa Dam and to the environmental highflow requirements downstream of Nwamitwa Dam.*
- *Polokwane supply was limited to its allocation from Ebenezer and Dap Naude dams.*

The yield is dependent on the abovementioned assumptions and changing the assumptions will have a significant impact on the yield.

***Table E1** summarises the results of a number of key scenarios which were investigated. This includes alternative full supply levels (FSL) for the proposed Nwamtiwa Dam. It should be noted that all the scenarios in **Table E1** assume a "system loss" of 50%.*

Table E1 Summary of Yields

Description	Scenario	Nwamitwa FSL	Tzaneen FSL	Rooipoort	Average Agric Supply + losses to GL Ranch	Nwamitwa HFY	Massingir HFY	Description of Scenario
		masl	masl	masl	Mm^3/a	Mm^3/a	Mm^3/a	
Present Day	PH	n/a	723.9	n/a	0	n/a	575	Present Day Condition. Current release of 14.7 Mm^3/a to KNP
	Pt77H	n/a	723.9	n/a	-7	n/a	*	Present Day Condition. Full EWR at Site 3 met. Optimised Scenario 7 met downstream of EWR Site 3. 50% "system losses" applied
Nwamitwa FSL of 479.5 masl	tH	479.5	723.9	n/a	0	27	*	Present Day Condition with Nwamitwa FSL of 479.5 masl. Full EWR at Site 3 met. No explicit supply to EWR Sites downstream of Site 3
	777H	479.5	723.9	n/a	0	21	*	Optimised Scenario 7 with Nwamitwa FSL of 479.5 masl. EWR low flows met. No EWR high flows met
	ct77H (1)	479.5	723.9	n/a	0	14	573	Full EWR met at Site 3. Optimised Scenario 7 met downstream of EWR Site 3. Nwamitwa FSL of 479.5 masl. 50% system losses applied
	-t77H	479.5	723.9	n/a	0	2	*	Same as ct77H, but with no additional freshets included in WRYM
	tttH	479.5	723.9	n/a	0	7	*	Full EWR met at all EWR sites d/s of Nwamitwa. 50% system losses applied
	tttF	479.5	723.9	n/a	0	0	*	Full EWR met at all EWR sites d/s of Nwamitwa.100% system losses applied
Yield of Nwamitwa at different FSLs	at77H	473.5	723.9	n/a	0	4	574	Full EWR met at Site 3. Optimised Scenario 7 met downstream of EWR Site 3. Nwamitwa FSL of 473.5 masl. 50% system losses applied
	bt77H	477.5	723.9	n/a	0	9	573	Full EWR met at Site 3. Optimised Scenario 7 met downstream of EWR Site 3. Nwamitwa FSL of 477.5 masl. 50% system losses applied
	ct77H(1)	479.5	723.9	n/a	0	14	573	Full EWR met at Site 3. Optimised Scenario 7 met downstream of EWR Site 3. Nwamitwa FSL of 479.5 masl. 50% system losses applied
	dt77H	481.5	723.9	n/a	0	17	*	Full EWR met at Site 3. Optimised Scenario 7 met downstream of EWR Site 3. Nwamitwa FSL of 481.5 masl. 50% system losses applied
	t77RH	479.5	723.9	733.9	0	14	*	Same as ct77H, but with proposed Rooipoort Dam included
	t77FH	479.5	726.9	n/a	0	18	572	Same as ct77H, but with Tzaneen Dam raised by 3 m. Nwamitwa yield shows incremental yield to system
	t77FRH	479.5	726.9	733.9	0	14	500	Same as ct77H, but with a raised Tzaneen Dam and the proposed Rooipoort Dam included

(1) Details of scenario ct77H are repeated for ease of reference

* indicates that the value was not determined

Raising of Tzaneen Dam

The benefit of installing fuse gates or constructing a labyrinth weir to raise the full supply level of Tzaneen Dam by 3 metres (from a gross storage of 158 Mm^3 to 193 Mm^3) was determined by finding the increase in the firm yield of the Tzaneen/Nwamitwa system, which equated to about 4 Mm^3/a.

Comparison with 1995 Feasiblity Study

The main differences between the earlier Feasibility Study and the current Bridging Study are:

- *The Bridging Study introduced additional freshets averaging about 34 Mm^3/a into the WRYM as a stopgap measure to introduce freshets that were missing in the streamflows simulated via the Pre-feasiblity Pitman parameters and adopted for the Feasibility Study.*
- *The urban requirements in the Bridging Study were fixed at about the 2007 level of development, rather than the 2020 level of development used in the Feasibility Study.*
- *Following the detailed survey of the Groot Letaba (excluding the Politsi Government Water Control Area) by Schoeman & Vennote, the irrigation and farm dam capacities were increased by 37 Mm^3/a and 27 Mm^3 respectively, primarily along the Groot Letaba downstream of the Tzaneen Dam.*
- *Subsequent to the Feasibility Study, the ecological water requirements were updated in the Letaba Catchment – Reserve Determination Study. The total requirements from both studies, i.e. the original full maintenance requirement and the later preliminary reserve determination, differ, but the original drought requirements and the requirements for the "Scenario 7" adopted in the Reserve Determination Study are similar.*
- *The Feasibility Study determined the additional average supply to irrigation possible for each of the scenarios, while the Bridging Study determined the additional firm yield available at Nwamitwa, assuming that the irrigation supply remained identical to pre-Nwamitwa conditions.*

However, despite these differences the historical firm yields for both systems releasing full ecological requirements down to the Klein Letaba confluence and ignoring the additional freshets introduced in the Bridging Study are both less than 10 Mm^3/a. If drought/"Scenario 7" requirements are supplied instead, the yield increases to between 7 and 14 Mm^3/a.

Filling Times

The "filling" time of Nwamitwa Dam was determined using present day demands only i.e. excluding any additional abstractions which may take place directly from the yield of the proposed dam. The dam fills but does not remain full because the evaporation from its full supply area (25 km^2) is of the same order of magnitude as the system yield. The analysis shows that there is a 50% probability that the dam will "fill" within about four years and a 80 % probability that the dam will "fill" within eight years.

3. IMPACTS OF FUTURE DEVELOPMENTS ON MASSINGIR DAM

The historical firm yield of Massingir Dam was determined for different upstream developments and ecological water requirements. The base scenario assumed that Tzaneen Dam was unraised and operated according to the current day rules at above its firm yield and releasing 14.7 Mm^3/a from the Nondweni Weir. The Olifants system was operated according to the target drafts adopted in the Olifants River Water Resources Development Project.

The available streamflow records for the Olifants River System only extend to September 1986 so the historical firm yield was determined for the period from October 1926 to September 1986, instead of until September 2005. The extended streamflow records of the Olifants system were not available at the time of this analysis. The criticial period for Massingir Dam was from October 1961 to October 1971, which is similar to that of the Ebenezer and Tzaneen dams. However there was a second critical period in the latter system from 1981 to 1995 which could not be modelled for the Massingir Dam because of the shorter record.

Under present day conditions, the historical firm yield of Massingir Dam (assuming that the dam starts full in October 1926) is 575 Mm^3/a.

*With the construction of Nwamitwa Dam (scenario ct77H), the historical firm yield at Massingir Dam is reduced by 2 Mm^3/a to 573 Mm^3/a. If Tzaneen Dam is raised by 3 m, then the historical firm yield of Massingir Dam reduces to 572 Mm^3/a. The results of other scenarios analysed are contained in **Table 2.3** in the main text of this report. This means that the EWR releases largely compensate for the impoundment of water during the critical period, even though the spillage from the system will decrease if Nwamitwa Dam is constructed.*

4. OPERATING RULES

In the yield analysis, the Nwamitwa Dam and Tzaneen Dam were operated conjunctively to maximise the yield. The Nwamitwa Dam was drawn down first, primarily to minimise the evaporation, as the Nwamitwa Dam has a larger surface area for a given storage volume than the Tzaneen Dam and a higher evaporation rate. Under this operating rule the average net evaporation from the Nwamitwa Dam was about 9 Mm^3/a. Were Nwamitwa Dam maintained at its full supply level, the net evaporation would exceed 20 Mm^3/a. A secondary benefit of drawing down the Nwamitwa Dam first, is that this also maximises the storage available to intercept floods from the Letsitele River.

One of the challenges of operating the Nwamitwa and Tzaneen dams as a system is the equitable distribution of water between two user groups with very different reliability requirements. On the one hand the domestic and industrial consumers require a high reliability of water supply, whereas the irrigators have adapted to a lower reliability of supply. The allocation to the urban consumers must be based on the additional yield from the Nwamitwa Dam to ensure that the irrigators continue to receive the same water at the same reliability. The supply to the irrigators must be curtailed in time to assure the domestic consumers a sufficiently reliable source. This curtailment of the irrigators and, and in more extreme cases, the domestic consumers, would be based on the combined total storage in the Tzaneen and Nwamitwa dams through the year. If the Hans Merensky and Magoebaskloof dams are under-utilised then the storage in these dams could also be considered. Unless all stakeholders understand the operating rule, there could be conflicts when the irrigators are curtailed and there is still a fair amount of water available in the Tzaneen Dam.

5. THE RAISING OF DAP NAUDE AND EBENEZER DAMS

The incremental increases in the firm yield of the Ebenezer/Tzaneen system from raising Ebenezer by 5 and 10 meters were 2.3 and 4.5 Mm^3/a respectively. If Nwamitwa Dam was constructed first, then the incremental firm yield from raising Ebenezer Dam reduces from 4.5 to 3.9 Mm^3/a.

The potential increase from raising the Dap Naude Dam will be significantly less and was not evaluated.

6. CONCLUSIONS

A summary of the main conclusions emanating from the Water Requirements and Water Resource Analysis is given below:

- *Currently, the yield from most of the major surface water schemes is over-allocated. The result of this pressure on the available surface water supply is that the supply of water to the irrigation sector is curtailed to below their allocations on an ongoing basis. The recent determination of the Ecological Water Requirement (EWR) has introduced an additional requirement, which has increased the pressure on the available surface water.*

- *One of the major conclusions from the water resource analysis was that the extended hydrology did not adequately reflect the low flows in the system. If the extended hydrology was used unmodified, the proposed Nwamitwa Dam would have zero yield, mainly because of the obligation to meet the EWR. Once the additional freshets (a series of low flow events based on observed flow records, with a mean annual runoff (MAR) of 34 Mm^3/a) were added to the simulated streamflows, the yield of the proposed Nwamitwa Dam increased to 14 Mm^3/a (scenario ct77H).*

- *The yield was found to be sensitive to the way in which the EWR was implemented in the WRYM. This is a concern because of the preliminary nature of the EWR and the lack of detail available regarding exactly how it needs to be implemented. Considerable further work is required to refine the EWR with particular attention to how it can be modelled within the WRYM.*

- *A Reserve Determination Study for the proposed Nwamitwa Dam still needs to be undertaken. The most recent Reserve Determination Study did not consider the modification in flows caused by the Nwamitwa Dam and the possible impact of channel losses along the Groot Letaba River.*

- *The historical firm yield at Nwamitwa decreases from 18 to 6 Mm^3/a, depending on the factor applied to the channel losses, i.e. 100%, 50% or zero %, downstream of the Letaba Ranch. If a 50% loss factor was assumed, the historical firm yield of Nwamitwa Dam would be 14 Mm^3/a (scenario ct77H). This yield assumes that the ecological water requirements at EWR Site 3 were met by the proposed Nwamitwa Dam.*

- *Given the modelling assumptions made regarding the freshets, the uncertainty regarding the implementation of the EWR and the coarse assumptions regarding "river losses", the yield results for the proposed Nwamitwa Dam should be viewed as preliminary until the recommended further studies have been undertaken.*
- *The incremental increases in the firm yield of the Ebenezer/Tzaneen system from raising Ebenezer by 5 and 10 meters were 2.3 and 4.5 Mm^3/a, respectively. If Nwamitwa was constructed first, then the incremental firm yield from raising Ebenezer reduces from 4.5 to 3.9 Mm^3/a.*
- *There is a 50% probability that the proposed Nwamitwa Dam (FSL 479.5 masl) will fill within four years and an 20% probability that the dam will fill within eight years.*
- *The construction of the proposed Nwamtiwa Dam and raising of Tzaneen Dam will have very limited impact on the yield of Massingir Dam (reduction of 3 Mm^3/a on 575 Mm^3/a). The development of the proposed Rooipoort Dam will reduce the historical firm yield from Massingir Dam by more than 70 Mm^3/a to 500 Mm^3/a.*
- *It is important that Nwamitwa Dam and Tzaneen Dam are operated conjunctively to maximise the yield. Nwamitwa Dam should be drawn down first, primarily to minimise the evaporation, as the Nwamitwa Dam has a larger surface area for a given storage volume than the Tzaneen Dam and a higher evaporation rate. Under this operating rule, the average net evaporation from the Nwamitwa Dam is about 9 Mm^3/a. Were Nwamitwa Dam maintained at its full supply level, the net evaporation would exceed 20 Mm^3/a. A secondary benefit of drawing down the Nwamitwa Dam first, is that this also maximises the storage available to intercept floods from the Letsitele River.*

7. RECOMMENDATIONS

The following recommendations are made:

- *Given the stressed nature of the available water resources and the anticipated growth in primary water requirements, it is important to undertake verification and validation of water use in the Groot Letaba Catchment.*
- *A Reserve Determination Study needs to be undertaken for the proposed Nwamitwa Dam. The EWR needs to be refined, and more attention needs to be given to how the EWR should be applied and modelled to reflect the day-to-day operation more accurately in the WRYM.*

- *Further investigations should be undertaken in order to refine the assumptions made regarding "river losses". This will enable the yield results to be portrayed with a higher level of certainity.*
- The historical firm yield from the proposed Nwamitwa Dam should be re-determined once the results of the abovementioned further investigations are available and once the rainfall runoff model has been re-calibrated.

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FIGURES

APPENDICES

Aurecon Electronic Reference: I:\HYDRO\401775 Groot Letaba\Reports\Vol 5 Water Resource Analysis\Water Resource Analysis Report (Final).doc

ABBREVIATIONS

chs	channels
d/s	downstream
DWA	Department of Water Affairs
EMM	Environmental Management Module
EWR	Ecological water requirement
FSL	full supply level
GLeWaP	Groot Letaba River Water Development Project
GLWUA	Groot Letaba Water Users Association
GL	Groot Letaba
HFY	Historical firm yield
IFM	Institutional and Financial Module
IFR	Instream flow requirements (outdated name for EWR)
IWR	Integrated water resources
km^2	square kilometres
KNP	Kruger National Park
masl	metres above sea level
m^3/a	cubic metres per annum
Mm^3/a	million cubic metres per annum
MAR	Mean Annual Runoff
PIP	Public Involvement Programme
PSP	Professional Service Provider
RESDSS	Reserve Decision Support System
RL	reduced level
SEE	Socio-economic evaluation
TSM	Technical Study Module
u/s	upstream
WRYM	Water Resources Yield Model
%	percentage

1. STUDY INTRODUCTION

1.1 BACKGROUND TO PROJECT

The catchment of the Groot Letaba River has many and varied land uses with their associated water requirements. These include significant use by agriculture in the form of irrigated crops, commercial afforestation, tourism (particularly linked to the Kruger National Park (KNP), which lies partially within the catchment), as well as primary requirements by the population in the catchment. The water resources available in the catchment are limited, and considerable pressure has been put on these resources in the past, with periods of severe and protracted water restrictions occurring over the past 25 years. This situation has been investigated at various levels by the Department of Water Affairs (DWA).

The first major study undertaken for this area was the Letaba River Basin Study in 1985 (DWAF, 1990a), which comprised the collection and analysis of all available data on water availability and use, as well as future water requirements and potential future water resource developments. This was followed by a Pre-feasibility Study (DWAF, 1994), which was completed in 1994. The focus of the Pre-feasibility Study was the complete updating of the hydrology of the Basin. The next study undertaken was the Feasibility Study of the Development and Management Options (DWAF, 1998 a and b), which was completed in 1988.

The Feasibility Study proposed several options for augmenting water supply from the Groot Letaba River. These included some management interventions, as well as the construction of a dam at Nwamitwa and the possible raising of Tzaneen Dam. These options would enable additional water to be allocated to the primary water users, would allow the ecological Reserve to be implemented and could also improve the assurance of supply to the agricultural sector.

This Bridging Study was initiated by the Department of Water Affairs in order to re-assess the recommendations contained in the Feasibility Study in the light of developments that have taken place in the intervening 10 years. Other contributing factors to the DWAF's decision to undertake Bridging Studies were the promulgation of the Water Services Act and the National Water Act in 1997 and 1998 respectively, and the recently completed Reserve Study on the Letaba River.

The study area is shown in **Figure 1.1**. It consists of the catchment of the Letaba River, upstream of its confluence with the Klein Letaba River. The catchment falls within the Mopane District Municipality, which is made up of six local municipalities. The local municipalities that lie within the catchment area are Greater Tzaneen, Greater Letaba, and Greater Giyani. The major town in the study area is Tzaneen, with the urban centre of Polokwane located just outside of the catchment to the West.

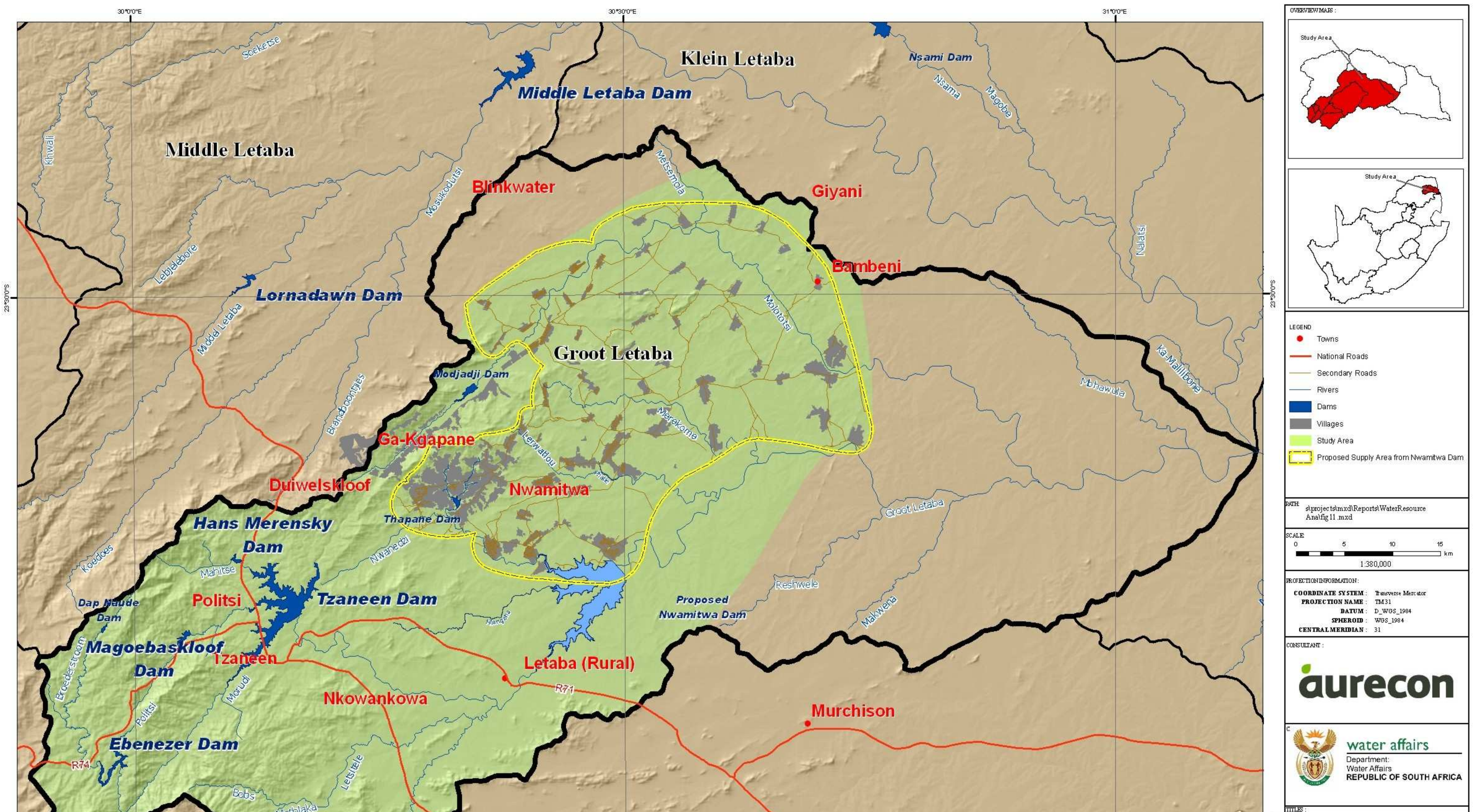
The site of the proposed Nwamitwa Dam is also shown in **Figure 1.1**. The focus of the Feasibility Study was the Groot Letaba Catchment, with the catchments of the other rivers (Middle Letaba, Klein Letaba and Lower Letaba Rivers) included to monitor the environmental flow requirements at the Kruger National Park, and to ensure that international agreements regarding flow entering Mozambique were met. This focus was kept for this Bridging Study. The locations of the catchments of the other rivers, as well as the Kruger National Park are shown in **Figure 1.2**.

1.2 SCOPE AND ORGANISATION OF PROJECT

The DWA Directorate: Options Analysis (OA), appointed Aurecon in association with a number of sub-consultants (listed below) to undertake this study. The official title of the study is: "The Groot Letaba River Water Development Project (Bridging Study).

An association exists between the following consultants for the purposes of this study:

- Aurecon
- Semenya Furumele Consulting
- KLM Consulting Services
- Urban-Econ Developmental Economists
- Schoeman & Vennote



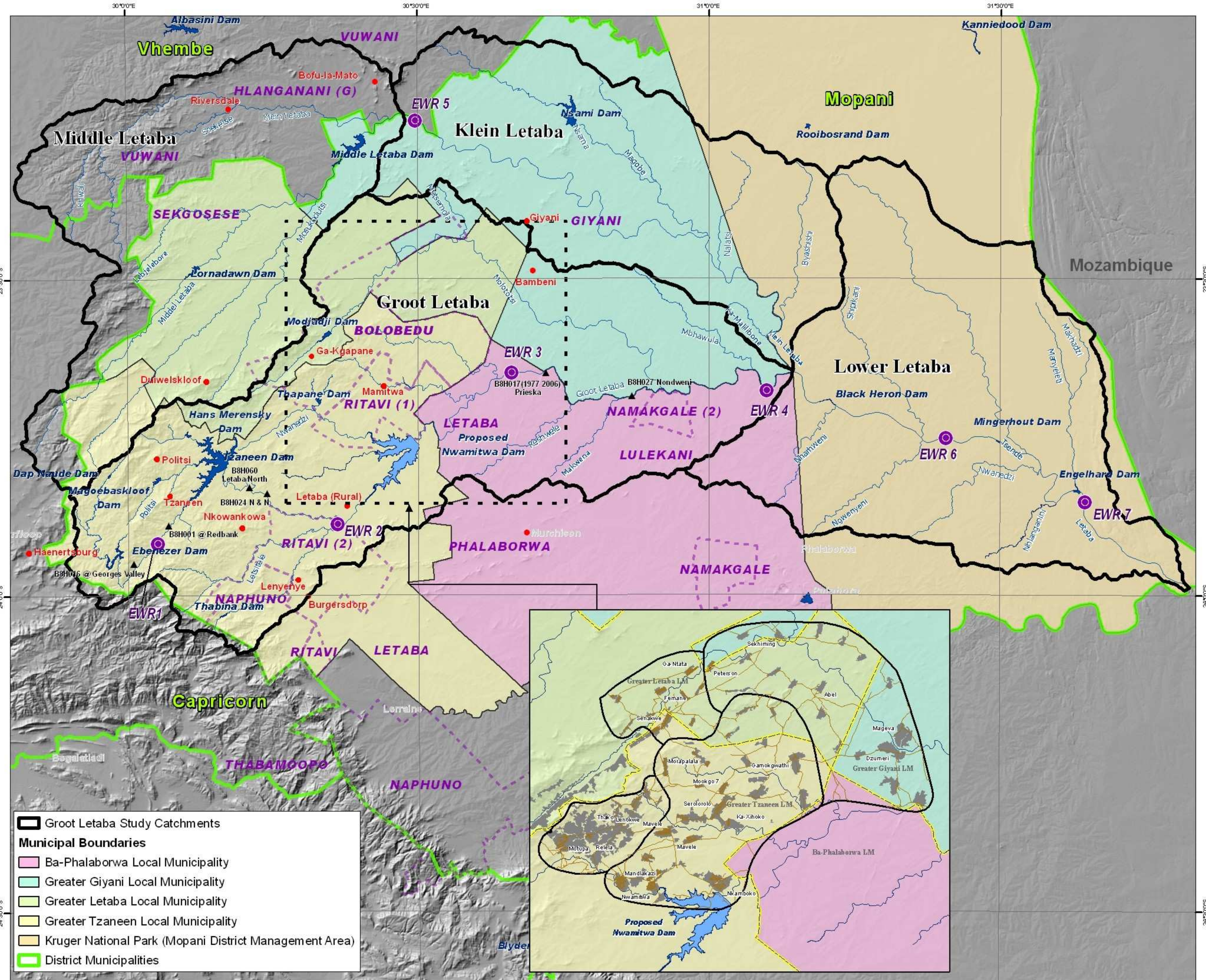
TITLES :

GROOT LETABA RIVER WATER DEVELOPMENT PROJECT

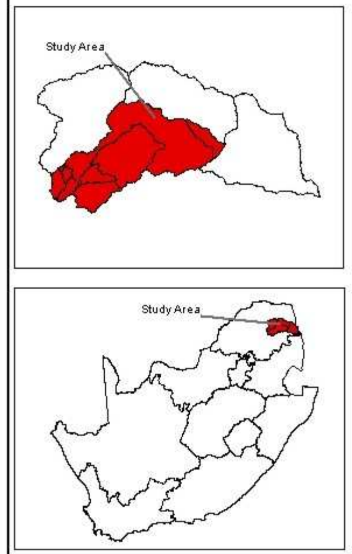
PROJECT AREA

FIGURE NO. :

1.1



OVERVIEW MAPS :



LEGEND

- Towns
- Weirs
- Ecological Water Requirements
- Dams
- Rivers
- Magisterial Districts

PATH: s\projects\H401775\mxd\WaterRes_Ana\fig12_wider.mxd

SCALE: 0 5 10 15 20 25 km — 1:610,000

PROJECTION INFORMATION:

COORDINATE SYSTEM :	Transverse Mercator
PROJECTION NAME :	TM31
DATUM :	D_WGS_1984
SPHEROID :	WGS_1984
CENTRAL MERIDIAN :	31

CONSULTANT :

aurecon

water affairs
Department: Water Affairs
REPUBLIC OF SOUTH AFRICA

TITLES :

GROOT LETABA RIVER WATER DEVELOPMENT PROJECT

WIDER PROJECT AREA

FIGURE NO. :

1.2

The Bridging Study comprises a number of modules, namely: an Environmental Management Module (EMM), a Public Involvement Programme (PIP) and a Technical Study Module (TSM). This Report focuses on a portion of Task 2 of the TSM.

The tasks comprising the TSM are summarised below:

TASK 1: WATER REQUIREMENTS

The objective of this Task is to:

- Review the current estimates of future water requirements in all user sectors;
- Establish present levels of water use in these sectors; and
- Assess the availability of groundwater in the project area.

TASK 2: WATER RESOURCE EVALUATION

The objective of this Task is to:

- Assess the present availability of surface water from the Groot Letaba River System; and
- Assess the increase in yield of the proposed new developments, taking account of the flow regime required to maintain the ecological Reserve.

TASK 3: PRELIMINARY DESIGN OF NWAMITWA DAM

The objective of this Task is to:

- Determine the most suited dam type and position for the proposed Nwamitwa Dam;
- Optimise the proposed development proposal; and
- Provide an updated estimate of the costs of implementing Nwamitwa Dam.

TASK 4: RAISING OF TZANEEN DAM

The objective of this Task is to:

- Determine the benefits from raising Tzaneen Dam, in terms of water availability and security of supply;
- Determine the optimum method of raising Tzaneen Dam;
- Optimise the proposed development proposal; and
- Provide an updated estimate of the costs of raising Tzaneen Dam.

TASK 5: BULK WATER DISTRIBUTION INFRASTRUCTURE

The objective of this Task is to:

- Assess infrastructure currently available to make bulk water supplies available to the rural areas;
- Undertake conceptual planning for the areas to be supplied from Nwamitwa Dam; and
- Undertake a preliminary design and cost estimate for the proposed new bulk water distribution infrastructure.

TASK 6: IMPLEMENTING PROGRAMME

The objective of this Task is to determine a realistic programme for the implementation of the proposed developments.

TASK 7: WATER QUALITY

The objective of this task is to undertake an in-lake water quality analysis of the proposed Nwamitwa Dam, to inform the design of the outlet structure of the dam.

1.3 SCOPE OF THIS REPORT

This report describes a portion of Task 2: Water Resource Evaluation, namely the Water Resource Analysis. The remainder of Task 2 is reported on in the report entitled *Review of Water Requirements* (DWA, 2010a).

The objective of the Water Resource Evaluation Task was to:

- Assess the present availability of surface water from the Groot Letaba River system; and
- Assess the increase in yield of the proposed new developments, taking account of the flow regime required to maintain the ecological Reserve.

The first objective is reported on in the study report entitled *Hydrology* (DWA, 2010b), and the second objective is reported on in this report.

The bulk of the work undertaken for and reported on in this report is contained in **Section 2**. This section describes the complete Water Resources Yield Model (WRYM) network which was configured for the Groot Letaba River System and contains most of the results of the WRYM analysis. The following aspects are reported on:

- The approach to the system modelling (**Section 2.3**);
- The historic firm yield (HFY) of the proposed Nwamitwa Dam (**Section 2.4**);
- Compliance with the Ecological Water Requirement (**Section 2.6**);
- Results from the Historical Analysis undertaken in the Feasibility Study (**Sections 2.2** and **2.7**);
- Water supply from Tzaneen Dam (**Section 2.8**);
- Long-term stochastic yield analysis (**Section 2.9**); and
- Filling times of Nwamitwa Dam (**Section 2.10**).

Section 3 contains a description of the impacts of future developments on Massingir Dam. Recommendations regarding operating rules for the proposed Nwamitwa Dam/ Tzaneen Dam system are discussed in **Section 4**. **Section 5** reports briefly on the potential increase in yield that would be obtained from the raising of Dap Naude Dam and Ebenezer Dam.

Conclusions are given in **Section 6** and Recommendations in **Section 7**. **Section 8** contains the references.

2. WATER RESOURCE ANALYSIS

2.1 INTRODUCTION

This section of the report primarily covers the determination of the HFY and long-term stochastic yield characteristics for three different dam capacities for the proposed Nwamitwa Dam, with and without a raised Tzaneen Dam, and with and without environmental water requirements (EWR). A system diagram showing the layout used for the yield analysis is included as **Appendix A** of this report.

The analysis details all the variables which could influence the yield of the proposed Nwamitwa Dam (e.g. implementation of the environmental water requirements and the impact of "system losses"). A comparison is also made between the water resources analysis results of the 1995 Feasibility Study and this Bridging Study.

2.2 RESULTS OF THE 1995 FEASIBILITY STUDY

At the onset of the Bridging Study there appeared to be confusion regarding the yield of the proposed Nwamitwa Dam, based on the Feasibility Study undertaken in 1995.

The following excerpts regarding the calculation of historic firm system yields were taken from Sections 6.6.2 and 6.6.4 of the 1995 Feasibility Study Report entitled *The Groot Letaba Water Resource Development: Main Feasibility Report* (DWAF, 1998a).

"The approach adopted for this evaluation was to start with the most upstream dam in the system, and using constant present day conditions, to determine the yield that could be obtained from the dam, using the historic inflows, without once failing. Using the spills from this dam under the simulated conditions and once again keeping everything else constant at 1995 levels, the firm yield for the net dam in the system was calculated. In this way the whole system was evaluated, including proposed new dams. The reason for this evaluation was to test the system analysis setup and also to get a first order estimate of the remaining development potential.

*Results are given in **Table 2.1** below which also shows the 1995 demands on each dam. It must be noted that water supplies for irrigation are not intended to be at a firm level of assurance. This gives a clear indication that present water needs far exceed the firm yield and water supplies in the region therefore have a very low level of assurance.*

It should be noted that the estimates of firm yield at Nwamitwa are based on no dam at Letsitele and for the present capacity of Tzaneen Dam. The increased system yield from the two new dams together is therefore not the sum of the increases. If Letsitele is built, it will significantly reduce the yield at the Nwamitwa.

Table 2.1 Historic Firm Yield of Existing and Proposed New Dams (Mm^3/a)

Dam	Capacity	Inflow	Firm Yield	Demand (1995)
Dap Naude	1.90	11.2	3.20	5.62
Ebenezer	70.10	34.4	23.90	26.41
Magoebaskloof	4.90	29.9	8.80	12.28
Hans Merensky	1.30	23.7	2.80	3.09
Tzaneen	157.00	112.4	59.80	102.20 *
Thabina	2.80	5.54	2.86	3.28
Modjadji **	8.16	8.4	4.47	0.00
Sub-total			**105.83**	**152.88**
Tzaneen raised	203.00	112.4	64.20	
Letsitele	14.47	27.8	12.12	
	27.80	27.8	17.01	
Nwamitwa	35.90	137.0	23.80	
	58.70	137.0	29.90	
	132.80	137.0	46.20	

* Includes releases for Kruger National Park (KNP) and irrigation – some of which can be supplied from run-of-river

** This dam was only completed in 1997. The 1995 demand of 2.4 Mm^3/a in the area was supplied from groundwater.

Water Availability from Development Options

After establishing the baseline in the previous section, the eight development options consisting of various combinations of storage capacity at the proposed Letsitele Valley and/or Nwamitwa Dam sites were analysed. The operating rules for irrigation releases as determined for Tzaneen Dam were also applied to irrigation releases from the proposed Letsitele and/or Nwamitwa Dams. Drought instream flow requirements (IFR) were imposed on the system. These analyses were only done for the 2020 time horizon; water availability was interpolated for intermediate dates. Results are summarised in ***Table 2.2****, which indicates that the water supply situation can be improved significantly by the introduction of additional storage. Note that water availability given in* ***Table 2.2*** *is the aggregate for the whole catchment.*

Table 2.2 Summary of System Yield (Mm³/a) for Eight Development Options (2020 Conditions)

Option	Domestic Supply	Irrigation Supply	Total Supply
Baseline	72.77	106.22	178.99
1	74.73	127.62	202.35
2	74.64	127.62	202.26
3	74.64	125.44	200.08
4	74.48	126.48	200.93
5	74.48	125.28	199.76
6	74.07	122.89	196.96
7	73.94	120.27	194.21
8	74.41	127.27	201.68
Tzaneen Raising	73.12	106.89	180.01

From the above, it is clear that the maximum increase in system yield of Option 8 of about 22 Mm³/a with regard to the "baseline" scenario is a lot less that the sum of the estimated firm yields from new storage units".

Option 8 in the **Table 2.2** above (Table 6.4 from Section 6.6.4 of the Feasibility Study) compares with the option of implementing Nwamitwa Dam in the Bridging Study making EWR releases close to the current day situation. The actual average supply of the proposed Nwamitwa Dam based on the 1995 Feasibility Study is therefore in the region of 22 Mm³/a (i.e. 201.68 minus 178.99). According to the 1995 Feasibility Study, if one assumed that the historic firm yield was abstracted from all the dams upstream of the proposed Nwamitwa Dam, and ignored the current use of the water from the Letsitele River by the irrigators along the Groot Letaba River, then the historic firm yield of Nwamitwa Dam would be 45 Mm³/a. However, operating the system in a manner consistent with that used in the Bridging Study would provide a yield of only 22 Mm³/a or less if the EWR were more stringent than a drought EWR. A detailed comparision of the results from the 1995 Feasibility Study and the results of the 2007 Bridging Study are given in **Section 2.7** of this report.

2.3 APPROACH TO SYSTEM MODELLING

2.3.1 Current Operation of the Groot Letaba System

Most of the irrigators are dependent on water supply from the Tzaneen Dam and if the storage in the dam is relatively low, then restrictions are imposed. This is a frequent occurrence and the irrigators have adapted to minimise the impact of these restrictions by using as much water as possible from the relatively unregulated tributaries downstream of Tzaneen Dam.

During summer, when there is a chance of freshets from these tributaries, the weirs at the Junction and at Nwanedzi in the Groot Letaba River, are drawn down as much as possible to intercept runoff. (The capacity of the Junction and Nwandezi weirs given in the Basin Study are 0.8 and 3.1 Mm^3 respectively, but the actual live storage that can be used to manage the system was not available at the time of this study and must still be determined). Many of the pumps at these weirs are now submersibles suspended from floats and can move up and down with changes in the water level.

The other weirs such as Jasi are not drawn down to the same extent. This means that shortfalls in supply further down the system can be met by releases from Jasi Weir rather than from Tzaneen Dam, which is further away and would result in a longer response time.

Another adaptation made by the irrigators is to increase the off-channel storage in the form of off-channel farm dams. Currently, the capacity of the off-channel storage alongside the Groot Letaba River from Tzaneen to Prieska is 26 Mm^3. The off-channel storage enables runoff that is intercepted to be stored until later when it is required.

When the system is in surplus and there is sufficient water for the existing consumers and the environment then the irrigators can insert additional pumps into the river to pump the additional water into their off-channel dams. The irrigators falling under the Letaba North Canal in particular would normally not have access to water flowing down the Letsitele River as they are not necessarily directly riparian. However, during periods of surplus they can access the additional runoff from the Letsitele. Usually a surplus condition is caused by strong runoff from the Letsitele and when the in-channel weirs, namely the Junction and Nondweni weirs, are full and more than 2.5 m^3/s is flowing down the Letsitele. Under these conditions, a surplus condition is declared. This surplus is not tallied with the normal abstractions and is not limited by the scheduled abstraction, or reduced by the curtailment in place at the time.

Two large canals, the Letaba North Canal and the N&N canal, with abstraction capacities of 2.6 and 1.6 m^3/s respectively, can also help to intercept as much water as can be stored in the off-channel dams. At present, the management of the canals is difficult as the inlet gates are locked in a certain position and it takes time for the bailiff to reach the canals and increase the abstraction capacity during surplus periods. The runoff at the inlets to these canals is also less than lower down as their off-takes are upstream of the Letsitele confluence. The capacity of the N&N canal may be reduced by siltation as the canal is fairly flat.

The significance of this efficient operation of the Letaba System is that there is less surplus to contribute to the yield of Nwamitwa Dam.

The Groot Letaba Water Users Association (GLWUA) manages the releases from Tzaneen Dam very carefully. Agricultural releases are only made from Tzaneen Dam to supplement the flow from the Letsitele River into the Groot Letaba River when required by the irrigators.

2.3.2 WRYM Diversions

The abstractions by the Letaba North, N&N and the pump irrigators from the Groot Letaba River were initially modelled on a daily basis to determine the efficiency with which they could abstract water from the Groot Letaba River. The initial analysis assumed that the abstraction capacities of these users were respectively 2.6, 1.6, and 2.5 m^3/s, and the live storage in the Junction and Prieska Weirs, which could capture the freshets, was ignored because detailed data was not available in time for the analysis. The daily streamflows were aggregated into monthly streamflows and a relationship between the monthly inflow and the monthly abstracted flow was determined for the combined canals and the pump irrigators. The water that could be abstracted by these schemes was combined with the water released from the Tzaneen Dam and distributed to the users along the Groot Letaba. The water that could not be abstracted was routed down to below Prieska where it was inaccessible to the consumers along the Groot Letaba. The magnitude of the freshets downstream of these abstractions were compared with the actual observed flows and it was found that the simulated freshet volumes were too low and additional freshets were introduced into the model (see **Section 2.3.3** below). Subsequently, discussions with the GLWUA indicated that the effective capacity of the canals might be less, but seemed to confirm that the abstraction of the pumps was about 2.5 m^3/s. The diversion functions were not adjusted again because this might have meant re-adjusting the freshet inflows. However, as demonstrated in **Figure 2.1** the missing freshets were not caused by over-abstraction, but were evident during the calibration of the Pre-feasibility Study.

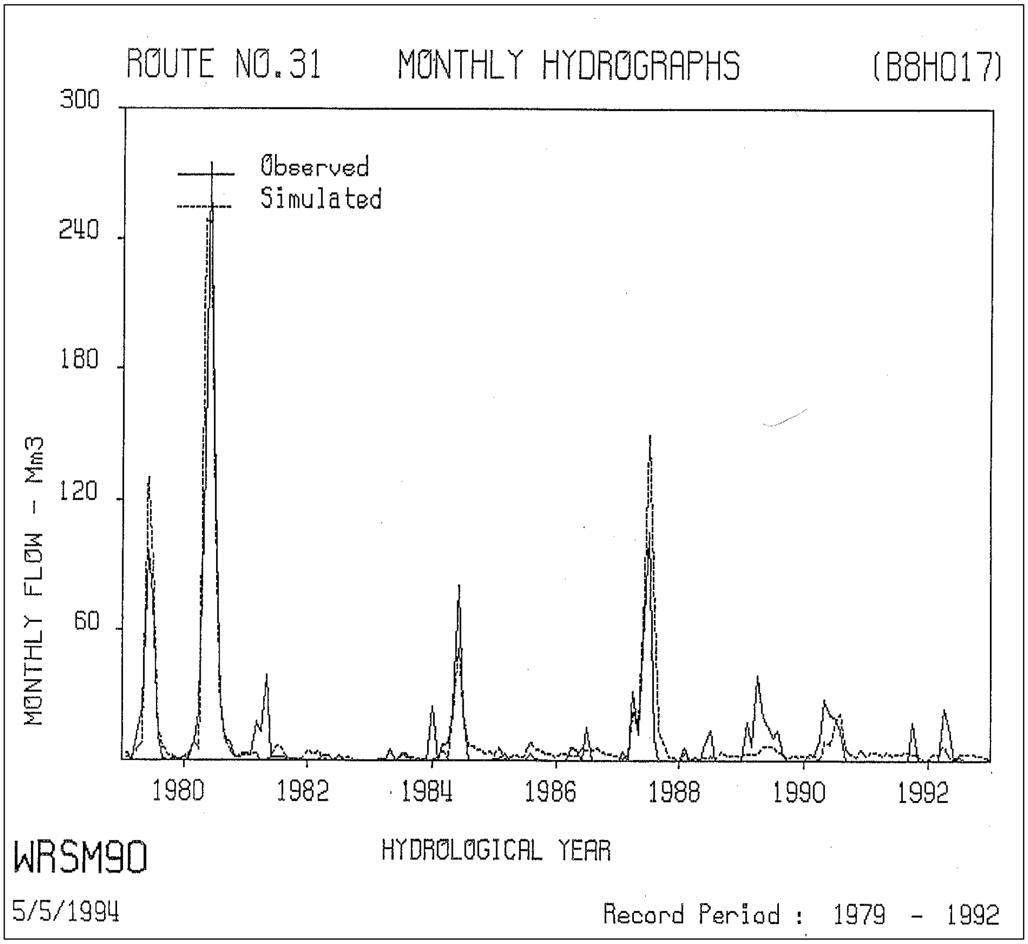


Figure 2.1 Comparison of observed streamflow at Prieska with streamflows generated during calibration (Pre-feasibility Study)

2.3.3 Initial Runs

Before the Water Resource Yield Model (WRYM) was used for yield analysis, it was set up to approximate present day conditions.

The simulated present day flows were compared with the gauged flows at selected points to see if the generated streamflows were reasonable. The streamflows generated at gauge B8H010 on the Letsitele were slightly conservative (see **Figure 2.2**). The Letsitele streamflows are particularly important as they could be regulated by the Nwamitwa Dam and would contribute to that dam's yield.

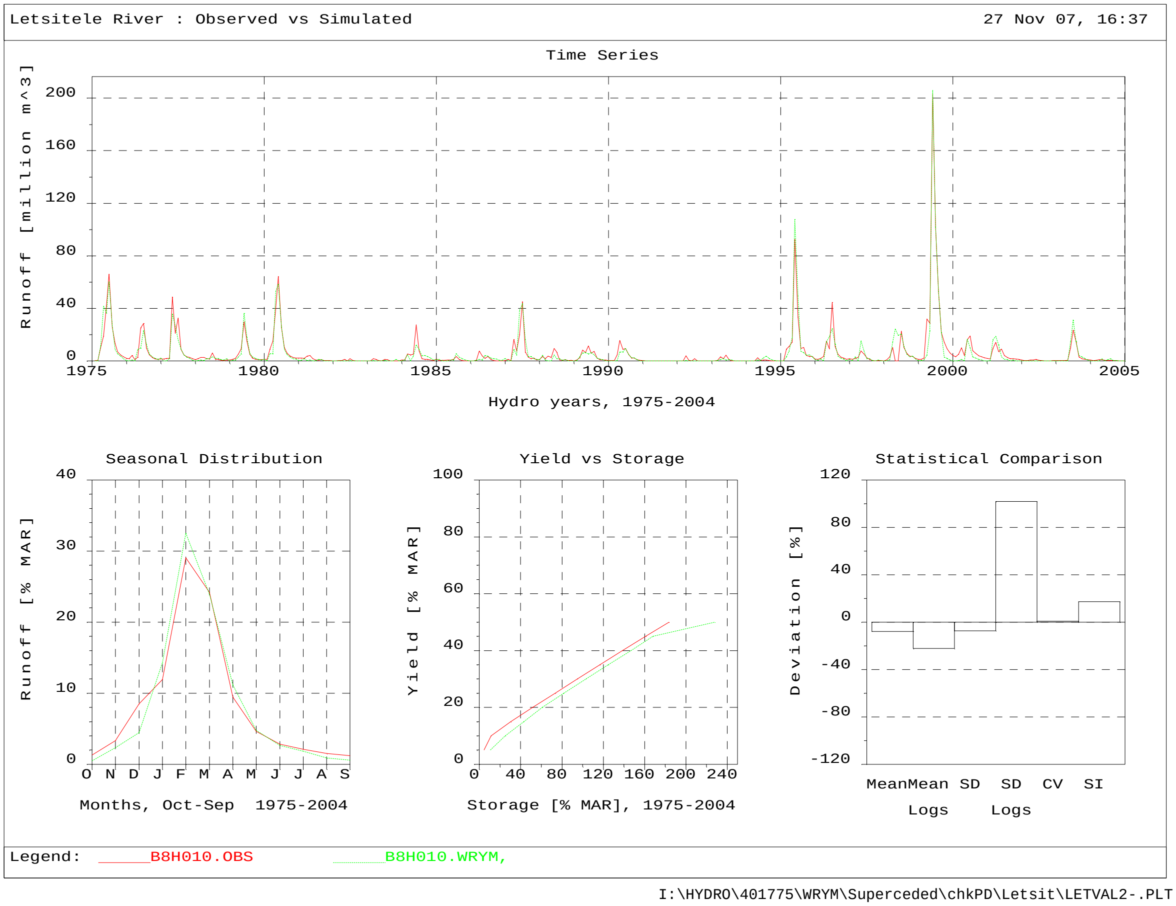


Figure 2.2 Comparison of observed streamflow from the Letsitele (B8H010) with flows simulated in the Water Resource Yield Model

It was also noticed that the observed freshets were missing in the simulated streamflows lower down the Groot Letaba River, a feature that was evident in the original calibration (see **Figure 2.1**). These freshets would contribute to the yield of Nwamitwa Dam as they would exceed the abstraction capacity of the irrigators, and because they would help recharge the environment. A re-examination of the Pitman Parameters indicated that modifying these parameters would improve the calibration and the observed record was reasonable. The observed records were used to estimate the magnitude of the freshets which would be about 8 Mm^3/a upstream of Nwamitwa, 5 Mm^3/a between Nwamitwa and Prieska and about 21 Mm^3/a between Prieska and Letaba Ranch. These freshets were added to the WRYM simulated flows in order to more closely match the observed flows.

At present, these freshets are not based on a thorough recalibration of the catchments, but on comparing the observed and simulated records at Prieska and Letaba Ranch for dry periods when no spill was likely from Tzaneen Dam (1982-1987, 1991-1995, and 2002-2004), and determining the average annual contribution over each of the periods. These freshets were all assumed to contribute to the highflow EWR downstream of Nwamitwa and the streamflow sequence of the required high flow streamflows was factored until it matched the additional contribution expected from the freshets. The factored high flow sequence was treated as an additional inflow into the system.

2.3.4 Potential Problems

The yield from the proposed Nwamitwa Dam is relatively small because the dam is downstream of a large existing dam and a large proportion of the streamflow from the remaining tributaries is already being used, due to the efficient operation of the GLWUA. The factors which could significantly affect the yield of the dam are listed below:

- The efficiency with which the irrigators upstream of the dam can abstract water using their canals and pumps;
- The amount of water that must be released from the dam for ecological requirements and the extent to which accruals downstream of the dam contribute toward this requirement;
- The river channel losses acting on the release as it enters the Kruger National Park (KNP) and how much extra must be released to counter this loss;
- The current hydrology does not replicate the freshets in the catchments downstream of the Letsitele River; and
- Revised demand and loss data have been obtained and should be used when the rainfall-runoff model for the catchment is re-calibrated to ensure that the runoff generated matches the historical observed values.

The approach adopted was to try to test the sensitivity of the yield to these influences, to derive the range of yields that can be expected.

The impacts of varying the following were discussed in the analysis:

- Ecological releases;
- Streamflow losses;
- Magnitude of additional freshets; and
- Abstraction efficiency.

Tzaneen Dam is currently operated above its firm yield, which means it is drawn down more than if it were operated at its firm yield. To replicate this behaviour an operating rule was included to start applying curtailments in April or September if the storage dropped too low. The monthly water supply to the three reaches of the Groot Letaba

River downstream of Tzaneen Dam was saved as file a10h.inf. This meant that the same demand sequences could be re-applied to the system when Nwamitwa Dam is in place to ensure that the reliability of supply to the existing irrigators remained identical after the introduction of Nwamitwa Dam.

2.4 HISTORIC FIRM YIELD OF THE PROPOSED NWAMITWA DAM

The historical firm yield of Nwamitwa Dam was determined for a considerable number of scenarios, which were configured in the WRYM. The results of these scenarios are reported in **Table 2.3** and discussed below. For ease of reference, the columns in the table have been labelled from "a" through to "x", and the rows have been numbered from "1" through to "65".

The results of 14 of the scenarios listed in **Table 2.3** (identified by means of an asterisk) have also been summarised in **Table 2.5** of **Section 2.4.7** of this report.

The scenario whose demand sequences were used to fix the existing irrigation supply from Tzaneen Dam when determining the yield from Nwamitwa Dam, as discussed in **Section 2.3**, is listed in column "j", "Reference scenario for fixing GLWUA supply. (providing a10h.inf and representing demand CH571 of existing system". This option does not apply to scenarios modelling the existing infrastructure and these scenarios entries are n.a. (not applicable).

The first set of 22 scenarios whose results are presented in **Table 2.3** (row no's 1 to 22) are present day scenarios (i.e. without the proposed Nwamitwa Dam in place). The remaining 43 scenarios (row no's 23 to 65) are potential future scenarios with the proposed Nwamitwa Dam in place, at various FSLs, and with a range of other factors being varied. These are explained in the following section.

2.4.1 Naming Convention of Scenarios Analysed

The naming convention used to describe all the scenarios which were analysed is described below:

Prefixes

P - Present day scenario (i.e. no Nwamitwa Dam). The "P" is omitted for scenarios with Nwamitwa Dam. To help keep the number of characters to 5 or less, no symbol is used for the Nwamitwa case – all non-"P" scenarios are understood to model Nwamitwa.

N	–	Release of 14.7 Mm^3/a from Nondweni Weir
– (minus sign)	–	No freshets included in analysis
a	–	Nwamitwa FSL 473.5 (capacity of 67 Mm^3)
b	–	Nwamitwa FSL 477.5 (capacity of 138 Mm^3)
c	–	Nwamitwa FSL 479.5 (capacity of 187 Mm^3)
d	–	Nwamitwa FSL 481.5 (capacity of 238 Mm^3)

(Prefixes a, b, c and d are only used when a comparative analysis was undertaken).

<u>Suffixes</u>

O	–	No losses applied downstream of Groot Letaba Ranch
H	–	50% of "system losses" applied downstream of Groot Letaba Ranch
F	–	Full "system losses" applied downstream of Groot Letaba Ranch
7	–	Optimised scenario 7 from Reserve Determination Study (no flood releases, only low flows) enforced at site.
t	–	Total preliminary Reserve (i.e. low flows + floods) enforced at site
R	–	Rooipoort Dam included
S	–	Reduced abstraction capacity of canals
t7_ or tt7 or t77	–	Each of the three digits represents the environmental water requirement enforced at different sites. Digit 1 = EWR at Site 3, Digit 2 = EWR at Site 4, Digit 3 = EWR at Sites 6 and 7.

Examples of the naming convention are given below:

Ptt_H	–	This is a present day condition, where the total preliminary reserve is met at EWR Site 3 and EWR Site 4 but not at EWR Sites 6 and 7. The "system losses" were factored by 50%.

t770 – Nwamitwa Dam constructed (i.e. not present day). The total preliminary reserve is met at EWR Site 3 and optimised Scenario 7 (from Preliminary Reserve determination report) is applied to EWR Sites 4 and Sites 6 and 7. No "system losses" are assumed.

2.4.2 Impact of Ecological Releases and Streamflow Losses

(a) Impact of Ecological Releases

The supply from the existing Tzaneen Dam is highly dependent on the EWR that are imposed at the downstream EWR sites, and also on how much river channel losses reduce the delivery of water to the EWR sites. The effect of these two factors on the availability of water for agricultural use is shown in **Figure 2.3**, which is discussed later in this section.

Another issue is whether the proposed EWR releases are first supplied by the existing users prior to the construction of Nwamitwa or not. In one case, the apparent benefit of constructing Nwamitwa increased by about 9 Mm^3/a (compare t77iH (row no. 59 in **Table 2.3** – HFY of 23 Mm^3/a) relative to t77H (row no. 36 in **Table 2.3** – HFY of 14 Mm^3/a)). In this scenario, the supply to existing users was fixed using scenario pt77H (row no. 15 in **Table 2.3**) which explicitly supplied the full reserve requirement at Prieska by making releases from Tzaneen Dam, if necessary. Usually the present day scenario (PH) was used to fix the supply to existing users which assumed that the Nwamitwa Dam would provide all the additional water required for the EWR. If the EWR requirement for the "Optimised" scenario (P777H - row no. 6 in **Table 2.3**) is supplied from the Tzaneen Dam and not Nwamitwa then the relative benefit of constructing Nwamitwa will increase by about 3 Mm^3/a. For each result, the scenarios used to fix the supply sequence are listed in column l of **Table 2.3**.

The Letaba Catchment Reserve Determination Study (DWAF 2006b) estimated the reduced ecological water requirements would be adequate at EWR Sites 3 to 7 assuming that accruals would provide the remainder of the freshets in their "Scenario 7". (Please refer to the Bridging Study report entitled *Review of Water Requirements* (DWA, 2010a), Section 6, Table 6.1, column f, which describes the requirements of “Scenario 7”). However, this scenario was developed without the impact of Nwamitwa Dam and the compliance with the reserve would still need to be rechecked.

Table 2.3 Selected Yield Scenarios

Row No.	Scenario	Infrastructure: Existing Dams	Infrastructure: Tzaneen Dam FSL (m)	Infrastructure: Nwamitwa FSL (m)	Infrastructure: Current release of 14.7Mm^3/a from Nondweni	Infrastructure: Massingir (raised by 10 m) FSL (m)	Infrastructure: Flag Boshielo (raised 5 m)	Infrastructure: De Hoop FSL (m)	Infrastructure: Rooipoort FSL (m)	Reference scenario for fixing GLWUA supply. (providing a10h.inf & representing demand CH571 of existing system)	Additional freshets	Demand / Supply – Groot Letaba – EWRs @ Sites 7=Optimised scenario from Reserve Determination Study $_t$ = total (lowflows + floods): 3	4	5	6	7	Losses (factor): Factor applied to losses betw Letaba Ranch and the Olifants(0=0,H=halved,F=full)	Change in avg agric supply + losses from Gt Letaba (excl tributaries) between Tzaneen to Letaba Ranch (Mm^3/a)	Nwamitwa HFY (Mm^3/a)	Olifants: Olifants EWRs (Mm^3/a)	Flag Boshielo (Mm^3/a)	De Hoop (Mm^3/a)	Rooipoort (Mm^3/a)	Massingir HFY within 0.5%) (Mm^3/a)
																		ch 571	ch 580		ch711	ch704	ch705	ch136
	Col a	b	c	D	e	f	g	h	I	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x
1	P0	Y	723.9	n.a.	Y	125			n.a.	n.a	Y	-	-	-	-	-	0	0	n/a	Y	80	80	0	See **Table 2.5** for selected scenarios
2 *	PH	Y	723.9	n.a.	Y	125			n.a.	n.a	Y	-	-	-	-	-	0.5	0	n/a	Y	80	80	0	
3	PF	Y	723.9	n.a.	Y	125			n.a.	n.a	Y	-	-	-	-	-	1	0	n/a	Y	80	80	0	
4	PHS (1)	Y	723.9	n.a.	Y	125	822	915	n.a.	n.a.	Y	-	-	-	-	-	0.5	-1	n/a	Y	80	80	0	
5	P7770	Y	723.9	n.a.	-	125			n.a.	n.a	Y	7	7	7	7	7	0	-1	n/a	Y	80	80	0	
6	P777H	Y	723.9	n.a.	-	125			n.a.	n.a	Y	7	7	7	7	7	0.5	-3	n/a	Y	80	80	0	
7	P777F	Y	723.9	n.a.	-	125			n.a.	n.a	Y	7	7	7	7	7	1	-5	n/a	Y	80	80	0	
8	Pt7_0	Y	723.9	n.a.	-	125			n.a.	n.a	y	C/D_t	7	7	-	-	0	-6	n/a	Y	80	80	0	
9	Pt7_H	Y	723.9	n.a.	-	125			n.a.	n.a	y	C/D_t	7	7	-	-	0.5	-7	n/a	Y	80	80	0	
10	Pt7_F	Y	723.9	n.a.	-	125			n.a.	n.a	y	C/D_t	7	7	-	-	1	-7	n/a	Y	80	80	0	
11	Ptt_0	Y	723.9	n.a.	-	125			n.a.	n.a	y	C/D_t	C/D_t	7	-	-	0	-3	n/a	Y	80	80	0	
12	Ptt_H	Y	723.9	n.a.	-	125			n.a.	n.a	y	C/D_t	C/D_t	7	-	-	0.5	-4	n/a	Y	80	80	0	
13	Ptt_F	Y	723.9	n.a.	-	125			n.a.	n.a	y	C/D_t	C/D_t	7	-	-	1	-4	n/a	Y	80	80	0	
14	Pt770	Y	723.9	n.a.	-	125			n.a.	n.a	y	C/D_t	7	7	7	7	0	-6	n/a	Y	80	80	0	
15 *	Pt77H	Y	723.9	n.a.	-	125			n.a.	n.a	y	C/D_t	7	7	7	7	0.5	-7	n/a	Y	80	80	0	
16	Pt77F	Y	723.9	n.a.	-				n.a.	n.a	y	C/D_t	7	7	7	7	1	-10	n/a	Y	80	80	0	
17	Ptt70	Y	723.9	n.a.	-				n.a.	n.a	y	C/D_t	C/D_t	7	7	7	0	-4	n/a	Y	80	80	0	
18	Ptt7H	Y	723.9	n.a.	-				n.a.	n.a	y	C/D_t	C/D_t	7	7	7	0.5	-6	n/a	Y	80	80	0	

Row No.	Scenario	Infrastructure: Existing Dams	Infrastructure: Tzaneen Dam FSL (m)	Infrastructure: Nwamitwa FSL (m)	Infrastructure: Current release of 14.7Mm^3/a from Nondweni	Infrastructure: Massingir (raised by 10 m) FSL (m)	Infrastructure: Flag Boshielo (raised 5 m)	Infrastructure: De Hoop FSL (m)	Infrastructure: Rooipoort FSL (m)	Reference scenario for fixing GLWUA supply. (providing a10h.inf & representing demand CH571 of existing system)	Additional freshets	Demand / Supply – Groot Letaba – EWRs @ Sites 7=Optimised scenario from Reserve Determination Study $_t$ = total (lowflows + floods): 3	4	5	6	7	Losses (factor): Factor applied to losses betw Letaba Ranch and the Olifants(0=0,H=halved,F=full)	Change in avg agric supply + losses from Gt Letaba (excl tributaries) between Tzaneen to Letaba Ranch (Mm^3/a)	Nwamitwa HFY (Mm^3/a)	Olifants: Olifants EWRs (Mm^3/a)	Flag Boshielo (Mm^3/a)	De Hoop (Mm^3/a)	Rooipoort (Mm^3/a)	Massingir HFY within 0.5%) (Mm^3/a)
																		ch 571	ch 580		ch711	ch704	ch705	ch136
	Col a	b	c	D	e	f	g	h	I	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x
19	Ptt7F	Y	723.9	n.a.	-				n.a.	n.a	y	C/D$_t$	C/D$_t$	7	7	7	1	-10	n/a	Y	80	80	0	
20	Pttt0	Y	723.9	n.a.	-				n.a.	n.a	y	C/D$_t$	C/D$_t$	C_t	C_t	C_t	0	-5	n/a	Y	80	80	0	
21	PtttH	Y	723.9	n.a.	-				n.a.	n.a	y	C/D$_t$	C/D$_t$	C_t	C_t	C_t	0.5	-8	n/a	Y	80	80	0	
22	PtttF	Y	723.9	n.a.	-				n.a.	n.a	y	C/D$_t$	C/D$_t$	C_t	C_t	C_t	1	-12	n/a	Y	80	80	0	
23	t0	Y	723.9	479.5	-				n.a.	PH	y	C/D$_t$					0	0	27	Y	80	80	0	
24 *	tH	Y	723.9	479.5	-				n.a.	PH	y	C/D$_t$					0.5	0	27	Y	80	80	0	
25	tF	Y	723.9	479.5	-				n.a.	PH	y	C/D$_t$					1	0	27	Y	80	80	0	
26	7770	Y	723.9	479.5	-				n.a.	PH	y	7	7	7	7	7	0	0	26	Y	80	80	0	
27 *	777H	Y	723.9	479.5	-				n.a.	PH	y	7	7	7	7	7	0.5	0	21	Y	80	80	0	
28	777F	Y	723.9	479.5	-				n.a.	PH	y	7	7	7	7	7	1	0	13	Y	80	80	0	
29	t7_0	Y	723.9	479.5	-				n.a.	PH	y	C/D$_t$	7	7			0	0	19	Y	80	80	0	
30	t7_H	Y	723.9	479.5	-				n.a.	PH	y	C/D$_t$	7	7			0.5	0	18	Y	80	80	0	
31	t7_F	Y	723.9	479.5	-				n.a.	PH	y	C/D$_t$	7	7			1	0	17	Y	80	80	0	
32	tt_0	Y	723.9	479.5	-				n.a.	PH	y	C/D$_t$	C/D$_t$	7			0	0	17	Y	80	80	0	
33	tt_H	Y	723.9	479.5	-				n.a.	PH	y	C/D$_t$	C/D$_t$	7			0.5	0	15	Y	80	80	0	
34	tt_F	Y	723.9	479.5	-				n.a.	PH	y	C/D$_t$	C/D$_t$	7			1	0	15	Y	80	80	0	
35	t770	Y	723.9	479.5	-				n.a.	PH	y	C/D$_t$	7	7	7	7	0	0	18	Y	80	80	0	
36	t77H	Y	723.9	479.5	-				n.a.	PH	y	C/D$_t$	7	7	7	7	0.5	0	14	Y	80	80	0	

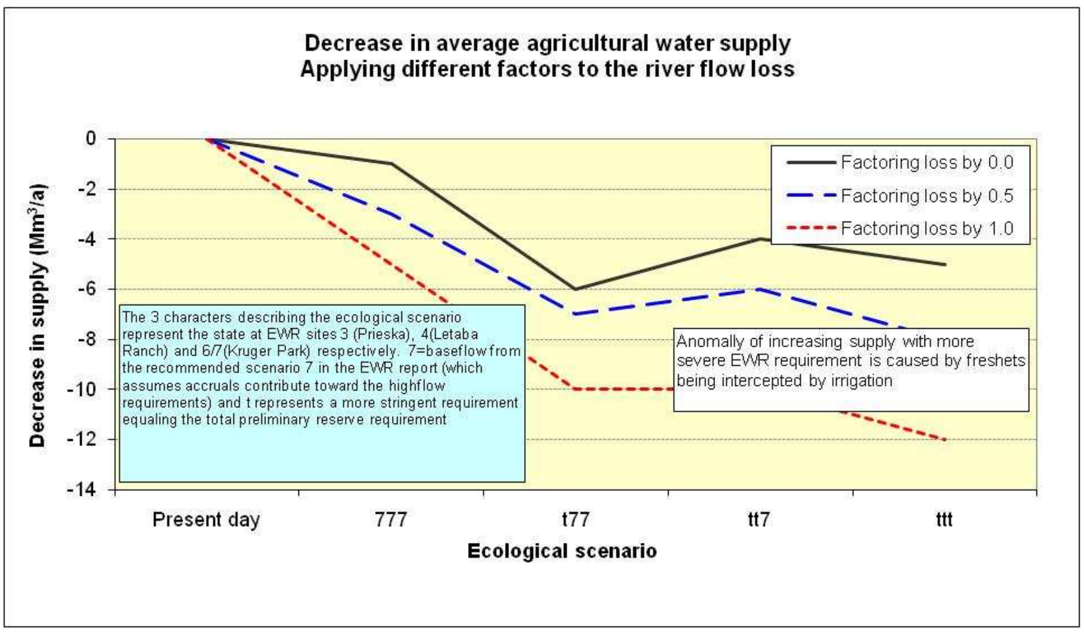
Row No.	Scenario	Infrastructure: Existing Dams	Infrastructure: Tzaneen Dam FSL (m)	Infrastructure: Nwamitwa FSL (m)	Infrastructure: Current release of 14.7Mm³/a from Nondweni	Infrastructure: Massingir (raised by 10 m) FSL (m)	Infrastructure: Flag Boshielo (raised 5 m)	Infrastructure: De Hoop FSL (m)	Infrastructure: Rooipoort FSL (m)	Reference scenario for fixing GLWUA supply. (providing a10h.inf & representing demand CH571 of existing system)	Additional freshets	Demand / Supply – Groot Letaba – EWRs @ Sites (7=Optimised scenario from Reserve Determination Study; $_t$ = total (lowflows + floods)): 3	EWRs @ Sites: 4	EWRs @ Sites: 5	EWRs @ Sites: 6	EWRs @ Sites: 7	Losses (factor): Factor applied to losses betw Letaba Ranch and the Olifants(0=0,H=halved,F=full)	Change in avg agric supply + losses from Gt Letaba (excl tributaries) between Tzaneen to Letaba Ranch (Mm³/a)	Nwamitwa HFY (Mm³/a)	Olifants: Olifants EWRs (Mm³/a)	Olifants: Flag Boshielo (Mm³/a)	Olifants: De Hoop (Mm³/a)	Olifants: Rooipoort (Mm³/a)	Olifants: Massingir HFY within 0.5%) (Mm³/a)
																		ch 571	ch 580		ch711	ch704	ch705	ch136
	Col a	b	c	D	e	f	g	h	I	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x
37	t77F	Y	723.9	479.5	-				n.a.	PH	y	C/D_t	7	7	7	7	1	0	6	Y	80	80	0	
38	at770	Y	723.9	473.5	-				n.a.	PH	y	C/D_t	7	7	7	7	0	0	9	Y	80	80	0	
39	bt770	Y	723.9	477.5	-				n.a.	PH	y	C/D_t	7	7	7	7	0	0	14	Y	80	80	0	
40	ct770	Y	723.9	479.5	-				n.a.	PH	y	C/D_t	7	7	7	7	0	0	18	Y	80	80	0	
41	dt770	Y	723.9	481.5	-				n.a.	PH	y	C/D_t	7	7	7	7	0	0	21	Y	80	80	0	
42 *	at77H	Y	723.9	473.5	-				n.a.	PH	y	C/D_t	7	7	7	7	0.5	0	4	Y	80	80	0	
43 *	bt77H	Y	723.9	477.5	-				n.a.	PH	y	C/D_t	7	7	7	7	0.5	0	9	Y	80	80	0	
44 *	ct77H	Y	723.9	479.5	-				n.a.	PH	y	C/D_t	7	7	7	7	0.5	0	14	Y	80	80	0	
45 *	dt77H	Y	723.9	481.5	-				n.a.	PH	y	C/D_t	7	7	7	7	0.5	0	17	Y	80	80	0	
46	at77F	Y	723.9	473.5	-				n.a.	PH	y	C/D_t	7	7	7	7	1	-0.7	0	Y	80	80	0	
47	bt77F	Y	723.9	477.5	-				n.a.	PH	y	C/D_t	7	7	7	7	1	0	2	Y	80	80	0	
48	ct77F	Y	723.9	479.5	-				n.a.	PH	y	C/D_t	7	7	7	7	1	0	6	Y	80	80	0	
49	dt77F	Y	723.9	481.5	-				n.a.	PH	y	C/D_t	7	7	7	7	1	0	9	Y	80	80	0	
50	tt70	Y	723.9	479.5	-				n.a.	PH	y	C/D_t	C/D_t	7	7	7	0	0	16	Y	80	80	0	
51	tt7H	Y	723.9	479.5	-				n.a.	PH	y	C/D_t	C/D_t	7	7	7	0.5	0	10	Y	80	80	0	
52	tt7F	Y	723.9	479.5	-				n.a.	PH	y	C/D_t	C/D_t	7	7	7	1	0	3	Y	80	80	0	
53	ttt0	Y	723.9	479.5	-				n.a.	PH	y	C/D_t	C/D_t	C_t	C_t	C_t	0	0	13	Y	80	80	0	
54	tttH	Y	723.9	479.5	-				n.a.	PH	y	C/D_t	C/D_t	C_t	C_t	C_t	0.5	0	7	Y	80	80	0	

Row No.	Scenario	Infrastructure								Reference scenario for fixing GLWUA supply. (providing a10h.inf & representing demand CH571 of existing system)	Additional freshets	Demand / Supply												
												Groot Letaba								Olifants				
												EWRs @ Sites 7=Optimised scenario from Reserve Determination Study $_t$ = total (lowflows + floods)					Losses (factor)							
		Existing Dams	Tzaneen Dam FSL (m)	Nwamitwa FSL (m)	Current release of 14.7Mm³/a from Nondweni	Massingir (raised by 10 m) FSL (m)	Flag Boshielo (raised 5 m)	De Hoop FSL (m)	Rooipoort FSL (m)			3	4	5	6	7	Factor applied to losses betw Letaba Ranch and the Olifants(0=0,H=halved,F=full)	Change in avg agric supply + losses from Gt Letaba (excl tributaries) between Tzaneen to Letaba Ranch (Mm³/a)	Nwamitwa HFY (Mm³/a)	Olifants EWRs (Mm³/a)	Flag Boshielo (Mm³/a)	De Hoop (Mm³/a)	Rooipoort (Mm³/a)	Massingir HFY within 0.5%) (Mm³/a)
																		ch 571	ch 580		ch711	ch704	ch705	ch136
	Col a	b	c	D	e	f	g	h	I	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x
55	tttF	Y	723.9	479.5	-				n.a.	PH	y	C/D$_t$	C/D$_t$	C$_t$	C$_t$	C$_t$	1	0	0	Y	80	80	0	
56	t77RH	Y	723.9	479.5	-				733.9	PH	y	C/D$_t$	7	7	7	7	0.5	0	14	Y	80	80	51	
57	t77FH	Y	726.9	479.5	-				n.a.	PH	y	C/D$_t$	7	7	7	7	0.5	0	18	Y	80	80	0	
58	N0	Y	723.9	479.5	Y				n.a.	n.a	y	-	-	-	-	-	0	0	26	Y	80	80	0	
59	t77iH	Y	723.9	479.5	-				n.a.	Pt77H	y	C/D$_t$	7	7	7	7	0.5	-7	23	Y	80	80	0	
60	-t77H	Y	723.9	479.5	-				n.a.	PH	n	C/D$_t$	7	7	7	7	0.5	0	2	Y	80	80	0	
61	-t7_H	Y	723.9	479.5	-				n.a.	PH	n	C/D$_t$	7	7			0.5	0	8	Y	80	80	0	
62	t77HS	Y	723.9	479.5	-				n.a.	PHS	y	C/D$_t$	7	7	7	7	0.5	-1	15	Y	80	80	0	
63	-77_0	Y	723.9	477.3	-				n.a.	PH	n	7	7	7			0	0	14	Y	80	80	0	
64	-tt_0	Y	723.9	477.3	-				n.a.	PH	n	C/D$_t$	C/D$_t$	7			0	-1	0	Y	80	80	0	
65	T77FRH	Y	726.9	479.5	-				733.9	PH	Y	C/D$_t$	7	7	7	7	0.5	0	14	Y	80	80	51	

(1) Reduce Letaba North, N&N and Letsitele pump abstractions to 0.7, 0.31 and 2 m³/s. Two days after Letsitele exceeds 2.5 m³/s, the capacities of these abstractions were increased to 2.6, 0.8, and 3 m³/s.
(2) Impacts on Massingir Dam are shown in **Table 2.5**. An asterisk * indicates those scenarios that also appear in **Table 2.5.**
(3) Gross capacities associated with various dam levels. Tzaneen Dam [RL 723.9 = 158 Mm³; 726.9 = 193 Mm³]. Nwamitwa Dam [RL 473.5 m = 67 Mm³; RL 477.5 m = 138 Mm³; RL 479.5 m = 187 Mm³; RL 481.5m = 238 Mm³]. Massingir Dam [RL 115 m = 1463; RL 125 = 2844]. De Hoop [RL 915 m = 347 Mm³]. Rooipoort [RL 733.9 m = 450 Mm³]. Flag Boschebelo [RL 812 m = 49 Mm³; RL 822 m = 179 Mm³].

As mentioned previously, **Figure 2.3** (below) illustrates the effect of the two main factors influencing the availability of water for agricultural use. The X-axis shows the EWR scenarios becoming more stringent as one move from left to right. Three different curves are plotted, corresponding to three different assumptions made regarding the river channel losses (factors of 0.0, 0.5 and 1.0). The overall trend is that the supply to agriculture decreases as the EWR becomes more strigent. There is an anomaly for the scenario tt7 where the supply to agriculture increases when moving from the t77 to the tt7 scenario. This is erroneous and should be ignored. It is caused by the irrigation using some of the water in the freshets.

In the t77 scenario, the freshets are forced out of the system by forcing flows equal to the sum of the EWR and the freshets out of the system at EWR Site 4. However, this is not possible in the tt7 scenario as the freshets overlap with the highflow component of the EWR at Site 4 and it would be incorrect to force the sum of both out of the system at EWR Site 4.



I:\HYDRO\401775\WRYM\TZ8\Results5.xls sheet "ScenarioGraph"

Figure 2.3 Decrease in average agricultural water supply applying different factors to the river flow

The effect of EWR and river channel losses on the yield of the proposed Nwamita Dam is shown graphically in **Figure 2.4**. This is similar to **Figure 2.3** except that the yield of Nwamitwa Dam is plotted on the Y-axis instead of the water supply to agriculture. The graph illustrates how the HFY of the Nwamitwa Dam is reduced as a result of increasing the stringency of the downstream EWR.

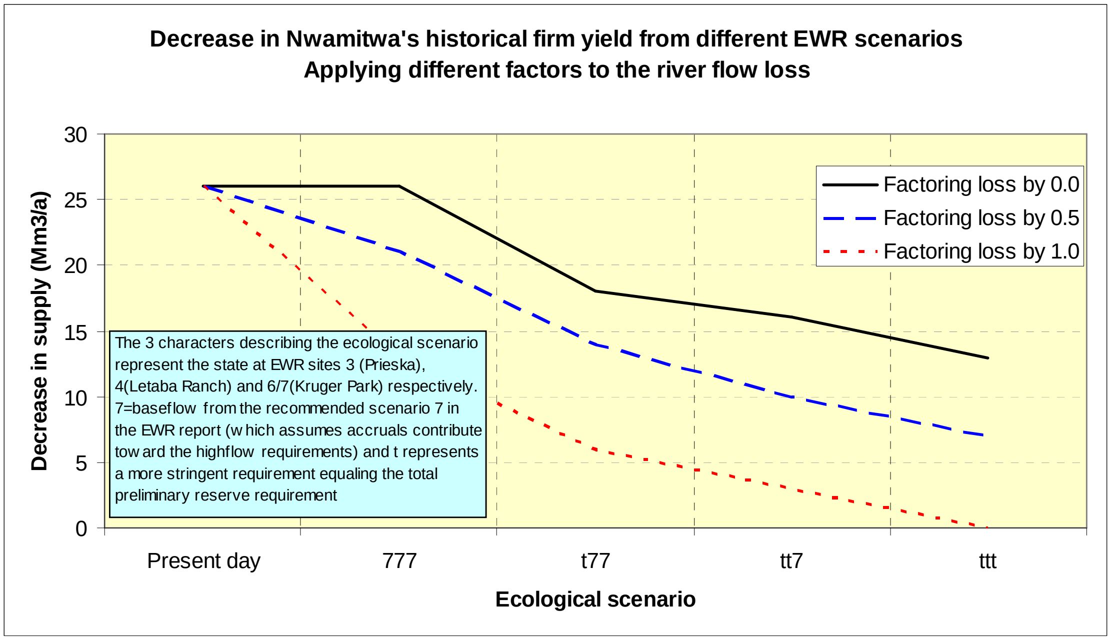


Figure 2.4 Decrease in Nwamitwa's historical firm yield from different EWR

(b) Impact of Streamflow Losses

For Scenario t77, the historical firm yield at Nwamitwa decreases from 18 Mm^3/a (t770 – row no. 35 in **Table 2.3**) to 6 Mm^3/a (t77F – row no. 37 in **Table 2.3**), depending on the factor applied to the losses downstream of the Letaba Ranch.

The potential losses were discussed in the Bridging Study report entitled *Review of Water Requirements* (DWA, 2010a) in **Section 2.4**. In this discussion, the losses between the Letaba Ranch and the Black Heron Weir were determined for dry periods when there were no accruals from the Klein Letaba tributary that enters between the two gauges. However, this approach did not allow one to estimate the losses over the full critical period which would include periods of accruals.

It is possible that the losses over the critical period might be less than the losses determined during the dry period. The losses in the system can vary depending on the antecedent river flow and on the operation of the system. If the antecedent conditions are wet then water may seep out of the sandy river banks into the river channel.

The operation of the system can also affect the losses. During droughts, the GLWUA reduced their losses by releasing water to Nondweni weir as "slug" releases. A "slug" release is a short, high flow release, rather than a constant, low flow release over a longer period. In some cases, it can reduce losses because the volume exceeds the capacity of abstractions from the river channel and it reduces the time that the river surface is subject to evaporation. The name is derived from the shape of the hydrograph, which resembles a slug, with a high blunt nose followed by a tapered tail. If a similar approach could be adopted for the KNP's water requirements, then losses could be reduced.

This would require a review of the historical difficulties experienced in the KNP and the nature of the supplementary flows that would have been required to support the system, considering also the possible impact of Nwamitwa Dam. The KNP has constructed dams, such as the Mingerhout Weir and Charles Engelhard Dam in the Letaba River, to support the ecosystem during droughts, even if no releases are made from the Tzaneen Dam. The locations of these dams are shown on **Figure 1.2**. These dams, or similar additional dams, could be modified and used in a more integrated manner with the releases from the Tzaneen/Nwamitwa Dam to provide both low flows along the Letaba River and a water supply during droughts. The releases would draw down the storage in the dams which could then be topped up by "slug" releases from the Tzaneen/Nwamitwa Dam.

2.4.3 Impact of Additional Freshets

If the additional freshets included in the Bridging Study are omitted, the yield can drop by about 12 Mm^3/a (compare Scenarios t77H (row no. 36 – HFY of 14 Mm^3/a) and –t77H (row no. 60 – HFY of 2 Mm^3/a) in **Table 2.3** "Yield Scenarios".

2.4.4 Impact of Abstraction Efficiency

If the current abstraction efficiency downstream of Tzaneen Dam is reduced then the spillage that will be regulated by the proposed Nwamitwa Dam will increase and the Nwamitwa Dam's yield will also increase. The following inefficiencies were introduced into the daily modelling of the abstractions by the Letaba North Canal, the N&N canal, and the remaining pump irrigators:

- Under normal conditions the abstraction capacities of the Letaba North Canal, the N & N canal, and the remaining pump irrigators are limited to 0.7, 0.31, and 2 m^3/s.

- Two days after Letsitele exceeds 2.5 m^3/s, the capacities of these abstractions were increased to 2.6, 0.8, and 3 m^3/s to simulate periods of "surplus".

The revised operating rule reduced the current consumption slightly, but only increased the yield of Nwamitwa Dam by an estimated 1 Mm^3/a (compare scenarios t77H (row no. 36 of **Table 2.3** – HFY of 14 Mm^3/a) and t77HS (row no. 62 of **Table 2.3** – HFY of 15 Mm^3/a) where the yield increased from 14 to 15 Mm^3/a). Currently about 5.9 Mm^3/a is abstracted during periods of surplus (**Table 2.6**) and this volume is not deducted from the annual allocation. The current modelling of the surplus removes the surplus from the system but does not consider constraints on its storage and usage which might increase the amount of this surplus that is currently spilt and hence potentially captured by the Nwamitwa Dam.

2.4.5 Sedimentation

The effect of sedimentation on the proposed Nwamitwa Dam is reported on in the Bridging Study report entitled *Preliminary Design of Nwamitwa Dam* (DWA, 2010c) and is summarised briefly below.

After 50 years the sediment trapped in the Nwamitwa Dam may reduce the storage capacity by about 17 Mm^3, or about 10% for a dam of 187 Mm^3 (RL479.5 m). The expected impact on the yield will be a reduction of about 1 Mm^3/a off the yield of 14 Mm^3/a which was estimated for the base case scenario in the this study. No deductions were made from the yields for dead storage or sedimentation.

2.4.6 Impact of Sensitive Variables on Historic Firm Yield

It is evident that a number of key factors have a significant impact on the yield of the proposed Nwamitwa Dam and these are listed below:

- The inclusion of the freshets in the analysis.

- The amount of water that is released for the EWR.

- The river channel losses acting on the release as it enters the KNP and how much extra must be released to counter this loss.

- The efficiency with which the irrigators upstream of the dam can abstract water using their canals and pumps.

- The effect of sedimentation of the dam.

The possible impact of these variables on the yield of the proposed Nwamitwa Dam is discussed below, and summarised in **Table 2.4**. .

The base case scenario against which comparisons are made is referred to as t77H (or ct77H) and is summarised in row no. 36, column s (or row 44, column s) of **Table 2.3**. It is also described in detail in **Section 2.4.7.** It is based on the assumption that the total EWR is met at EWR site 3, and the "Scenario 7" EWR is met at EWR sites 4, 6 and 7. The EWR is met from Nwamitwa Dam only. The factor used for losses is 0.5. The yield for this base case scenario is 14 Mm³/a, and appears in the first row of **Table 2.4**.

If the "Scenario 7" EWR is met from Tzaneen Dam instead of Nwamitwa Dam, the yield of Nwamitwa Dam would increase from 14 Mm³/a by an estimated 9 Mm³/a to 23 Mm³/a (Scenario t77iH in row no. 59, column s of **Table 2.3**).

If the full EWR was supplied from Nwamitwa Dam to all three EWR sites downstream (Scenario tttH instead of t77H), the yield would drop to 7 Mm³/a (row no. 54, column s in **Table 2.3**).

Increasing the factor for losses from 0.5 to 1.0 during the low flow period will reduce the yield to 6 Mm³/a (Scenario t77F, row no. 37, column s in **Table 2.3**).

Omitting the freshettes will reduce the yield to 2 Mm³/a (Scenario –t77H (row no. 60 in Table **2.3**).

Table 2.4 Assumptions Affecting the Yieldof the proposed Nwamitwa Dam

Yield of (Mm^3/a) Nwamitwa Dam	Assumption	Yield increase or decrease compared to base case scenario (Mm^3/a)
14	Base case scenario t77H (row no. 36, column s of **Table 2.3)**	n/a
23	In the t77iH scenario (row no. 59 in column s in **Table 2.3**) the yield of Nwamitwa increased by about 9 Mm^3/a with respect to the base case scenario t77H (row no. 36 in **Table 2.3**, HFY of 14 Mm^3/a).	+9
7	Increase EWR at the Letaba Ranch and in the Kruger National Park from "Scenario 7" to the full Preliminary Reserve Requirement (t77H (row no. 36 in **Table 2.3**) *vs* tttH (row no. 54 in **Table 2.3**)).	-7
6	Increase average losses over the critical drawdown period from half to the full observed losses during the low flow period (Scenario t77F (row no. 37, column s in **Table 2.3**) *vs* t77H (row no. 36, column s in **Table 2.3**)).	-8
2	Omit freshets (-t77H (row no. 60 in **Table 2.3**) *vs* t77H (row no. 36 in **Table 2.3**)).	-12
15	Reduce efficiency of abstraction by the GLWUA at the Letaba North and N&N canals and the pump irrigators.	+1
14 to 19.9	Reduce usage of surplus water not included with the allocation.	+0 to +5.9
13	Sedimentation over 50 years.	-1

2.4.7 Summary of Results of Historic Firm Yield Analysis

A summary of the results of the most significant scenarios for which historic firm yield analyses were undertaken is given in **Table 2.5**. This information appears in **Table 2.3** for all 65 scenarios modelled, and the relevant row no. from **Table 2.3** is given in **Table 2.5** for ease of reference.

Table 2.5 Summary of Yields

Description	Column no from Table 2.3	a	d	c	l	r	s	x	New information which does not appear in Table 2.3
	Row no. from Table 2.3	Scenario	Nwamitwa FSL	Tzaneen FSL	Rooipoort FSL	Average Agric Supply + losses to GL Ranch	Nwamitwa HFY	Massingir HFY	Description of Scenario
			m	m	m	Mm^3/a	Mm^3/a	Mm^3/a	
Present Day	2	PH	n/a	723.9	n/a	0	n/a	575	Present Day Condition. Current release of 14.7 Mm^3/a to KNP
	15	Pt77H				-7	n/a	*	Present Day Condition. Full EWR at Site 3 met. Optimised Scenario 7 met downstream of EWR Site 3. 50% "system losses" applied
Nwamitwa FSL of 479.5 masl	24	tH	479.5	723.9	n/a	0	27	*	Present Day Condition with Nwamitwa FSL of 479.5 masl. Full EWR at Site 3 met. No explicit supply to EWR sites downstream of Site 3
	27	777H					21	*	Optimised Scenario 7 with Nwamitwa FSL of 479.5 masl. EWR low flows met. No EWR high flows met
	44	ct77H (1)					14	573	Full EWR met at Site 3. Optimised Scenario 7 met downstream of EWR Site 3. Nwamitwa FSL of 479.5 masl. 50% system losses applied
	60	-t77H					2	*	Same as ct77H, but with no additional freshets included in WRYM
	54	tttH					7	*	Full EWR met at all EWR Sites d/s of Nwamitwa. 50% system losses applied
	55	tttF					0	*	Full EWR met at all EWR Sites d/s of Nwamitwa.100% system losses applied
Yield of Nwamitwa at different FSLs	42	at77H	473.5	723.9	n/a	0	4	574	Full EWR met at Site 3. Optimised Scenario 7 met downstream of EWR Site 3. Nwamitwa FSL of 473.5 masl. 50% system losses applied
	43	bt77H	477.5				9	573	Full EWR met at Site 3. Optimised Scenario 7 met downstream of EWR Site 3. Nwamitwa FSL of 477.5 masl. 50% system losses applied
	44	ct77H (1)	479.5				14	573	Full EWR met at Site 3. Optimised Scenario 7 met downstream of EWR Site 3. Nwamitwa FSL of 479.5 masl. 50% system losses applied
	45	dt77H	481.5				17	*	Full EWR met at Site 3. Optimised Scenario 7 met downstream of EWR Site 3. Nwamitwa FSL of 481.5 masl. 50% system losses applied
	56	t77RH	479.5	723.9	733.9	0	14	*	Same as ct77H, but with proposed Rooipoort Dam included
	57	t77FH		726.9	n/a		18	572	Same as ct77H, but with Tzaneen Dam raised by 3 m. Nwamitwa yield shows incremental yield to system
	65	t77FRH		726.9	733.9		14	500	Same as ct77H, but with a raised Tzaneen Dam and the proposed Rooipoort Dam included

* Value not determined.
(1) Details for scenario ct77H are repeated for ease of reference.

The current historical firm yield of the Nwamitwa Dam of 14 Mm^3/a for scenario ct77H (same as t77H) in

Table 2.5 (also appearing in row no. 44 (same as row 36) of **Table 2.3**) assumes that:

- Nwamitwa Dam is constructed to RL 479.5 m/amsl (187 Mm^3).
- The Preliminary Reserve Requirement is supplied at Site 3 (Prieska) but that the sites lower down must rely on accruals for those EWR exceeding "Scenario 7".
- The supply from Tzaneen remains unchanged.
- The current operating rules at Tzaneen Dam remain unchanged.
- The average losses over the critical drawdown period are half the observed losses during the low flow period.
- About 34 Mm^3/a of freshets are missing from the WRYM simulation and these will contribute about 8 Mm^3/a extra inflow to Nwamitwa and to the environmental high flow requirements downstream of Nwamitwa Dam.
- Polokwane was limited to its allocation from Ebenezer and Dap Naude.
- The full capacity is available for the yield (no deductions for dead storage or sedimentation).

The yield is very dependent on certain assumptions and changing these will have a significant impact on the yield.

Clarity concerning the ecological water requirements and losses downstream of Nwamitwa is required before the benefit of the scheme can be finalised.

If one assumes that additional releases of about 4 Mm^3/a will be required from the Tzaneen Dam to meet its ecological water requirements, then these releases will cause a corresponding increase in the supply from the Nwamitwa Dam, giving a total incremental yield for Nwamitwa Dam of about 18 Mm^3/a.

2.5 WATER BALANCE

A water balance was undertaken for the present day condition, assuming 100% "system losses" (Scenario PF (row no. 3 in **Table 2.3**)). **Table 2.6** summarises the inflows and demands on the present day system which are combined to determine the net outflow from the system. Please also refer to the System Diagram in **Appendix A**, which shows these flows schematically. In addition to the natural inflow, the additional freshets have been included. On each row, the usage by afforestation, irrigation, and urban consumers is deducted from the inflow. If there is a shortfall in supply then the usage may be less than the requirement. The irrigation supply was broken up into three components, namely the Groot Letaba Water User Association (GLWUA), river channel losses, and irrigation from local dams and tributaries remote from the GLWUA scheme.

A portion of the urban supply to Tzaneen from the Tzaneen Dam (10%) was assumed to be returned to the river and added to the inflows. This assumption was not verified against actual recorded return as it would not add to the yield of Nwamitwa Dam. Constant base flows would be used by existing irrigators in this water stressed area. According to Schoeman & Vennote, about 0.47% recycled water or water from municipal sources is used by irrigators. Both the return flow percentage and the percentage used by irrigators could be far higher than reported here. Finally, the net evaporation from the dams was deducted and the annual rate of drawdown in storage (i.e. drawdown divided by analysis time period – column "p") was added to the outflow for each row.

Table 2.6 Inflows and Demands (Mm^3/a) used in the Present Day Analysis of the Letaba Catchment

Reach		Quaternary	Natural inflow (1925-2004)	Additional freshets	Afforestation usage	Irrigation						Urban			Net Rainfall on dams or Evaporation (if negative)	Storage adjustment	Average Net inflow	Auxilliary information		Remarks
						GLWUA		river channel losses (2)		Local										
From	To					Demand	Supply	Demand	Supply	Demand	Supply	Demand	Supply	Return flow				Major Dams (Gross storage)	Farm Dams	
Column a	b	c	D		f	g	h	I	j	k	l	m	n	o	p	q	r	s	t	U
Groot Letaba head-waters (Broederstroom and Helpmekaar)	Ebenezer Dam	B81A	48.79	0.0	3.4							19	15.2		0.1	0.0	22.3	1.9		Urban allocation of Polokwane is only 18.5 Mm^3/a but actual consumption is 23.4 Mm^3/a. Curtailment rule adopted for analysis reduced supply to the urban demand to 15.2 Mm^3/a.
				0.0	7.9					1.1	1.1				0.4	-0.7		70.0	1.7	Tzaneen
Ebenezer	Grysappel		31.32		6.7	10	7.5	3	3.0			2.4	2.1		0.0	0.0	12.0		0.5	
Politsi headwaters	u/s Magoebaskloof	B81B	36.09	0.0	5.2	0.0	0.0	0.0	0.0	12	11.6	2.0	2.0		0.1	0.0	17.4	4.9	0.0	Urban allocation 2,0 to Politsi, Duiwelskloof, GaKgapane. Agricultural allocation 12 Mm^3/a: 4.47 NON-SAPEKO from Magoebaskloof (671hax6670m³/ha/a) 6.67 SAPEKO from Magoebaskloof (1000hax6670m³/ha/a) 0.87 SAPEKO (Debengeni) Although the SAPEKO fields have been abandoned, the SAPEKO demand was still modelled in case the water is granted as part of the land claim by the Magoeba tribe
Ramadiepa headwaters	u/s Hans Merensky		32.44		6.0					3.9	3.9				-0.1	0.0	22.4	1.2	0.4	Local irrigation includes an estimate of 0.8 Mm^3/a supplied d/s of Hans Merensky Dam
Selokwe R and remainder downstream of Grysappel, downstream of Magoebaskloof, downstream of Hans Merensky excluding Politsi Government Water Control Area	Tzaneen Dam		54.58		11.7					9.4	9.4				-1.4	-1.2	33.3	157.6	1.9	Includes 2 Mm^3/a from Selokwe and 0.8 Mm^3/a directly from the dam and 7.4 Mm^3/a additional irrigation area from H Schoeman's survey. According to Schoeman & Associates these demands excluded the Politsi GWCA

Reach		Quaternary	Natural inflow (25-04)	Additional freshets	Afforestation	Irrigation						Urban			Net Rainfall on dams or Evaporation (if negative)	Storage adjustment	Average Net inflow	Auxilliary information		Remarks
						GLWUA		river channel losses		Local										
From	To					Demand	Supply	Demand	Supply	Demand	Supply	Demand	Supply	Return flow				Major Dams (Gross storage)	Farm Dams	
Column a	b	c	d		f	g	h	I	j	k	l	m	n	o	p	q	r	s	t	U
												1.2	1.2							Tzaneen 1.2 Mm^3/a
Tzaneen Dam	u/s Letsitele confluence	B81C	30.9			38.9	26.0	0.0	0.0	6.2	5.8	8.2	8.0		-0.8	0.0	-12.0		6.3	Includes Letaba N and N & N canal offtakes (2.6+1.6 m^3/s capacity). Urban allocation to Nkowakowa is only 3.5 but usage is 8.2 Mm^3/a. Demand of canals is approx 31.9 Mm^3/a
												0.3	0.3							Letsitele urban 0.3 Mm^3/a
											0.8	1.5	1.5			-0.1				Urban supply to Consolidated Murchison and Maranda Mining and Letaba Citrus Processors whose total allocation is 3.3 Mm^3/a
Letsitele confluence	Nwamitwa	B81E (portion)	8.5	8.0				8.0	8.0	3.2		1.9	1.9		-0.8				9.9	No urban allocation for Mamitwa Demand of 1.9 Mm^3/a
							5.9							1.4						Surplus abstraction by GLWUA during floods/surplus
Letsitele/Thabina headwaters	Gt Letaba	B81D	87.0		7.2					16.4	16.0	2.9	2.9		-1.3	0.0	59.6	2.8	7.0	Urban demand assumed equal to yield of Thabina Dam
Nwanedzi + Hlangana headwaters	Gt Letaba	B81E (portion)	32.7		3.2					13.8	11.4				-2.1	-0.1	16.2		11.4	
Nwamitwa	Prieska	B81F (portion)	19.4	5.0		11.6	7.7	6.3	6.3	4.0	0.4				-0.9	-0.1	9.2		9.3	
Potentially for emerging farmers						22.2	15.0										-15.0			Potentially additional 22.2 emerging farmers - modelled at request of GLWUA
Prieska (excluding Molototsi River)	Klein Letaba confluence	B81F (portion) + B81J	17.6	21.2		7.1	4.7	14.8	13.7	0.8	0.2	0.8	0.8		-0.4	0.0	19.0		1.1	0.8 Mm^3/a urban @ Nondweni
Molototsi		B81G + B81H	36.1							2.9[*1]	1.9	5.1	5.1		-0.8	0.0	28.4	8.2	5.2	Urban demand assumed equal to yield of Modjadji Dam
Total on Groot Letaba upstream of Klein Letaba confluence			**435.3**	**34.2**	**51.4**	**89.7**	**66.8**	**32.1**	**31.0**	**73.4**	**62.4**	**44.8**	**40.8**		**-8.1**	**-2.3**	**212.8**	**246.6**	**54.7**	

Reach		Quaternary	Natural inflow (25-04)	Additional freshets	Afforestation	Irrigation						Urban			Net Rainfall on dams or Evaporation (if negative)	Storage adjustment	Average Net inflow	Auxilliary information		Remarks
From	To					GLWUA		river channel losses		Local								Major Dams (Gross storage)	Farm Dams	
						Demand	Supply	Demand	Supply	Demand	Supply	Demand	Supply	Return flow						
Column a	b	c	d		f	g	h	I	j	k	l	m	n	o	p	q	r	s	t	U
B82A		B82A	20.8		0.6					6.0	5.6				-2.3	-0.2	12.4		12.2	
B82B		B82B	16.2		1.5					18.3	9.9				-1.4	-0.4	3.7		30.2	
B82C		B82C	13.1		1.5					12.9	6.1				-0.2	-0.1	5.4		4.5	
B82D		B82D	10.3		1.3							2.3	1.0		-3.7	-2.2	6.6	184.2	0.4	
B82E		B82E	11.6		0.9					0.2	0.2				-0.2	0.0	10.4		1.1	
B82F		B82F	16.3		1.0					0.6	0.3				0.0	0.0	15.0		0.5	
B82G		B82G	17.2		0.0					1.6	0.1				-6.0	-0.1	11.2		6.0	
B82H		B82H	8.3		0.0					20.0	8.6				-1.1	-0.3	-1.2	24.1	1.0	Giyani urban demand lumped with the agricultural demand
B82J		B82J	16.2		0.0			22.5	12.8						-3.7	0.0	-0.2		4.0	
Total on Middle/Klein Letaba			**130.1**		**6.8**			**22.5**	**12.8**	**59.6**	**30.8**	**2.3**	**1.0**		**-18.6**	**-3.1**	**63.2**	**208.3**	**59.8**	
Total from Groot Letaba			**435.3**	**34.2**	**51.4**	**89.7*1**	**66.8**	**32.1*1**	**31.0**	**73.4*2**	**62.4**	**44.8**	**40.8**	**1.4**	**-8.1**	**-2.3**	**212.8**	**246.6**	**54.7**	
Total from Klein Letaba		B83A	**130.1**		**6.8**			**22.5**	**12.8**	**59.6**	**30.8**	**2.3**	**1.0**		**-18.6**	**-3.1**	**63.2**	**208.3**	**59.8**	
B83A		B83B and B83C	15.1		0.0			7.4	4.6						-1.1	0.0	9.4		2.7	
B83B and B83C		B83D and B83E	17.4		0.0										-0.8	0.0	16.6		2.5	
B83D and B83E			15.9		0.0			14.8	11.4						-1.6	0.0	2.9		3.9	River channel losses down to EWR 7
Total Letaba upstream of confluence with Olifants			**613.8**	**34.2**	**58.2**	**89.7**	**66.8**	**76.8**	**59.8**	**133.0**	**93.3**	**47.1**	**41.7**	**1.4**	**-30.2**	**-5.4**	**304.9**	**455.0**	**123.5**	

*1 The GLWUAs allocation of 118Mm³/a includes losses. Combining the abstraction and the river channel losses (ignoring those below Letaba Ranch which are downstream of the last irrigators), used in the Bridging Study gives a comparable allocation of 119 Mm³/a (89.7 + 32.1-3 (losses below Letaba Ranch) = 118.8)

*2 Total irrigation requirement for the Groot Letaba Catchment (including losses) is 192 Mm³/a (118.8 (from *1) + 73.4 = 192.2)

*3 Note that the losses realized are less than the potential losses when the river ceases flowing, mainly in drought periods or in reaches not subject to irrigation releases

2.6 COMPLIANCE WITH ECOLOGICAL WATER REQUIREMENT

This section contains comparisons of streamflows at various sites downstream of the Nwamitwa Dam for different scenarios with the corresponding ecological requirement.

2.6.1 Introduction

The monthly streamflow requirements at each EWR site described in the Reserve Determination Study (DWAF, 2006b) were sorted in descending order and plotted in **Figure 2.5** and **Figure 2.6** to show the relative frequency required for maintenance high and low flows, respectively. The relative frequency is measured along the percentage exceedance axis. A flow with an exceedance of 60% will be exceeded 60% of the time and will be less than a flow with a percent exceedance of 30%. Note that the reserve classification of Sites 6 and 7 is a Category C while that of Sites 3 and 4 is a Category C/D. As a result, the flows at Sites 6 and 7 with exceedance values of between 60% and 70% are larger than those at Sites 3 and 4 and may require additional releases over and above those satisfying the Groot Letaba (i.e. Sites 3 and 4) if the proposed Nwamitwa Dam is used to supplement the EWR requirements in the KNP.

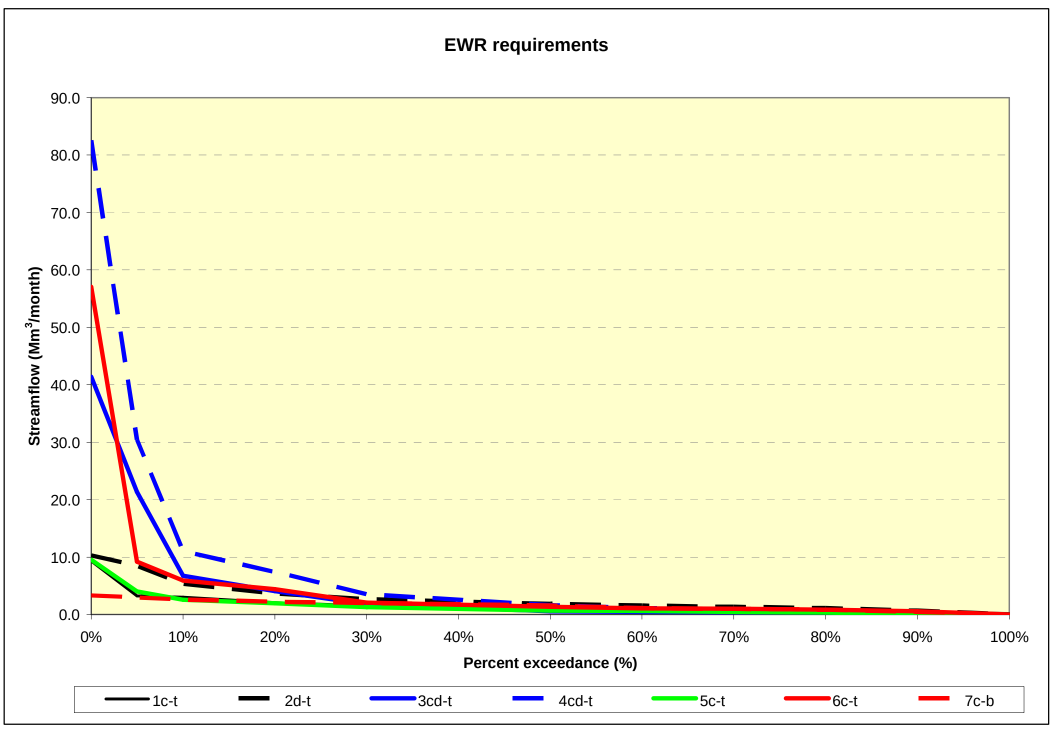


Figure 2.5 Total EWR requirements at Sites 1 to 7 along the Letaba River

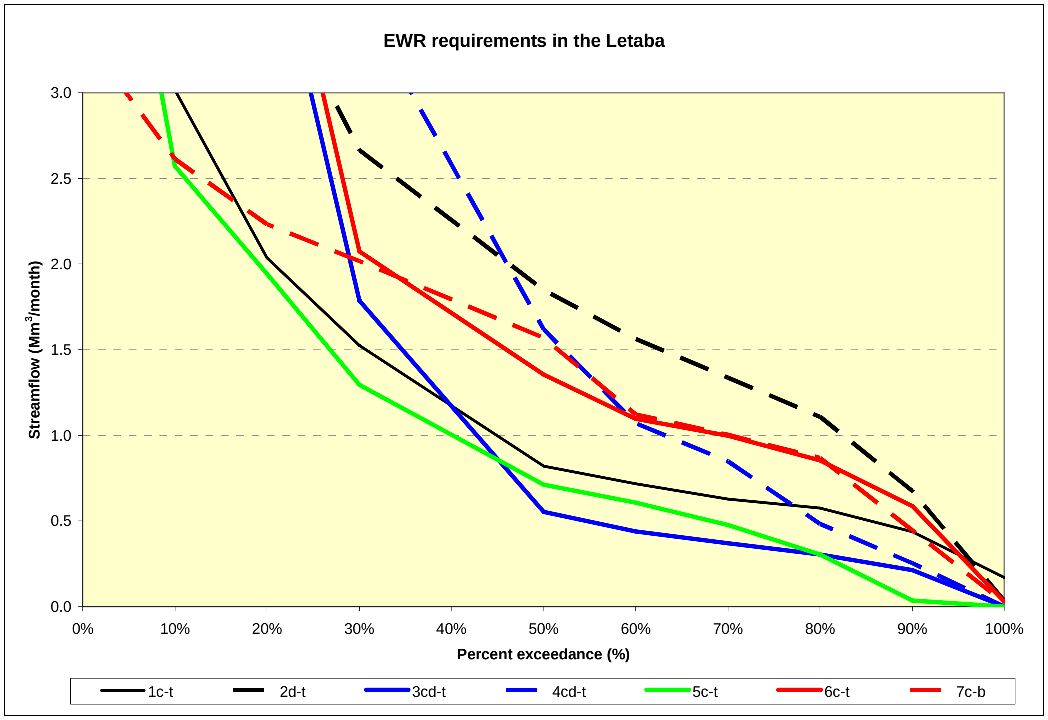


Figure 2.6 Total EWR requirements at Sites 1 to 7 along the Letaba River focusing on the lower flows

These plots were used to compare the EWR requirement with the actual stream flow for different scenarios to help identify scenarios that might meet the EWR requirements. If the actual stream flow is more than the EWR then it should be checked using more detailed plots. For instance, flow exceedance plots can be produced for individual months and the historical streamflow sequences can be plotted.

Figure 2.7 compares the total EWR requirement at a site with the corresponding estimate of the requirement used in "Scenario 7" in the Main Report of the Reserve Determination Study (DWAF, 2006b).

Detailed comparisons of the compliance with the EWR are provided for each EWR site in **Annexure B** of this report.

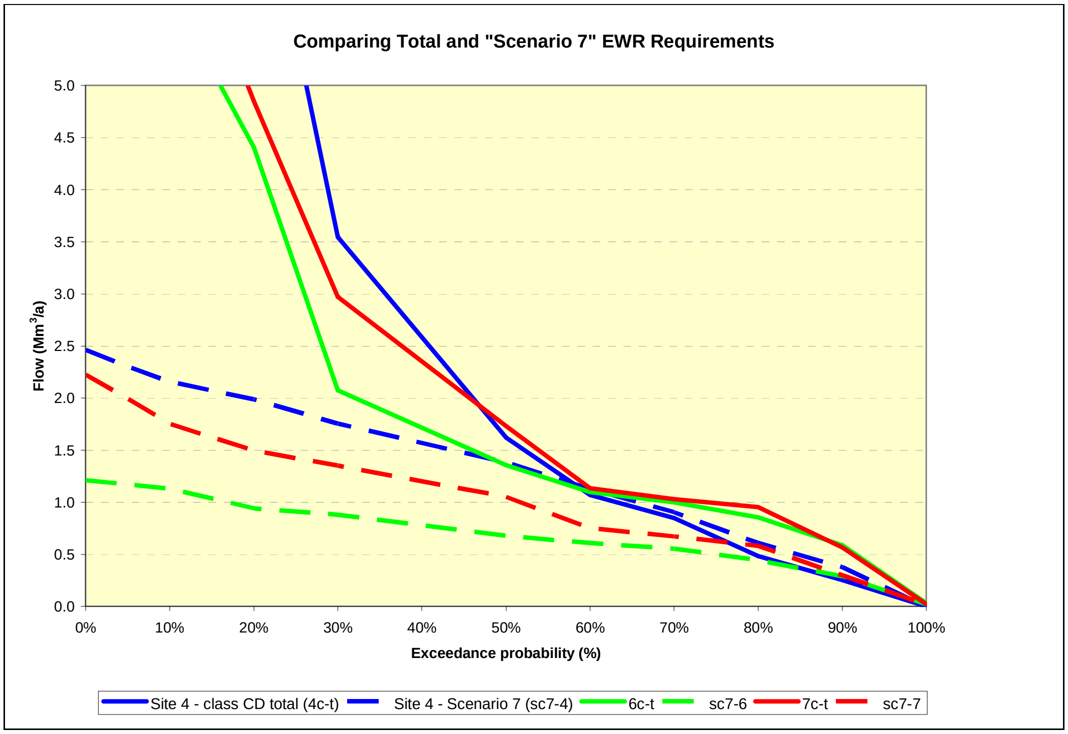


Figure 2.7 Comparing total and "Scenario 7" EWR requirements

2.6.2 Conclusions and Recommendations

The proposed Nwamitwa Dam will increase the proportion of the Letaba Catchment's streamflows that are regulated by major dams from 43% to 69% (see **Table 2.7**). For one scenario, the outflow from the Groot Letaba System decreases by about 25 Mm^3/a for an increase in yield of about 14 Mm^3/a (see **Table 2.8**). The evaporation from the system increases by about 9 Mm^3/a.

Table 2.7 Approximate Proportion of the Catchment Regulated by Major Dams

Reach	Natural streamflow			Approximate proportion upstream of major dams	
	Mm^3/a		%	Present Day	After Nwamitwa
Upstream of Tzaneen	203	435	33%	33%	33%
Tzaneen to Nwamitwa	158		26%	0%	26%
Remainder of Groot Letaba	74		12%	0%	0%
Upstream of Middle Letaba	61	131	10%	10%	10%
Remainder of Klein Letaba	70		11%	0%	0%
Letaba downstream of confluence	48	48	8%	0%	0%
Total	**614**		**100%**	**43%**	**69%**

Table 2.8 Impact of Nwamitwa Dam on Streamflows

Component	Mm^3/a	% Decrease in Streamflow
Yield from Nwamitwa	14	58%
Evaporation increase	9	38%
Increased losses	1	4%
Impact on streamflows upstream of Klein Letaba confluence	24	100%

During this study the following were revised:

- Farm dams and demands;
- Operating rate for irrigation;
- Additional freshets were introduced on the Groot Letaba between the confluence with the Letsitele River and the Letaba Ranch; and
- River channel losses were included.

The magnitude of these impacts is significant compared to the relatively small yield obtained from Nwamitwa Dam, but because the scope of work specifically excluded recalibration, the existing hydrology was adapted to include these features rather than recalibrating the system.

Recalibration of the lower reaches may generate additional freshets in other reaches such as those downstream of the confluence with the Klein and Groot Letaba.

The EWR rules for the Preliminary Reserve should be checked to see that they will help resolve historical problems. The Reserve Determination Study did not consider the modification in flows caused by the Nwamitwa Dam and the possible impact of channel losses along the Groot Letaba River. For instance, the rules seem to generate low streamflows in the 1991/92 and 2002/3 periods. Some additional EWR releases may be required during those times rather than during periods when more runoff was generated in the system (see **Figure 12** of **Appendix B** of this report). The practical implementation of the rules could consider integrating the releases with the management of the dams in the KNP such as the Charles Engelhardt and the Mingerhout. If the dams in the KNP can intercept and regulate "slug" releases from the Nwamitwa Dam, then this will help to reduce channel losses.

Prior to the construction of the Nwamitwa Dam, the current practice of releasing a baseflow from Nondweni (located on the Groot Letaba River about 5 km upstream of the Molototsi confluence – see **Figure 1.2**) seemed to provide adequate environmental flows, providing the additional freshets added to the hydrology reasonably represent the situation. However, when the system was modelled to meet "Scenario 7" releases downstream of Tzaneen Dam, the average supply to irrigators reduced by 4 Mm^3/a.

The proposed Nwamitwa Dam will intercept the freshets currently flowing from the Letsitele and the Nwanedzi/Hlangana Rivers. To compensate for this, the Nwamitwa Dam was modelled to meet the total environmental flow (including highflows) downstream at EWR Site 3 near Prieska. It was also necessary to make releases from Nwamitwa to supplement the stream flows at EWR Sites 6 and 7 for the following reasons:

- The streamflow requirements at Sites 6 and 7 are higher than those at Sites 3 and 4 further upstream because they have been assigned a higher environmental class;
- The releases from the Middle Letaba Dam are unreliable as the system is over-allocated; and
- River channel losses reduce the stream flows.

The following might change the releases necessary from Nwamitwa:

- Reviewing the licensing and the hydrology in the Middle Letaba;
- Using "slug" releases to supply water to the KNP as large pulses instead of as constant baseflows to reduce losses (as explained in **Section 2.4.2** of this report);
- Investigate using the storage in the KNP dams to intercept freshets and provide low flows when necessary; and
- Checking the streamflows simulated for different environmental scenarios using the historical hydrology to assess their impact on the ecology. For instance, if one examines **Figure 12** in **Appendix B** of this report, the following question arises : "were additional releases necessary in say 2002/3?"

Scenario t77H (row no. 36 in **Table 2.3** - which meets the total environmental requirement at Site 3 and meets estimates of the requirements for "Scenario 7" at Sites 4, 6 and 7) provides a historical firm yield at the proposed Nwamitwa Dam of 14 Mm^3/a. This assumes that the supply to existing users from Tzaneen Dam remained unchanged. If the existing users must meet "Scenario 7" requirements downstream of the Tzaneen Dam, then their supply may decrease by about 4 Mm^3/a which means that the incremental benefit to Nwamitwa Dam from the t77H scenario increases by a further 4 Mm^3/a to 18 Mm^3/a.

2.7 COMPARISON WITH THE 1995 FEASIBILITY STUDY RESULTS

The main differences between the earlier Feasibility Study and the current Bridging Study are:

- The Bridging Study introduced additional freshets averaging about 34 Mm^3/a into the WRYM as a stopgap measure to introduce freshets that were missing in the hydrology.
- The urban requirements in the Bridging Study were fixed at about the 2007 level of development, rather than the 2020 level of development used in the Feasibility Study.
- Following the detailed survey of the Groot Letaba Catchment (excluding the Politsi Government Water Control Area) by Hennie Schoeman, the irrigation and farm dams capacities were increased by 37 Mm^3/a and 27 Mm^3 respectively, primarily along the Groot Letaba River downstream of the Tzaneen Dam.
- Subsequent to the Feasibility Study, the ecological water requirements were updated in the Letaba Catchment – Reserve Determination Study. The total EWR from the two studies, i.e. the original full maintenance requirement and the later preliminary reserve determination differ, but the original drought requirements and the requirements for the "Scenario 7" adopted in the Reserve Determination Study are similar.
- The Feasibility Study determined the additional average supply to irrigation possible for each of the scenarios while the Bridging Study determined the additional firm yield available at Nwamitwa, assuming that the irrigation supply remained identical to pre-Nwamitwa conditions.

These differences are discussed in more detail in **Sections 2.7.1** to **2.7.6**.

However, despite these differences the yields for both systems releasing full maintenance/preliminary reserve EWR down to the Klein Letaba confluence and ignoring the additional freshets introduced in the Bridging Study are both less than 10 Mm^3/a. If drought/"Scenario 7" EWR are supplied instead, then the yields obtained in the Bridging Study increase to between 7 and 14 Mm^3/a.

2.7.1 Freshets

The Bridging Study modified the hydrology to include an allowance for freshets that were visible in the observed records but not in the streamflows of the Water Resources Yield Model (WRYM). The streamflows were increased by 34 Mm^3/a along the various reaches:

- 8 Mm^3/a upstream of Nwamitwa Dam;
- 5 Mm^3/a between Nwamitwa and EWR Site 3; and
- 21 Mm^3/a between EWR Site 3 and the Letaba Ranch.

2.7.2 Urban Requirements

The "Primary water requirements" table in the Bridging Study report entitled **Review of Water Requirements** shows that the total urban requirement on the Letaba System was 48.9 Mm^3/a in 2006/7. Of this, 6 Mm^3/a was required in the Middle and Klein Letaba catchments, leaving 42.9 Mm^3/a in the Groot Letaba Catchment. This is similar to the 43.42 Mm^3/a obtained by interpolation of estimates in the Feasibility Study (see **Table 2.9**).

Table 2.9 Estimated Future Domestic and Industrial Requirement (Mm^3/a)

Year	User sector			Total
	Urban	Rural	Industrial	
1995	23.46	8.82	1.5	33.78
2000	25.19	8.34	1.5	35.03
2007 (by interpolation)	28.90	13.02	1.5	43.42
2010	30.66	15.75	1.5	47.91
2020	39.89	29.01	1.5	70.40

From Table 5.6 in the Groot Letaba WRD Main Feasibility Report (DWAF 1998a).

2.7.3 Irrigation Requirements

The following differences in irrigation demands were found when the results of the 1995 Feasibility Study were compared to the 2007 Bridging Study Analysis:

- The local demands supplied upstream of Tzaneen Dam increased by 8 Mm^3/a.
- Increase of 29 Mm^3/a along the Groot Letaba River from Tzaneen Dam to the Letaba Ranch. Part of this increase was from incorporating the proposed (as opposed to existing) supply of 22 Mm^3/a to emerging farmers downstream of the Nondweni Weir. The Feasibility Study reported that 7.9 Mm^3/a was supplied to the Masalal Canal but this has not been maintained and is now unusable.

Table 2.10 illustrates the comparative difference in irrigation requirements.

2.7.4 Major and Farm Dams

The following difference between the two studies was established regarding the capacity of farm dams:

- The volume of farms dams along the Groot Letaba River increased by 27 Mm^3, primarily between Tzaneen Dam and the confluence with the Molototsi River (sub-catchments B81C, B81E and B81F).

Table 2.11 illustrates the comparative difference in capacity in the major and farm dams.

Table 2.10 Comparison of Irrigation Requirements (Mm^3/a)

Reach	This (Bridging) Study				Feasibility Study (Table 4 in Water requirements and system analyses report (DWAF, 1998b))	Increase (Bridging Study with respect to Feasibility Study)	Driver behind increased demand in Bridging Study
	GLWUA Field Edge Requirements	GLWUA River channel / transmission losses	Other irrigation from surface water	Total			
Supplied from upstream of Tzaneen	10	3	9	21	13.4	8	Additional local demands, possibly in Ramadiepa, Selokwe River and around the Tzaneen Dam
Tzaneen to Nwamitwa	40	8	9	57	46.53	10	Additional local demands
Nwamitwa to EWR 3	12	6	4	22	15.17	7	Additional local demands
Below EWR 3	29	11	1	41	29.74	11	Bridging Study assumes unused GLWUA allocation will be used for emerging irrigators 22 Mcm/a+losses
Politsi, Ramadiepa and Selokwe	0		17	17	17.43	0	
Letsitele	0		16	16	16.38	0	
Nwanedsi	0		14	14	12.76	1	
Molototsi	0		3	3	2.4	1	
Middle Letaba	0		37	37	-	-	
Klein Letaba	0		14	14	-	-	
Totals (rounded)*	**91**	**28**	**124**	**242**	**154**	**38**	

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*Note : rounding of totals may lead to slight inconsistencies.

Table 2.11 Comparison of Storage in Major and Farm Dams (Mm^3/a)

Quaternary	Feasibility Study *1			Bridging Study			Difference	
	Major Dams (Gross)	Major Dams (Net)	Lumped dams	Major Dams (Gross)	Major Dams (Net)	Lumped dams	Major Dams	Lumped Dams
B81A	72.1	71.1	2.1	72.0	71.1	1.7	0	0
B81B	163.8	162.7	4.4	163.6	162.6	2.8	0	-2
B81C	--		1.8	0.0	0.0	6.3	0	5
B81D	2.8	2.5	6.1	2.8	2.5	7.1	0	1
B81E	--	--	7.3	0.0	0.0	21.4	0	14
B81F	--	--	2.8	0.0	0.0	9.4	0	7
B81G	--	--	2.0	8.2*2	7.8	2.8	8	1
B81H	--	--	1.0	0.0	0.0	2.5	0	1
B81J	--	--	0.0	0.0	0.0	1.1	0	1
B81	**246.9**	**236.3**	**27.5**	**246.6**	**244.0**	**55.0**	**8**	**28**
B82A	--	--	13.9	0.0	0.0	12.3	0	-2
B82B	--	--	15.4	0.0	0.0	30.5	0	15
B82C	--	--	3.5	0.0	0.0	4.6	0	1
B82D	184.2	171.9	1.8	184.2	171.9	0.4	0	-1
B82E	--	--	1.1	0.0	0.0	0.0	0	-1
B82F	--	--	6.4	0.0	0.0	0.0	0	-6
B82G	--	--	6.0	0.0	0.0	0.0	0	-6
B82H	24.1	21.9	1.0	24.1	21.9	0.0	0	-1
B82J	--	--	4.2	0.0	0.0	0.0	0	-4
B82	**208.3**	**193.8**	**53.3**	**208.3**	**193.8**	**47.8**	**0**	**-5**
B83A	--	--	0.0	0.0	0.0	2.7	0	3
B83B	--	--	--	0.0	0.0	2.2	0	2
B83C	--	--	--	0.0	0.0	0.3	0	0
B83D	--	--	0.6	0.0	0.0	3.9	0	3
B83E	--	--	--	0.0	0.0	0.0	0	0
B83	**0.0**	**0.0**	**0.6**	**0.0**	**0.0**	**9.1**	**0**	**8**
Total	**455.2**	**430.1**	**81.4**	**454.8**	**437.8**	**112.0**	**8**	**31**

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*1 Data for the Groot Letaba was obtained from Tables 3 and 4 of the Feasibility Study (DWAF 1998b) and the data for the remaining systems was obtained from the legacy system used by Stewart Scott Inc. for the Olifants River Water Resources Development Project (2006a)

*2 Modjadji Dam built 1997

2.7.5 Ecological Water Requirements

The drought EWR determined in the Feasibility Study for the sites downstream of the Nwamitwa Dam (i.e. at Prieska Weir, Letaba Ranch and inside the Kruger Park) are within 3 Mm^3/a of the Scenario "7" requirements from the Reserve Determination Study.

The difference varies from site to site as can be seen by comparing the annual drought total from the Feasibility Study with the corresponding entry for "Scenario "7" from the Reserve Determination Study in **Table 2.13** of this report.

The annual maintenance (as opposed to drought) requirements from the Feasibility Study differ far more from the Preliminary Reserve but the impact on the yield would depend on the magnitude of the baseflows and the timing of the flood releases. Again, the difference varies from site to site and can be checked using **Table 2.13** by comparing the annual maintenance requirements for the Feasibility Study with the adjacent figure in the "Preliminary Reserve" column. At Letaba Ranch, the Preliminary Reserve is 9 Mm^3/a more than the Feasibility Study, while at Prieska it is 15 Mm^3/a less than the Feasibility Study.

2.7.6 Yield Comparison

Two approaches were used in determining the yield from Nwamitwa Dam in the Feasibility Study.

(a) Approach 1: Cascading Firm Yields

The first approach applied the historical firm yield to each of the upstream dams, starting with the most upstream dam in the system. In practice, the current demand on Tzaneen Dam exceeds the historical firm yield of the dam, which means that Nwamitwa Dam will receive less spills from Tzaneen Dam than assumed in this approach. Also, this method assumes that the accruals from the Letsitele River will only be accessed from Nwamitwa Dam, whereas the GLWUA currently intercepts as much water from the Letsitele River as possible.

The historical firm yield under this approach, if a 1 MAR dam is constructed at Nwamitwa, was 46 Mm^3/a (see **Table 2.12** for the yield of Nwamitwa Dam with a capacity of 132.8 Mm^3).

Table 2.12 Historic Firm Yield of Existing and Proposed New Dams

Dam	Capacity (Mm^3)	Inflow (Mm^3/a)	Firm Yield (Mm^3/a)
Dap Naude	1.9	11.2	3.2
Ebenezer	70.1	34.4	23.9
Magoebaskloof	4.9	29.9	8.8
Hans Merensky	1.3	23.7	2.8
Tzaneen	157	112.4	59.8
Thabina	2.8	5.54	2.86
Tzaneen raised	203	112.4	64.2
Nwamitwa (26% MAR)	35.9	137	23.8
Nwamitwa (43% MAR)	58.7	137	29.9
Nwamitwa (97% MAR)	132.8	137	46.2

Based on Table 6.3 of the Main Feasibility Report (DWAF 1998a)

Table 2.13 Ecological Water Requirements (Instream Flow Requirements in Feasibility Report)

Site	Feasibility study															From Reserve Determination Study[2]	
	IFR Site number		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual[1]	EWR Site Number	Preliminary Reserve[3]	Scenario "7"
			Mm³/month												Mm³/a		Mm³	Mm³
Letsitele River near B8H010	1	Maintenance	0.81	1.41	2.95	3.59	3.74	4.16	2.64	2.20	1.81	1.61	1.07	0.67	26.69	2	32	n.a
		Drought	0.49	0.66	0.80	0.85	0.91	0.98	0.87	0.75	0.65	0.59	0.51	0.44	8.51[4]		n/a	23[4]
Groot Letaba near Prieska Weir B8H017	2	Maintenance	2.48	3.40	6.86	5.66	8.70	9.16	5.03	4.37	3.47	3.11	2.60	2.23	57.07	3	42	n.a
		Drought	0.71	1.02	1.67	1.38	1.67	1.33	0.91	0.78	0.70	0.67	0.62	0.54	12.00[4]		n/a	12[4]
Groot Letaba near Letaba Ranch B8H008	3	Maintenance	2.57	3.58	7.91	6.10	9.90	9.85	5.18	4.55	3.63	3.21	2.68	2.33	61.49	4	70	n.a
		Drought	0.74	1.09	1.75	1.48	1.87	1.45	0.96	0.80	0.73	0.70	0.64	0.57	12.77[4]		n/a	16[4]
Inside Kruger National Park (KNP)	4, 5	Maintenance	2.74	8.64	10.63	8.62	14.69	12.48	5.81	5.01	3.99	3.51	2.92	2.49	81.52	6, 7	47 – 52[5]	n.a
		Drought	0.79	1.27	2.10	1.90	2.43	1.74	1.14	0.88	0.78	0.75	0.70	0.60	15.07[4]		n/a	9 -13[4] [5]

(1) From Table 6.3 of the Water Requirements and System Analysis Report of the Feasibility Study (DWAF, 1998b)
(2) From Appendix K of the Hydrological Support and Water Resources Evaluation from the Reserve Determination Study (DWAF, 2006b)
(3) Compare the "Preliminary Reserve" totals with the "Maintenance" annual total
(4) Compare scenario "7" with the "Drought" totals
(5) Two values are given corresponding to the requirements at the two sites, 6 and 7, within the KNP

Additional Supply with regard to Current Use

The yield results for this approach in the Feasiblity Study are distributed in three places:

- The main *Feasibility* Report (DWAF, 1998a);
- Annexure B1 "System Analysis" of the *Water Requirements and System Analysis* Report (DWAF, 1998b); and
- A "Water Resources Yield Analysis Section" after the Annexure B3 for the Letsitele River Stabilisation (DWAF, 1998b).

Considerable effort was required to unravel the different results and a detailed description of the conclusions is presented here to act as a springboard for further checking if necessary. It will not be necessary to read the full description to understand the implications which are summarised in the following paragraphs. The reason for this effort was that when the yield results of the Bridging Study were initially released there were concerns that the results were much less than the yield of 46 Mm^3/a used for costing the scheme. Closer investigation of the results of the Feasibility Study indicated that similar low yields were in fact determined as part of the Feasibility Study.

Summary of Results

The results of the Feasibility Study indicated that the incremental yield from constructing Nwamitwa Dam (capacity 133 Mm^3) if the "drought" EWR is provided down to the confluence with the Klein Letaba River at Letaba Ranch, is 23 Mm^3/a. A similar scenario using the "Scenario 7" EWR in the current study provides a yield of 26 Mm^3/a. The yield of the current study also benefits from the freshets and omitting these would reduce the yield by about 12 Mm^3/a to 14 Mm^3/a.

The results of the Feasibility Study indicate that the incremental yield from constructing Nwamitwa Dam (capacity 133 Mm^3) is 8 Mm^3/a, if the "maintenance" EWR is provided down to the confluence with the Klein Letaba River at Letaba Ranch. A similar scenario in the current study using the "Preliminary Reserve" EWR provides a yield of 17 Mm^3/a. The yield of the current study also benefits from the freshets and omitting these would reduce the yield by about 12 Mm^3/a to 5 Mm^3/a.

Detailed description of conclusions

Please note that this section contains detailed information intended for those readers who wish to interrogate/check the interpretation of the results.

(b) Approach 2: Existing Upstream System Operating above HFY

In the second approach, Tzaneen Dam was operated above its firm yield by modelling the "present day" operation of the system and increasing the demand from irrigation to the current high levels and curtailing the demands when the storage dropped below certain predefined levels. In addition, the accruals downstream of Tzaneen Dam, from rivers such as the Letsitele River, were used whenever possible to augment the supply to irrigators. In this approach, a larger proportion of the inflow upstream of Tzaneen was used by the existing infrastructure, so less water was available to contribute to the yield of Nwamitwa Dam.

In the Feasibility Study, the present day supply to urban consumers and irrigators in the Groot Letaba River under this scenario was about 180 Mm^3/a (Case Identifier "C" in **Table 2.14**). In the similar scenario in the Bridging Study, the present day supply to these consumers was 198 Mm^3/a. This total is obtained from **Table 2.6** by combining the supply to the GLWUA plus the associated river channel losses upstream of Letaba Ranch, the local irrigation and the urban supply (i.e. 66.8 + [31.0 – 3.4] + 62.4 + 40.8). (The river channel losses were included as these appear to be combined with the irrigation requirements in the Feasibility Study). The 19 Mm^3/a increase in supply in the Bridging Study reflects the apparent increase in storage and irrigation requirements downstream of Tzaneen Dam following Hennie Schoeman's detailed survey of the area (DWAF, 2007a). Most of the 27 Mm^3 increase in farm dam capacity (see **Section 2.7.4**) and the 37 Mm^3/a increase in demand (see **Section 2.7.3**) is located downstream of the Tzaneen Dam.

The yield of the Nwamitwa Dam is obtained from storing the spills over the Tzaneen Dam and the freshets from the Letsitele River and the other tributaries located between Tzaneen Dam and the Nwamitwa Dam site.

Table 2.14 Yields from the Proposed Nwamitwa Dam obtained in the Feasibility Study (1998a and 1998b) (Mm^3/a unless otherwise stated)

Identifier	Option Description used in Feasibility Study	Net Nwamitwa Dam capacity	Tzaneen Dam Net Capacity	Environmental releases	Domestic requirement (2020)	Irrigation requirement (1995)	Demand adjustment to include A01,B20,B30,B01	Natural inflow; Table 1 Water Req and System Analysis	Unaccounted for inflows such as urban return flows(+) and extra evap(-)	Afforestation;; Table 1 Water Req and System Analysis	Evaporation estimate	Domestic supply	Irrigation supply	Supply adjustment to include local demands from A01,B20,B30,B01 [1]	Outflow p = i+j-k-l-m-n-o-p	Total Supply reported in Tables **6.4, 8.3** and **8.4**	Adjustment to include local demands from A01,B20,B30,B01 [1]	Total supply	Incremental reference	Incremental yield	Reference
a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v
A	Baseline	0	156	drought	77	153	0	405	18	51	10	73	106	0	183	**179**	0	179		n.a	Table 11 : Water Req (1998b)
B	8	133	156	drought	77	153	0	405	7	51	10	74	127	0	149	**202**	0	202	A	23	Table 11 : Water Req
C	1	133	156	14.8 to KNP	77	134(1)	19	405	37	51	10	76	86	19	201	**161**	19	180		n.a	Table 8.3; IFR in Section 5.4 ; Main Report, Table 15 Water Req
D	3	133	156	Full Maint	77	134	19	405	*	51	10	76	87	19	*	**162**	19	181	C	1	Table 8.3 ; Main Report (1998a)
E	4 – full	133	156	Full Maint	77	134	19	405	26	51	10	76	93	19	182	**170**	19	189	C	8	Table 8.3 & 8.4 ; Main Report, Table 16 Water Req
F	4 – maint	133	156	Maint baseflow	77	134	19	405	28	51	10	76	98	19	179	**174**	19	193	C	11	Table 8.4 ; Main Report, Table 16 Water Req
G	4 – drought	133	156	Drought	77	134	19	405	24	51	10	76	99	19	173	**176**	19	195	C	14	Table 8.4 ; Main Report, Table 16 Water Req
H	Interpolation	133	156	Drought	77	134	19	405	*	51	10	76	93	19	*	**168**	19	187	C	7	Estimate using row H=D+G–E
I	Scenario 8	133	156	Full Maint	77	134	19	405	29	51	10	76	93	19	185	**169**	19	188	C	7	Table 15; Water Req
J	Interpolation	133	156	Drought	77	134	19	405	26	51	10	76	99	19	177	**175**	19	194	C	13	Estimate using row J=I+G–E

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[1] Increase Irrigation requirements and supply for case id's C to G by 19 so that they are comparable with id's A and B
* not available

The yields obtained from various sources in the Feasibility Study for the second approach have been grouped together in **Table 2.14**. The domestic supply, irrigation supply, and total supply for the scenarios (columns "m", "n", and "q") were reported in Tables 8.3 and 8.4 in the *Main Report* of the Feasibility Study (DWAF, 1998a) and Tables 11, 15 and 16 in the *Water Requirements and System Analysis Report (DWAF, 1998b)*.

The irrigation supply from **Tables 8.3** and **15** do not include the local demands on the Politsi, Ramadiepa and Selokwe Rivers of about 17.4 Mm^3/a (see

Table 2.10). The reported difference in demand is actually 18.76 Mm^3/a (18.76=153.56-133.8) so the figures do not gel exactly but this assumption seems the most reasonable. It seems likely that **Tables 15** and **16** also only reported how much of the 133.8 Mm^3/a irrigation requirements (ignoring local demands on the Politsi, Ramadiepa and Selokwe Rivers) was supplied, rather than how much of the 152.56 Mm^3/a was supplied. To enable the results of **Table 8.3**, **15** and **16** to be compared with the other results from **Table 11**, their irrigation requirements increased by 18.76 Mm^3/a (i.e. 152.56 – 133.8). These are wet catchments and it was assumed that the demand would always be supplied. Consequently, the demand and supply were both increased by 19 Mm^3/a (columns "o" and "r") to obtain the total domestic and irrigation requirement in columns "i" and the supply in column "s". The incremental yields were obtained by calculating the increase in supply for each scenario with respect to the correct baseline as identified in column "t". For instance, the increase in supply for the "B" case of 23 Mm^3/a was determined relative to the "A" case (note "A" in column "t") by deducting 179 from 202 Mm^3/a. Similarly, the increases in average supply for cases "D" to "E" were determined relative to case "C".

The results of the Feasibility Study indicate that the incremental yield from constructing Nwamitwa Dam (capacity 133 Mm^3), if the "drought" EWR is provided down to the confluence with the Klein Letaba River at Letaba Ranch, is 23 Mm^3/a (see case "B" in **Table 2.14**). A similar scenario in the current study provides a yield of 26 Mm^3/a (see 7770 – row no. 26 in **Table 2.3** "Selected Yield Scenarios"). The 7770 scenario from the current study provides the "Scenario 7" EWR, similar to the drought EWR at all the sites into the KNP, but because the losses downstream of the Letaba Ranch are zero the EWR requirements in the KNP have little impact on the yield. The 7770 scenario also benefits from the freshets and omitting these would reduce the yield by about 12 Mm^3/a to 14 Mm^3/a.

The results of the Feasibility Study indicate that the incremental yield from constructing Nwamitwa Dam (capacity 133 Mm^3) is 8 Mm^3/a, if the "maintenance" EWR is provided down to the confluence with the Klein Letaba River at Letaba Ranch (see case "D" in **Table 2.14**). A similar scenario in the current study provides a yield of 17 Mm^3/a (see tt_0 – row no. 32 in **Table 2.3** “Selected Yield Scenarios”). The tt_0 scenario from the current study provides the "Preliminary Reserve" EWR, similar to the "Maintenance

EWR" at the same sites as case D from the Feasibility Study. The tt_0 scenario also benefits from the freshets and omitting these would reduce the yield by about 12 Mm^3/a to 5 Mm^3/a.

There appear to be some anomalies in the results from the Feasibility Study:

i. **Cases 2 and 3 in Table 8.3**. The results for raising Tzaneen and constructing Nwamitwa (Scenarios 2 and 3) appear inconsistent and may be swopped around. Otherwise the benefit of constructing Nwamitwa Dam is only 1 Mm^3/a while that of raising Tzaneen Dam is 8 Mm^3/a.

ii. **Scenario 4 in Table 8.3 vs Scenario 8 in Table 16**. The results for "Scenario 4" in Table 8.3 from the *Main Feasibility Report* (DWAF, 1998a) and "Scenario 8 – Full IFR Released" in Table 16 from the *Water Requirements and System Analysis Report* (DWAF, 1998b) are identical to the second decimal place meaning that the runs are the same. However, the description for Scenario 4 states that Tzaneen is raised, while no mention is made of Tzaneen being raised for Scenario 8 and the dam raising seems to be a separate scenario (listed after Scenario 8 in Table 11).

iii. **Baseline scenario** in Table 11 *vs* Scenario 8 (Full IFR released) in Table 16. The flow out of the system for the baseline scenario of Table 11 (182.94 Mm^3/a) is very similar to that for the Scenario 8 with the proposed Nwamitwa Dam releasing the Maintenance EWR Requirement in Table 16 (181.52 Mm^3/a). The Increased evaporation and usage from the new dam should reduce the outflow from the system.

iv. **Mass Balance**. Some additional data was included in **Table 2.14** to try to provide the complete mass balance for the Groot Letaba, showing all the inflows, usages and the remaining outflows. The Natural Inflows (column "i") and Afforestation Demand (column "k") were obtained from Table 1 in the *Water Requirement and System Analysis Report*. Evaporation (column "l") was estimated to be the same as in the Bridging Study. The Feasibility Study provided outflows for most of the scenarios and the additional inflow required to balance the inflows and outflows (column "j") was initially assumed to come from urban return flows. However, in some cases the required inflow was as high as 45 Mm^3/a. This may be because of anomalous reporting of outflows from the system, as mentioned in point **iii** above.

2.8 WATER SUPPLY FROM TZANEEN DAM

The benefit of installing fuse gates or constructing a labyrinth weir to raise the full supply level of Tzaneen Dam by 3 metres (from a gross storage of 158 Mm^3 to 193 Mm^3) was determined by finding the increase in the firm yield of the Tzaneen/Nwamitwa system, which equated to about 4 Mm^3/a.

2.9 LONG-TERM STOCHASTIC YIELD ANALYSIS

In the current study, the additional yield from constructing the proposed Nwamitwa Dam was determined in two ways:

The first method used total yields. The total yield available from the existing system before and after the construction of Nwamitwa Dam was determined. By subtracting the yield of the existing system from the increased yield obtained by incorporating Nwamitwa Dam, the incremental benefit of the Nwamitwa Dam was determined.

The second approach modelled the water used by the existing system to determine the surplus water that would be stored in Nwamitwa Dam. The current usage was "fixed" and the incremental yield provided by the surplus water was determined directly.

Although the results are presented with high precision, the accuracy is limited by assumptions concerning the hydrology, losses, and ecological water requirements referred to in **Section 2.4**. As part of the process to determine the stochastic parameters used to generate the stochastic inflow sequences, the GENTEST proram was used to generate stochastic sequences that were compared with the historical streamflow sequences. The yield capacity curves produced by GENTEST have been included in the digital version of this report as **Appendix D** (95 pages), and indicate that the stochastic sequences are a reasonable representation of the historical streamflow sequences.

The hydrology used to prepare the stochastic parameters comes from different sources and spans different periods. The following time periods were used for the stochastic parameters:

- Letaba River 1925 – 2004
- Olifants River 1925 – 1986

When the system was analysed stochastically, the shortest common period from 1925 to 1986 was used.

During the stochastic analysis, the WRYM identifies the historical year whose annual streamflow (obtained from summing flows at user specified key gauges) is closest to that from summing the corresponding stochastic streamflows. The demands in this year are used in the stochastic analysis. To avoid the model selecting undefined demands for the Olifants River from the period after 1986, only the period from 1925 to 1986 was used for the analysis.

Figure 2.8 shows the reliability of the existing Ebenezer and Tzaneen systems, assuming that the all upstream demands are set to zero and no environmental releases are made.

In practice, both the Ebenezer and Tzaneen dams make releases to downstream users to augment the accruals used by those users. At each dam, the yields with and without the contribution of these accruals to the downstream demands, were determined. In **Figure 2.8**, the yield from Ebenezer with the accruals is labelled "Eb (Ebenezer + downstream to Grysappel)" and that without the accruals is labelled "E (Ebenezer)".

The yield from Ebenezer and Tzaneen with accruals is labelled "ETd (Ebenezer + Tzaneen Dam to Letaba Ranch)" and that without the accruals is labelled "ET" (Ebenezer + Tzaneen). **Figure 2.8** also shows the total system yield if the Tzaneen Dam is raised and if the proposed Nwamitwa Dam is constructed to a FSL of RL 479.5 (gross capacity = 187 Mm^3).

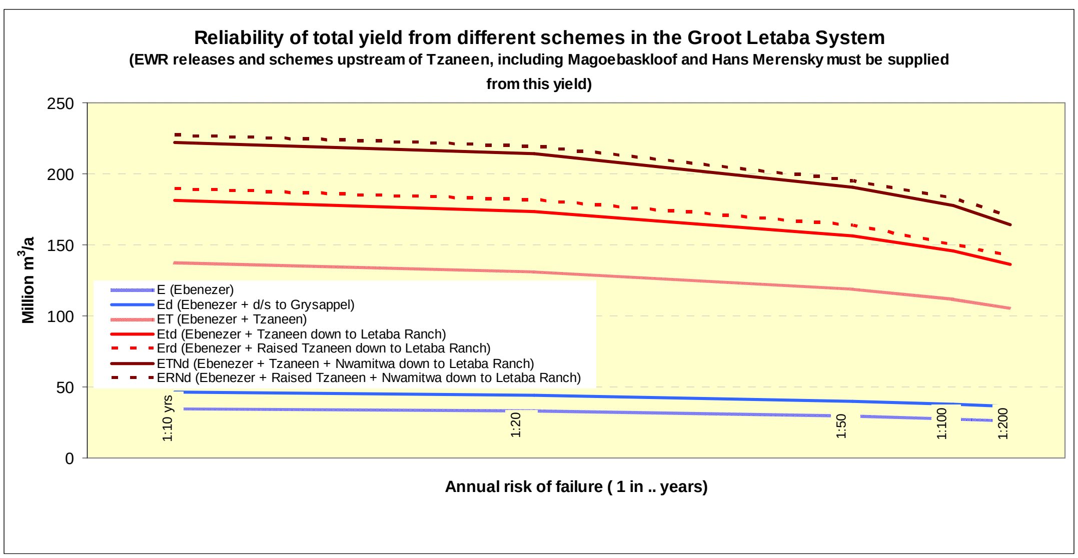

Figure 2.8 Reliability of total yield from different schemes in the Groot Letaba System

These yields are compared to the applied demands in **Figure 2.9**.

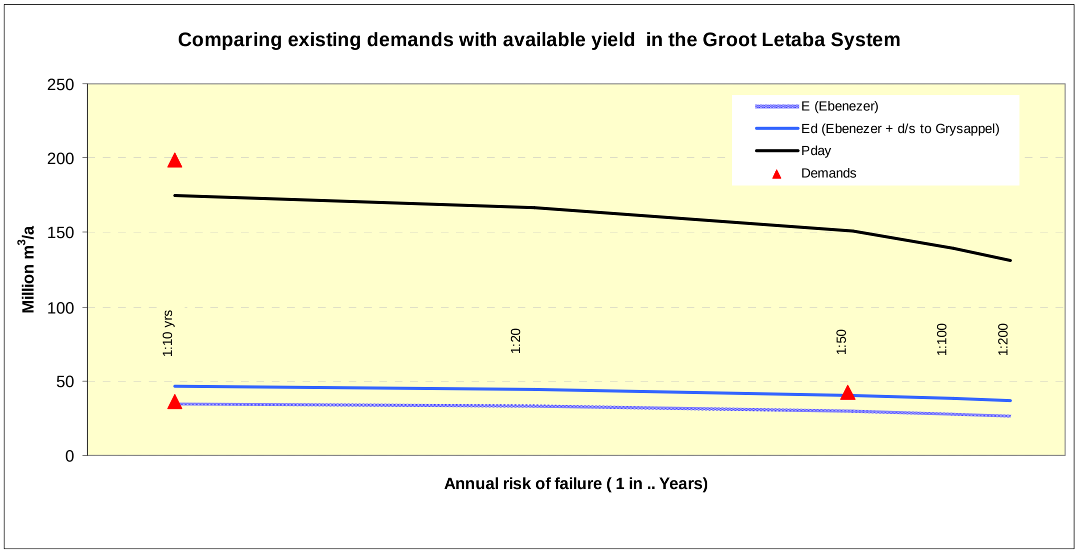

Figure 2.9 Comparing existing demands with the total available yield in the Groot Letaba System

The demands on Ebenezer were increased to allow for compensation/environmental releases though the actual yield lost depends on how much of the flow at EWR Site 1 is used by downstream consumers such as the Pusela Canal and the Tzaneen Municipality. It was assumed that about 10 Mm^3/a of the 17.5 Mm^3/a required at Site 1 was used, so that the effective release from the Ebenezer system was about 7.5 Mm^3/a (17.5-10). The demands on Ebenezer assume that the Polokwane Municipality only abstracts their allocation of 18.5 Mm^3/a from Dap Naude and Ebenezer, which is significantly less than their historical abstraction of 23.5 Mm^3/a. With this assumption the yield is approximately in balance with the demand, depending on the environmental assumptions.

However, when the Tzaneen system is added to the Ebenezer System then the demands exceed the 1 in 10 year yield of the system. The demand added to the Tzaneen System excludes the environmental component as the system yield shown in **Figure 2.9** already allows for the release of 14.7 Mm^3/a from the Nondweni Weir. Many of the demands upstream of Tzaneen (such as the Ebenezer and the Magoebaskloof/ Hans Merensky demands) are supplied at a fairly high reliability so that the residual water available from Tzaneen Dam has an even lower reliability.

The present day demands, applied to the system (as opposed to water actually supplied) are derived from **Table 2.6** and have been summarised in **Table 2.15**.

Table 2.15 Summary of Present Day Demands in the Groot Letaba upstream of the Klein Letaba Confluence

Reach			Consumptive Demands				Sub-total	EWR / Compensation	Total	Comments
			GLWUA	GLWUA losses	local	urban				
Column a	b	c	d	E	f	g	h	I	j	k
G Letaba headwaters	Ebenezer		0.0	0.0	0.0	18.5	18.5	17.4	**35.9**	
G Letaba headwaters	Grysappel		10.0	3.0	1.1	20.9	35.0	7.5	**42.5**	Assume that the Pusela canal (4.5), Tzaneen (2.1) and losses(3) use about 10 Mcm/a of the 17.5 EWR requirement. EWR effectively reduces yield by 7.5Mm^3/a
G Letaba, Politsi, Ramadiepa, Selokwe headwaters	Tzaneen Dam		48.9	3.0	32.3	32.6	116.8			
G Letaba, Politsi, Ramadiepa, Selokwe headwaters	Letaba Junction	Excluding Letsitele, Nwanedsi and Molototsi	89.7	32.1	40.3	36.8	198.9	14.7	**213.6**	Compensation has subsequently increased to 0.6 m^3/s release not 0.46m^3/s (14.7Mm^3/a),and will be superceded by the reserve
Letsitele, Nwanedsi and Molototsi headwaters	Letaba River		0.0	0.0	33.1	8.0	41.1			
Check total			**89.7**	**32.1**	**73.4**	**44.8**	**240.0**			

The yields plotted in **Figures 2.8**, **2.9** and **2.10** are summarised in **Table 2.16**.

Table 2.16 Total Yields of Schemes in the Groot Letaba Catchment (Mm³/a)

Case	HFY	Yields for different recurrence intervals					Scenario in \hydro\401775\wrym\tz8sv7a
		10	20	50	100	200	
E (Ebenezer)	27	35	33	30	28	27	E
Ed (Ebenezer + downstream to Grysappel)	37	46	44	40	38	37	Ed
ET (Ebenezer + Tzaneen)	108	138	132	119	112	105	T
Etd (Ebenezer + Tzaneen down to Letaba Ranch)	146	182	174	157	146	137	Td
Erd (Ebenezer + Raised Tzaneen down to Letaba Ranch)	151	190	181	164	150	142	R_d
ETNd (Ebenezer + Tzaneen + Nwamitwa down to Letaba Ranch)	176	222	214	191	178	164	N
ERNd (Ebenezer + Raised Tzaneen + Nwamitwa down to Letaba Ranch)	179	228	219	195	183	169	R_dN
Pday	140	175	167	151	139	131	T_dN
ETd_EWR(777)	131	170	163	144	134	125	T_dEH
Ebenezer + Raised Tzaneen releasing baseflows ("optimised scenario")	139	178	170	152	140	129	R_dEH
ETNd_EWR(T77)	154	198	189	169	158	144	T_dNEH
Ebenezer + Raised Tzaneen + Nwamitwa releasing preliminary reserve down-stream of Nwamitwa	157	201	195	174	162	149	R_dNEH

Figure 2.10 shows the reduction in yield caused by the environmental releases. It was assumed Tzaneen Dam would only make sufficient releases to meet the EWR corresponding to the "optimised" or "Scenario 7" scenario at sites down the Groot Letaba River, as spills down the Letsitele River would supply the freshets. These baseflow releases caused a reduction in yield of about 10 to 12 Mm^3/a, if it is assumed that Tzaneen Dam initially makes no releases at all (not even the 14.7 Mm^3/a compensation release) (compare the dashed red line with the solid red line with green dots in **Figure 2.10**). When the Nwamitwa Dam is constructed it would block the spills from the Letsitele River so the releases from the Nwamitwa Dam would include more freshets and would meet the total (as opposed to just baseflow) preliminary flow requirements at EWR Site 3 near Prieska. These larger releases would cause a reduction in yield of between 20 and 25 Mm^3/a (compare the dashed brown line with the solid brown line with green dots in **Figure 2.10**). The increase in yield from constructing Nwamitwa and raising Tzaneen varies from 20 to 25 Mm^3/a, if the above environmental releases are considered (compare the red line with green dots against the brown line with green dots). This is similar to the increase in yield with regards to the present day operation of the system (compare the solid brown with green dots to the solid black line representing the present day conditions). **Figure 2.10** also shows that after the construction of Nwamitwa Dam, and the raising of Tzaneen Dam, the existing users from Tzaneen and Ebenezer Dams will be supplied at 1 in 10 year risk of failure, if no additional demands

are placed in the system (the red triangle representing the current demands is close to the brown line with green dots at a 1 in 10 year annual risk of failure).

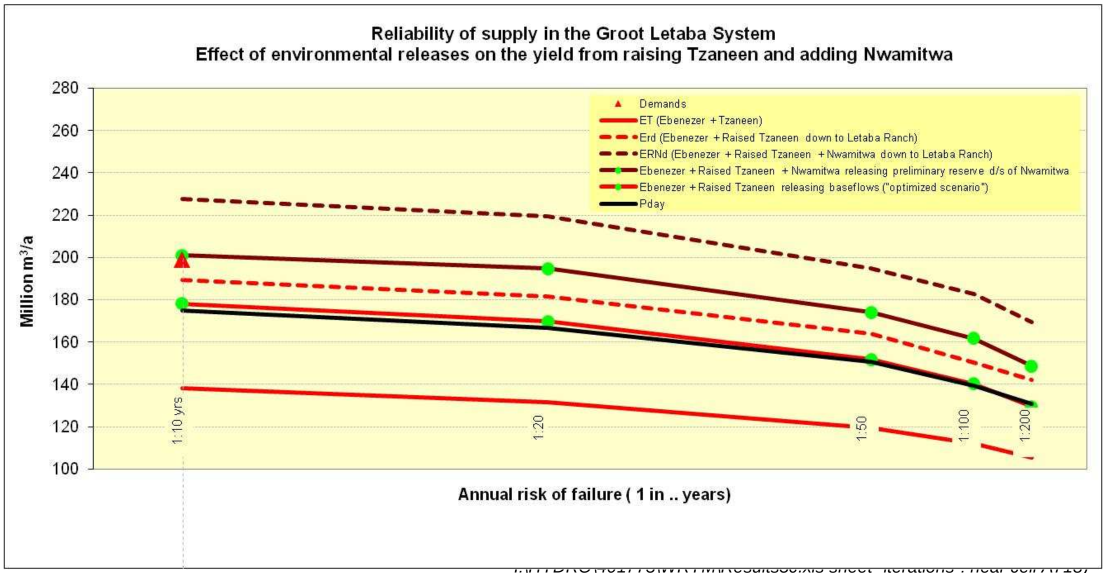

Figure 2.10 **The effect of environmental releases on the reliability of supply in the Groot Letaba System**

Figure 2.11 shows the incremental yield from the additional schemes in the Groot Letaba, assuming that the supply to existing users is fixed. In the historical analysis, the supply to the existing users was fixed at their current level, but in these stochastic analyses it was assumed that the current system would have to make "optimised" baseflow releases, which effectively reduces the supply to the existing users to support these baseflow releases. Because the existing users are contributing toward a portion of the EWR, the benefit of the additional schemes appears to increase, as less yield from the new scheme is required to support the EWR.

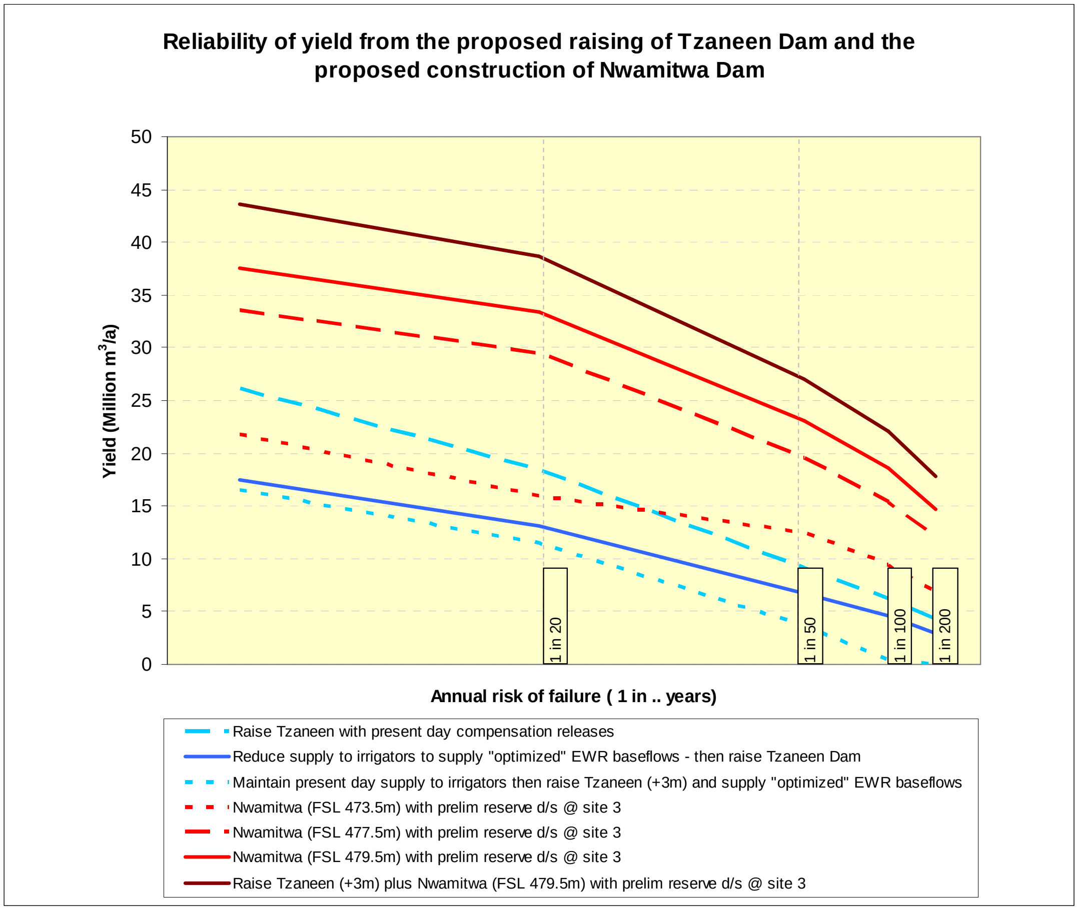

Figure 2.11 **Reliability of the yield from the proposed raising of the Tzaneen Dam and the proposed construction of the Nwamitwa Dam**

In the case of raising Tzaneen Dam, the 1 in 50 year yield increases from 3 Mm^3/a (short dashed light-blue line) to about 7 Mm^3/a (medium solid blue line) if the "optimised" baseflow releases are supplied by the existing users. If the EWR requirement remains as a 14.7 Mm^3/a release from Nondweni then the benefit of raising Tzaneen is about 9 Mm^3/a (long dashed light-blue line).

If the optimised baseflows are supplied by the current users, then constructing Nwamitwa to FSLs of 473.5, 477.5, and 479.5 masl will increase the 1 in 50 year yield of the system by 12, 20, and 23 Mm^3/a, respectively relative to the "optimised" scenario. The yields represented in **Figure 2.11** are summarised in **Table 2.17**.

Table 2.17 Incremental Yields of Proposed Schemes in the Groot Letaba Catchment

Case	HFY previously reported assuming that Nwamitwa provides all the increased EWR releases		Updated yields assuming that Irrigation from Tzaneen is reduced to allow for "optimised' EWR releases						Scenario in \hydro\401775\wrym\tz8sv7a
			HFY	1 in .. year risk of failure					
				10	20	50	100	200	
Raise Tzaneen with present day compensation releases			8	26	18	9	6	4	RH
Reduce supply to irrigators to supply "optimised" EWR base-flows - then raise Tzaneen Dam			5	18	13	7	5	3	R777H
Maintain present day supply to irrigators then raise Tzaneen (+3m) and supply "optimised" EWR baseflows			2	17	11	4	0	0	R777b
Nwamitwa (FSL 473.5m) with preliminary reserve down-stream at Site 3	at77H	4	7	22	16	12	9	7	at77H
Nwamitwa (FSL 477.5m) with preliminary reserve down-stream at Site 3	bt77H	9	13	34	30	20	15	12	bt77H
Nwamitwa (FSL 479.5m) with preliminary reserve down-stream at Site 3	ct77H	14	17	38	33	23	19	15	ct77H
Raise Tzaneen (+3m) plus Nwamitwa (FSL 479.5m) with preliminary reserve down-stream at Site 3	t77FH	18	22	44	39	27	22	18	crt7H

Table 2.18 shows the impact of the upstream developments on the yields at Massingir Dam. The 1 in 50 year yields decrease from a present day value of about 621 Mm^3/a down to 618 Mm^3/a when Nwamitwa Dam (FSL = 479.5 masl) is constructed upstream. In addition, constructing Rooipoort on the Olifants River has a larger impact and reduces the yield to about 585 Mm^3/a.

Table 2.18 Yields at Massingir Dam for Different Upstream Development Levels

Scenarios	HFY	Yields for different recurrence intervals					Scenario in \hydro\401775\wrym\tz8hm and tz8hms
		10	20	50	100	200	
Present day	575	794	718	621	557	501	ph
Reduce supply to irrigators to supply "optimised" EWR baseflows	580	794	723	628	561	504	p777h
Raise Tzaneen with present day compensation releases	574	794	717	623	557	502	rh
Nwamitwa (FSL 473.5m) with preliminary reserve downstream at Site 3	574	785	719	623	560	502	at77h
Nwamitwa (FSL 477.5m) with preliminary reserve downstream at Site 3	573	776	714	622	557	500	bt77h
Nwamitwa (FSL 479.5m) with preliminary reserve downstream at Site 3	573	767	714	621	557	501	ct77h
Raise Tzaneen (+3m) plus Nwamitwa (FSL 479.5m) with preliminary reserve downstream at Site 3	572	766	713	618	557	499	crt7h
Raise Tzaneen (+3m) plus Nwamitwa (FSL 479.5m) with preliminary reserve downstream at Site 3 Rooipoort (RL734)	500	745	662	585	518	469	crtrh

The scenarios and results are summarised in more detail in **Table 2.19**.

Table 2.19 Detailed Description of Scenarios and Yields

Scenario (from \hydro\401775\wrym\tz8Sv7a and tz8hms directories)		Infrastructure										Start levels for stochastics??						Model curtailment of supply from Ebenezer and Tzaneen	Use accruals d/s of Ebenezer / Tzaneen	Reference scenario for fixing GLIB supply. (providing a10h.inf & representing demand CH571 of existing system)	Nodes feeding yield channel							additional freshets	Demand / Supply																													
																													Groot Letaba																				Olifants									
																													EWRs @Sites 7=Optimized scenario from Reserve Det Study t = total (lowflows + floods)						Losses		Stochastic (tz8Sv7a directory)					Incremental benefit											Massingir yield (tz8hmsb)					
		Dap Naude	Ebenezer Dam	Magoebaskloof/H Merensky	Tzaneen Dam	Nwamitwa (RL479.5:187Mcm)	14.7Mm³/a from Nondweni	Massingir (raised 10m)	Flag Boshielo (raised 5m)	De Hoop	Rooipoort	Tzaneen	Nwamitwa	Flag Boshielo	de Hoop	Rooipoort	Other				Ebenezer & u/s	d/s Ebenezer	Magoebaskloof & H Marensky	Tzaneen & u/s	u/s Nwamitwa	u/s Nondweni	Nwamitwa		1	3	4	5	6	7	Factor applied to losses betw Letaba Ranch and the Olifants(0=0,H=halved,F=full)	Historical firm yield	1 in 10 year	1 in 20 yr	1 in 50 yr	1 in 100 yr	1 in 200 yr	wrt	Historical	1 in 10 year	1 in 20 yr	1 in 50 yr	1 in 100 yr	1 in 200 yr	Olifants EWRs	Flag Boshielo	De Hoop	Rooipoort	Historical firm yield	1 in 10 year	1 in 20 yr	1 in 50 yr	1 in 100 yr	1 in 200 yr
Description	channel/dam -->											218	266	117	32	122					480	481	482	483	484	485	266									ch 571								580						711	704	705						
Total yields setting upstream usage to 0																																																										
Ebenezer Dam	E	y	1352.55	y														n	n	n.a	y															27	35	33	30	28	27	na																
Ebenezer Dam + accruals	Ed	y	1352.55	y														n	y	n.a	y	y														37	46	44	40	38	37	EH																
Ebenezer + Tzaneen Dam	T	y	1352.55	y	723.9													n	n	n.a	y	y	y	y												108	138	132	119	112	105	EH																
Ebenezer + Tzaneen Dam + accruals	Td	y	1352.55	y	723.9									100% if active				n	y	n.a	y	y	y	y	y	y										146	182	174	157	146	137	E_dH																
Ebenezer + Raised (+3m) Tzaneen Dam	R_d	y	1352.55	y	723.9													n	y	n.a	y	y	y	y	y	y										151	190	181	164	150	142	E_dH																
Ebenezer + Tzaneen Dam + Nwamitwa + accruals	N	y	1352.55	y	723.9	479.5												n	y	n.a	y	y	y	y	y	y	y									176	222	214	191	178	164	E_dH																
Ebenezer + raised (+3m) Tzaneen Dam + Nwamitwa + accruals	R_dN	y	1352.55	y	726.9	479.5												n	y	n.a	y	y	y	y	y	y	y									179	228	219	195	183	169	E_dH																
Yields "fixing" existing usage																																																										
Present Day	T_dN	y	1352.55	y	723.9		y											n	y	n.a	y	y	y	y	y	y										140	175	167	151	139	131	E_dH																
Present Day with "optimized" EWR releases	T_dEH	y	1352.55	y	723.9													n	y	n.a	y	y	y	y	y	y			C	7	7	7	7	7	0.5	131	170	163	144	134	125	E_dH																
Present Day with raised Tzaneen (+3m) "optimized" EWR releases	R_dEH	y	1352.55	y	723.9									100% if active				n	y	n.a	y	y	y	y	y	y			C	7	7	7	7	7	0.5	1 39	178	170	152	140	129	E_dH																
Ebenezer + Tzaneen Dam + Nwamitwa + accruals with prelim reserve d/s Nwamitwa	T_dNEH	y	1352.55	y	723.9	479.5												n	y	n.a	y	y	y	y	y	y	y		C	C/D_t	7	7	7	7	0.5	154	198	189	169	158	144	E_dH																
Ebenezer + raised (+3m) Tzaneen Dam + Nwamitwa + accruals with prelim reserve d/s Nwamitwa	R_dNEH	y	1352.55	y	726.9	479.5												n	y	n.a	y	y	y	y	y	y	y		C	C/D_t	7	7	7	7	0.5	157	201	195	174	162	149	E_dH																
Massingir yield																																																										
Present Day Supply from Tzaneen Dam	PH	y	1352.55	y	723.9	n.a.	y	125	822	915	n.a.							n	y	n.a	y	y	y	y	y	y		-	C	-	-	-	-	-	0.5														Y	80	80	0	575	794	718	621	557	501
Present Day Supply from Tzaneen Dam	P777H	y	1352.55	y	723.9	n.a.	n	125	822	915	n.a.							n	y	n.a	y	y	y	y	y	y		-	C	7	7	7	7	7	0.5														Y	80	80	0	580	794	723	628	561	504
Raised Tzaneen	RH	y	1352.55	y	726.9	n.a.	y	125	822	915	n.a.							na	y	PH							y	y	C	-	-	-	-	-	0.5								8	26	18	9	6	4	Y	80	80	0	574	794	717	623	557	502
Raised Tzaneen	R777H	y	1352.55	y	726.9	n.a.	-	125	822	915	n.a.							na	y	P777H							y	y	C	7	7	7	7	7	0.5								5	18	13	7	5	3										
Raised Tzaneen	R777b	y	1352.55	y	726.9	n.a.	-	125	822	915	n.a.							na	y	PH							y	y	C	7	7	7	7	7	0.5								2	17	11	4	0	0					580					
RL473.5 Nwamitwa	at77H	y	1352.55	y	723.9	473.5	-	125	822	915	n.a.			100% if active				na	y	P777H							y	y	C	C/D_t	7	7	7	7	0.5								7	22	16	12	9	7	Y	80	80	0	574	785	719	623	560	502
RL477.5 Nwamitwa	bt77H	y	1352.55	y	723.9	477.5	-	125	822	915	n.a.							na	y	P777H							y	y	C	C/D_t	7	7	7	7	0.5								13	34	30	20	15	12	Y	80	80	0	573	776	714	617	557	500
RL479.5 Nwamitwa	ct77H	y	1352.55	y	723.9	479.5	-	125	822	915	n.a.							na	y	P777H							y	y	C	C/D_t	7	7	7	7	0.5								17	38	33	23	19	15	Y	80	80	0	573	767	714	621	557	501
Raised Tzaneen plus RL479.5 Nwamitwa	crt7H	y	1352.55	y	726.9	479.5	-	125	822	915	n.a.							na	y	P777H	Fix equal to demands of reference scenario						y	y	C	C/D_t	7	7	7	7	0.5								22	44	39	27	22	18	Y	80	80	0	572	766	713	618	557	499
Massingir impact : Raised Tzaneen plus RL479.5 Nwamitwa plus Rooipoort	crtRH	y	1352.55	y	726.9	479.5	-	125	822	915	733.9							na	y	P777H							y	y	C	C/D_t	7	7	7	7	0.5								22	44	39	27	22	18	Y	80	80	51	500	745	662	585	518	469
Dam Filling																																																										
Nwamitwa filling : Tz 100% initially	F100H	y	1352.55	y	723.9	479.5	-	125	822	915	n.a.	100%	0%					na	y	P777H								y	C	C/D_t	7	7	7	7	0.5														Y	80	80	0						
	PMedH or PMeeH	y	1352.55	y	723.9	479.5	-	125	822	915	n.a.	70%	n.a	100% if active				na	y	n.a								y	C	C/D_t	7	7	7	7	0.5														Y	80	80	0						
Nwamitwa filling : Tz median initially	FMedH or FMeeH	y	1352.55	y	723.9	479.5	-	125	822	915	n.a.	70%	0%					na	y	PMedH								y	C	C/D_t	7	7	7	7	0.5														Y	80	80	0						

I:\HYDRO\401775\WRYM\Results5d.xls SHEET StochScenarios

2.10 FILLING TIMES OF NWAMITWA DAM

The "filling" time of Nwamitwa Dam was determined assuming that Nwamitwa Dam is constructed without any demands on the dam except those already supplied from the existing system prior to the construction of the proposed Nwamitwa Dam. The dam does not remain full, as the evaporation from the full area supply (25 km²) is of the same order of magnitude as the system yield. The storage of the system with and without Nwamitwa Dam, if both systems supply the same present day demands, was compared for 201 stochastic inflow sequences. For each of these sequences, when the storage of the system with Nwamitwa Dam exceeded the other system by a volume equal to the capacity of Nwamitwa then it was assumed that Nwamitwa had been filled, even if the difference diminished thereafter. **Figure 2.12** shows that there is a 50% chance that the dam will "fill" within about 4 years and an 80 % chance that it will "fill" within 8 years.

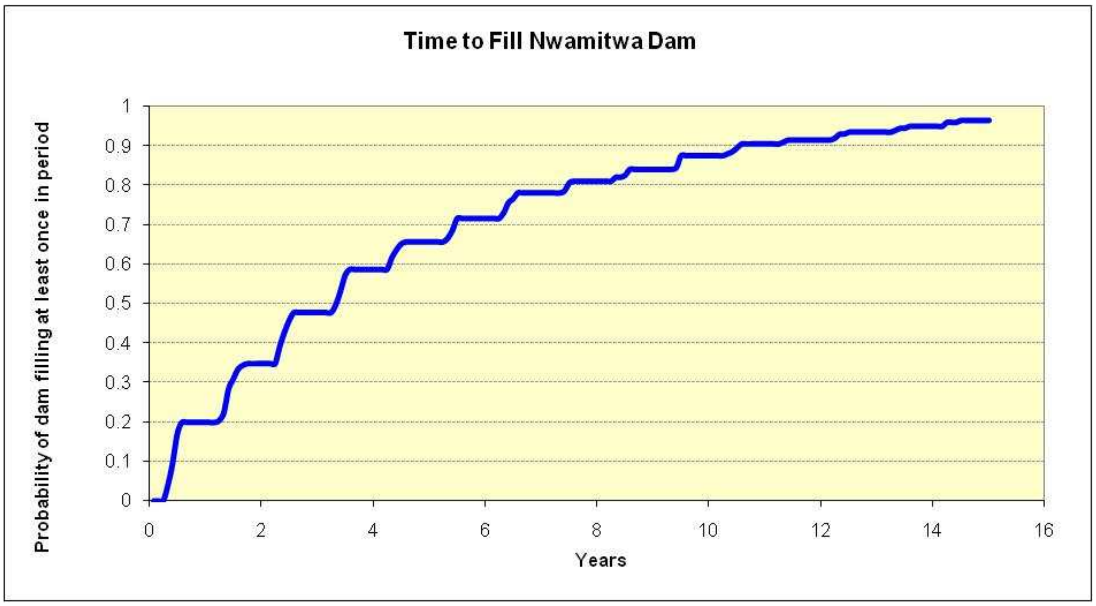

Figure 2.12 Time to fill Nwamitwa Dam

3. IMPACTS OF FUTURE DEVELOPMENTS ON MASSINGIR DAM

This section of the report covers the determination of the historical firm yield and long-term stochastic yield characteristics of Massingir Dam, considering the implications of raising Tzaneen Dam and constructing Nwamitwa Dam and additional dams in the Olifants River Basin.

The historical firm yield of Massingir Dam was determined for different upstream developments and ecological water requirements. The base scenario assumed the following:

The existing Tzaneen Dam operating under current conditions:

- trying to supply demands far exceeding the available yields and imposing restrictions when the storage drops too low; and
- making releases from Tzaneen Dam to support releases of 14.7 Mm^3/a from the downstream Nondweni Weir.

The Olifants River system was operated according to the target drafts adopted in the Olifants River Water Resources Development Project (ORWRDP (DWAF, 2006a)):

- Flag Boshielo Dam raised 10 m (179 Mm^3) and supplying a target draft of 80 Mm^3/a;
- De Hoop Dam constructed to 915 m (347 Mm^3) and supplying 80 Mm^3/a; and
- Massingir Dam was assumed to be raised by 10 m to RL125 m (2 844 Mm^3).

The available streamflow records for the Olifants System only extend to September 1986, so the historical firm yield of Massingir Dam was determined for the period from October 1926 to September 1986, instead of September 2005.

Under present day conditions, the historical firm yield of Massingir Dam (assuming that the dam starts full in October 1926) is 575 Mm^3/a.

If Nwamitwa Dam is constructed, and the following Reserve requirements are met:

- full preliminary Reserve at EWR site 3 downstream of Nwamitwa; and
- Scenario 7 EWR at EWR sites 6 and 7 in the KNP

then the historical firm yield at Massingir Dam reduces to essentially 573 Mm^3/a. If Tzaneen Dam is raised by 3 m, then the historical firm yield of Massingir Dam reduces to 572 Mm^3/a. This means that the EWR releases largely compensate for the impoundment of water during the critical period, even though the spillage from the system will decrease if Nwamitwa Dam is constructed.

Table 3.1 shows that although the flows into Massingir Dam over the full record vary, with the present day scenario exhibiting higher flows due to increased spillage, the flows during the critical period are very similar for all three scenarios. **Figure 3.1** shows the critical period for Massingir from October 1961 to October 1971 (note that the critical period for Tzaneen Dam actually ends in October 1994 and therefore the Tzaneen Dam is not drawn down in the simulated record shown in **Figure 3.1**). During the critical drawdown period from 1961 to 1971, the lower pane of **Figure 3.2** shows that the flows at the Letaba Junction from the Present Day scenario differ from the other scenarios from year to year, although they are very similar when averaged over the entire critical drawdown period.

Table 3.1 Average System Streamflows over Different Periods (Mm^3/a)

Scenario	Critical period May 61 to Sep 71	Full record Oct 1925 to Sep 2005	Dataset in c:\hydro\401775\wrym\TZ8m directory	Reference row no. in Table 2.3 of this report
Present day	491	1 244	pH	2
Nwamitwa	490	1 220	T77H	36
Nwamitwa plus raising of Tzaneen Dam	490	1 217	T77FH	57

If the flow records of the Olifants Catchment are extended, the yield of Massingir may decrease as a result of the extreme dry 1980's to early 1990's. .

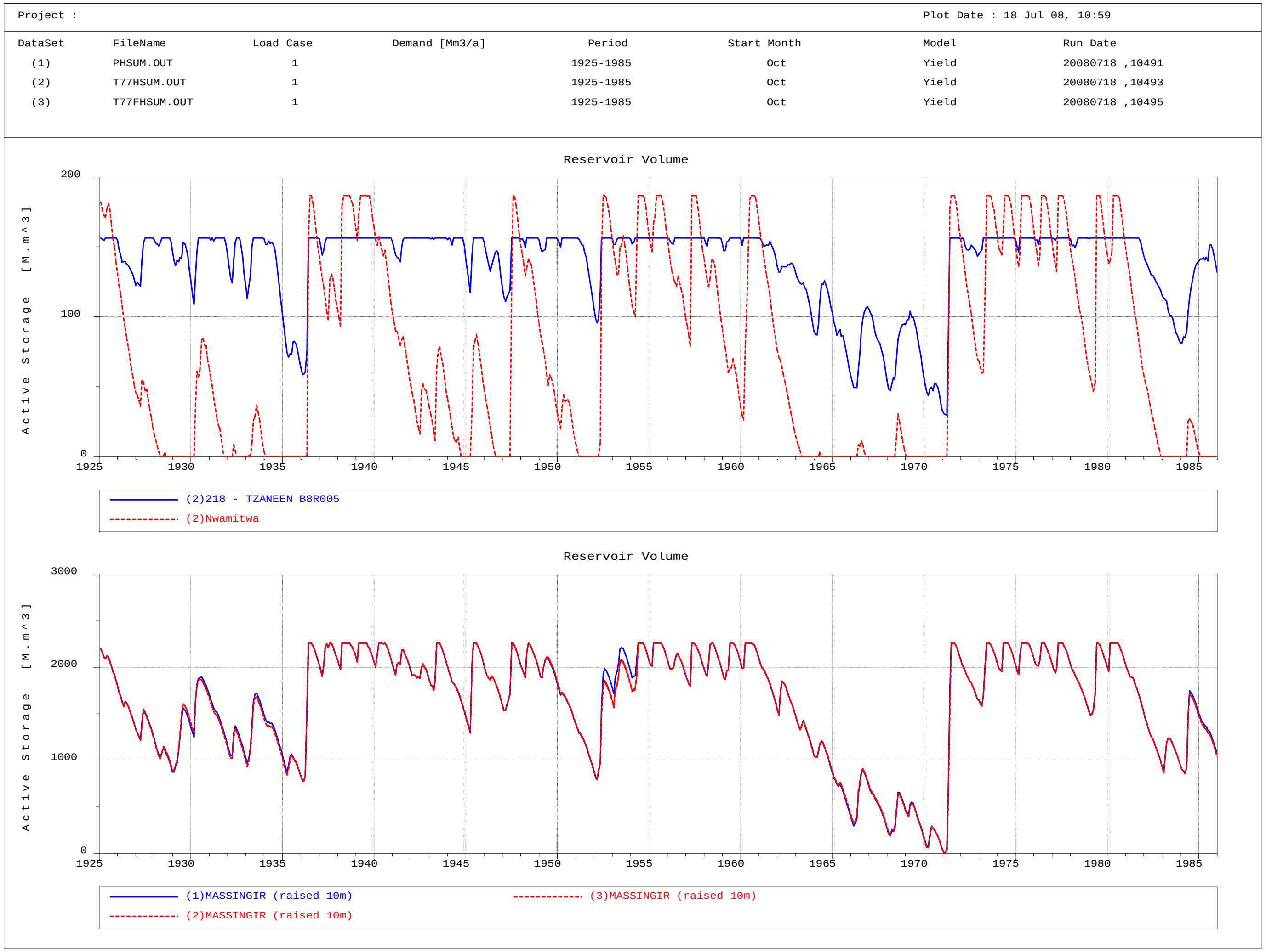

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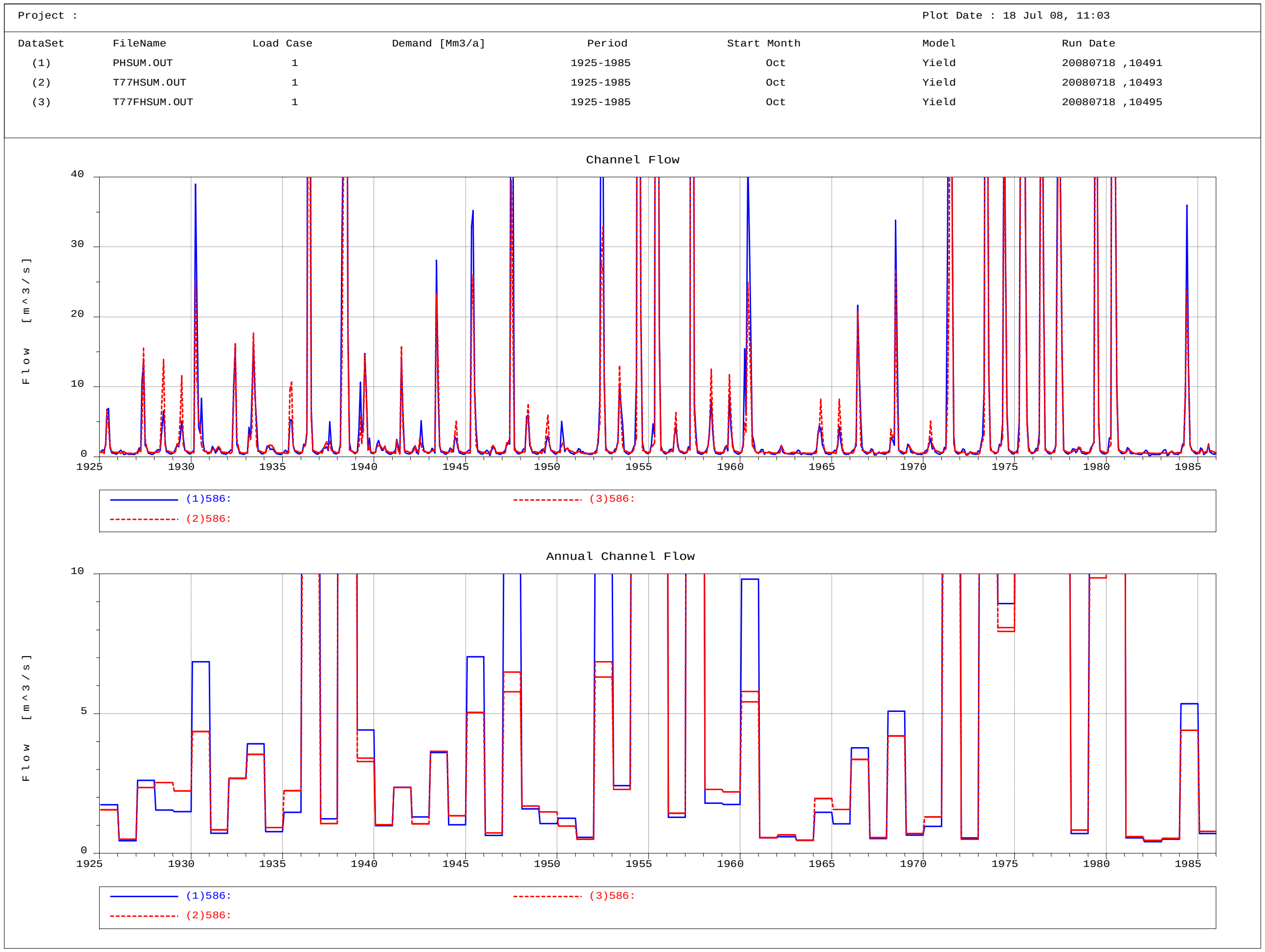
Figure 3.1 Storage trajectories of Tzaneen and Nwamitwa Dam (top pane) and of Massingir Dam (lower pane) under different upstream development scenarios



c:\hydro\401775\wrym\TZ8m\INFLOW.emf

Note: Top pane units are average daily flow and lower pane units are average annual flow

Figure 3.2 Streamflow at the Letaba Junction for present day scenario (SC1), compared with scenarios with the proposed Nwamitwa Dam (SC2) and with the proposed Nwamitwa Dam plus the proposed raising of Tzaneen Dam by 3 metres (SC3).

4. OPERATING RULES

It is important that Nwamitwa Dam and Tzaneen Dam are operated conjunctively to maximise the yield. Nwamitwa Dam should be drawn down first, primarily to minimise evaporation, as the Nwamitwa Dam has a larger surface area for a given storage volume than the Tzaneen Dam and a higher evaporation rate. Under this operating rule, the average net evaporation from the Nwamitwa Dam is about 9 Mm^3/a. Were Nwamitwa Dam to be maintained at its full supply level, the net evaporation would exceed 20 Mm^3/a. A secondary benefit of drawing down the Nwamitwa Dam first, is that this also maximises the storage available to intercept floods from the Letsitele River and Tzaneen Dam.

One of the challenges of operating the Nwamitwa and Tzaneen dams as a system is the equitable distribution of water between two user groups with very different reliability requirements. On the one hand, the domestic and industrial consumers require a high reliability of water supply, whereas the irrigators have adapted to a lower reliability of supply. The allocation to the urban consumers must be based on the additional yield from the Nwamitwa Dam, to ensure that the irrigators continue to receive the same water at the same reliability. The supply to the irrigators must be curtailed in time to ensure that the domestic consumers have a sufficiently reliable source. This curtailment of the irrigators and, in more extreme cases, the domestic consumers, would be based on the combined total storage in the Tzaneen and Nwamitwa dams through the year. If the Hans Merensky and Magoebaskloof dams are under-utilised then the storage in these dams could also be considered. Unless all stakeholders understand the operating rule there could be conflicts when the irrigators are curtailed and there is still a fair amount of water available in the Tzaneen Dam.

Theoretically, it could be possible to keep track of the additional water accruing in the Nwamitwa Dam that would not have been available to the current irrigators. In this way, Nwamitwa would be treated as a separate dam, storing water for the domestic consumers. The disadvantage of this approach is that the evaporation from the system would increase.

5. THE RAISING OF DAP NAUDE AND EBENEZER DAMS

The incremental increases in the firm yield of the Ebenezer/Tzaneen system from raising Ebenezer by 5 and 10 meters were 2.3 and 4.5 Mm^3/a, respectively. If Nwamitwa Dam was constructed first, then the incremental firm yield from raising Ebenezer Dam reduces from 4.5 to 3.9 Mm^3/a.

The Dap Naude Dam has a smaller capacity, inflow and smaller potential increase in storage than Ebenezer Dam. Therefore the potential yield increase from raising the Dap Naude Dam will be significantly less than that for Ebenezer Dam and was not evaluated.

6. CONCLUSIONS

The conclusions drawn from the work described in this report are given below.

6.1 WATER RESOURCE ANALYSIS (YIELD OF THE SYSTEM)

The observed freshets were missing in the simulated streamflows lower down the Groot Letaba River, a feature that was evident in the original calibration. These freshets would contribute to the yield of Nwamitwa Dam as they would exceed the abstraction capacity of the irrigators, and because they would help recharge the environment. A re-examination of the Pitman Parameters indicated that modifying these parameters would improve the calibration and the observed record was reasonable.

Due to the missing freshets, the extended hydrology does not adequately reflect the small flood events in the system. A series of these events whose annual MAR of 34 Mm^3/a was based on observed flow records was therefore added to the hydrology files in the WRYM in order to try to simulate the freshets. If the extended hydrology was used unmodified, the proposed Nwamitwa Dam had zero yield, mainly because of the obligation to meet the EWR. Once the additional freshets were added to the hydrology, these low flows contributed significantly to the EWR requirement, which meant that the yield of the proposed Nwamitwa Dam increased to 14 Mm^3/a (for scenario ct77H, refer to row no. 44 in **Table 2.3** of this report).

The WRYM was found to be extremely sensitive to the way in which the EWR was implemented. This is a concern because of the preliminary nature of the EWR and the lack of detail available regarding exactly how it needs to be implemented. Considerable further work is required to refine the EWR with particular attention to how it is going to be implemented and modelled within the WRYM.

The historical firm yield at Nwamitwa decreases from 18 to 6 Mm^3/a, depending on the factor applied to the losses downstream of the Letaba Ranch. Losses were determined between the Letaba Ranch and the Black Heron Weir for dry periods when there were no accruals from the Klein Letaba tributary that enters between the two gauges. However, this approach did not allow one to estimate the losses over the full critical period which would include periods of accruals. It is possible that the losses over the critical period might be less than the losses determined during the dry period. The losses in the system can vary depending on the antecedent river flow and on the operation of the system. If the antecedent conditions are wet then water may seep out of the sandy river banks into the river channel. The operation of the system can also affect the losses. During droughts the GLWUA reduced their losses by releasing water to Nondweni weir as slugs (short high flow releases) rather than as constant low flows. If a similar approach could be adopted for the Kruger Park's water requirements then losses could be reduced.

The benefit of installing fuse gates to raise the full supply level of Tzaneen Dam by 3 metres (from a gross storage of 158 Mm^3 to 193 Mm^3) was determined by finding the increase in the firm yield of the Tzaneen/Nwamitwa system. This benefit equated to about 4 Mm^3/a.

6.2 IMPACTS OF FUTURE DEVELOPMENTS ON MASSINGIR DAM

The construction of the proposed Nwamtiwa Dam and raising of Tzaneen Dam will have very limited impact on the yield of Massingir Dam (reduction of 3 Mm^3/a on 575 Mm^3/a). The development of the proposed Rooipoort Dam will reduce the historical firm yield of Massingir Dam to 500 Mm^3/a.

6.3 OPERATING RULES

Nwamitwa Dam should be drawn down first, primarily to minimise the evaporation, as the Nwamitwa Dam has a larger surface area for a given storage volume than the Tzaneen Dam and a higher evaporation rate. Under this operating rule the average net evaporation from the Nwamitwa Dam is about 9 Mm^3/a. Were Nwamitwa Dam to be maintained at its full supply level, the net evaporation would exceed 20 Mm^3/a. A secondary benefit of drawing down the Nwamitwa Dam first, is that this also maximises the storage available to intercept floods from the Letsitele River.

6.4 THE RAISING OF DAP NAUDE AND EBENEZER DAMS

As stated in Section 5, the incremental increases in the firm yield of the Ebenezer/Tzaneen system from raising Ebenezer by 5 and 10 meters were 2.3 and 4.5 Mm^3/a, respectively. If Nwamitwa Dam was constructed first, then the incremental firm yield from raising Ebenezer Dam reduces from 4.5 to 3.9 Mm^3/a. (scenarios et5tn, eatn and eatnb).

The Dap Naude Dam has a smaller capacity, inflow and smaller potential increase in storage than Ebenezer Dam. Therefore the potential yield increase from raising the Dap Naude Dam will be significantly less and was not evaluated.

6.5 SUMMARY OF MAIN CONCLUSIONS

A summary of the main conclusions emanating from the Water Resource Analysis is given below:

- Currently the yield of most of the major surface water schemes is over-allocated. The result of this pressure on the available surface water supply is that the supply of water to the irrigation sector is curtailed to below their allocations on an ongoing basis. The recent determination of the EWR has introduced an additional requirement, which has increased the pressure on the available surface water.

- One of the major conclusions from the water resource analysis was that the extended hydrology did not adequately reflect the low flows in the system. If the extended hydrology was used unmodified, the proposed Nwamitwa Dam would have zero yield, mainly because of the obligation to meet the EWR. Once the additional freshets (a series of low flow events based on observed flow records, with a MAR of 34 Mm^3/a) were added to the simulated streamflows, the yield of the proposed Nwamitwa Dam increased to 14 Mm^3/a (scenario ct77H). This indicates that the results at this study cannot be accepted before a thorough re-calibration of the flows are done.

- The yield was found to be extremely sensitive to the way in which the EWR was implemented in the WRYM. This is a concern because of the preliminary nature of the EWR and the lack of detail available regarding exactly how it needs to be implemented.

- A Reserve Determination Study still needs to be undertaken for the proposed Nwamitwa Dam. The most recent Reserve Determination Study did not consider the modification in flows caused by the Nwamitwa Dam and the possible impact of channel losses along the Groot Letaba River.

- The historical firm yield at Nwamitwa decreases from 18 to 6 Mm^3/a, depending on the factor applied to the losses, i.e. 100%, 50% or 0%, downstream of the Letaba Ranch. If a 50% loss factor was assumed, the historical firm yield of Nwamitwa Dam would be 14 Mm^3/a (scenario ct77H). This yield assumes that the environmental water requirements at EWR Site 3 were met by the proposed Nwamitwa Dam.

- Given the modelling assumptions made regarding the freshets, the uncertainity regarding the implementation of the EWR and the coarse assumptions regarding "river losses", the yield results for the proposed Nwamitwa Dam should be viewed as preliminary until the recommended further studies have been undertaken.

- The incremental increases in the firm yield of the Ebenezer/Tzaneen system from raising Ebenezer by 5 and 10 meters were 2.3 and 4.5 Mm^3/a, respectively. If Nwamitwa Dam was constructed first, then the incremental firm yield from raising Ebenezer reduces from 4.5 to 3.9 Mm^3/a.

- There is a 50% probability that the proposed Nwamitwa Dam (FSL 479.5 masl) will fill within four years and a 80% probability that the dam will fill within eight years.

- The construction of the proposed Nwamtiwa Dam and raising of Tzaneen Dam will have very limited impact on the yield of Massingir Dam (reduction of 3 Mm^3/a on 575 Mm^3/a). The development of the proposed Rooipoort Dam will reduce the historical firm yield of Massingir Dam to 500 Mm^3/a.

- It is important that Nwamitwa Dam and Tzaneen Dam are operated conjunctively to maximise the yield. Nwamitwa Dam should be drawn down first, primarily to minimise the evaporation, as the Nwamitwa Dam has a larger surface area for a given storage volume than the Tzaneen Dam and a higher evaporation rate. Under this operating rule, the average net evaporation from the Nwamitwa Dam is about 9 Mm^3/a. Were Nwamitwa Dam to be maintained at its full supply level, the net evaporation would exceed 20 Mm^3/a. A secondary benefit of drawing down the Nwamitwa Dam first, is that this also maximises the storage available to intercept floods from the Letsitele River and Tzaneen Dam.

7. RECOMMENDATIONS

The following recommendations are made:

- Given the stressed nature of the available water resources and the anticipated growth in primary water requirements, it is important to undertake verification and validation of water use in the Groot Letaba Catchment.

- A Reserve Determination Study for the proposed Nwamitwa Dam needs to be undertaken. The EWR needs to be refined, and more attention needs to be given to how the EWR should be applied and modelled to reflect the day-to-day operation more accurately in the WRYM. Implementation of the EWR which relates to the way the EWR is modelled in the WRYM needs to be clarified with DWA and other consultants using the WRYM.

- The reduced ecolocial water requirement scenario ("Scenario 7") was developed without considering the proposed Nwamitwa Dam. It relies on unregulated flows in the Letsitele River to supply the EWR. If Nwamitwa Dam were constructed, the Letsitele River flows would be captured in the dam. Compliance with the reserve would need to be rechecked.

- Further investigations should be undertaken in order to refine the assumptions made regarding "river losses". This will enable the yield results to be portrayed with a higher level of certainity.

- The historical firm yield of the proposed Nwamitwa Dam should be re-determined once the results of the abovementioned further investigations are available and once the rainfall runoff model has been re-calibrated. The results at this study cannot be accepted before a thorough re-calibration is done.

8. REFERENCES

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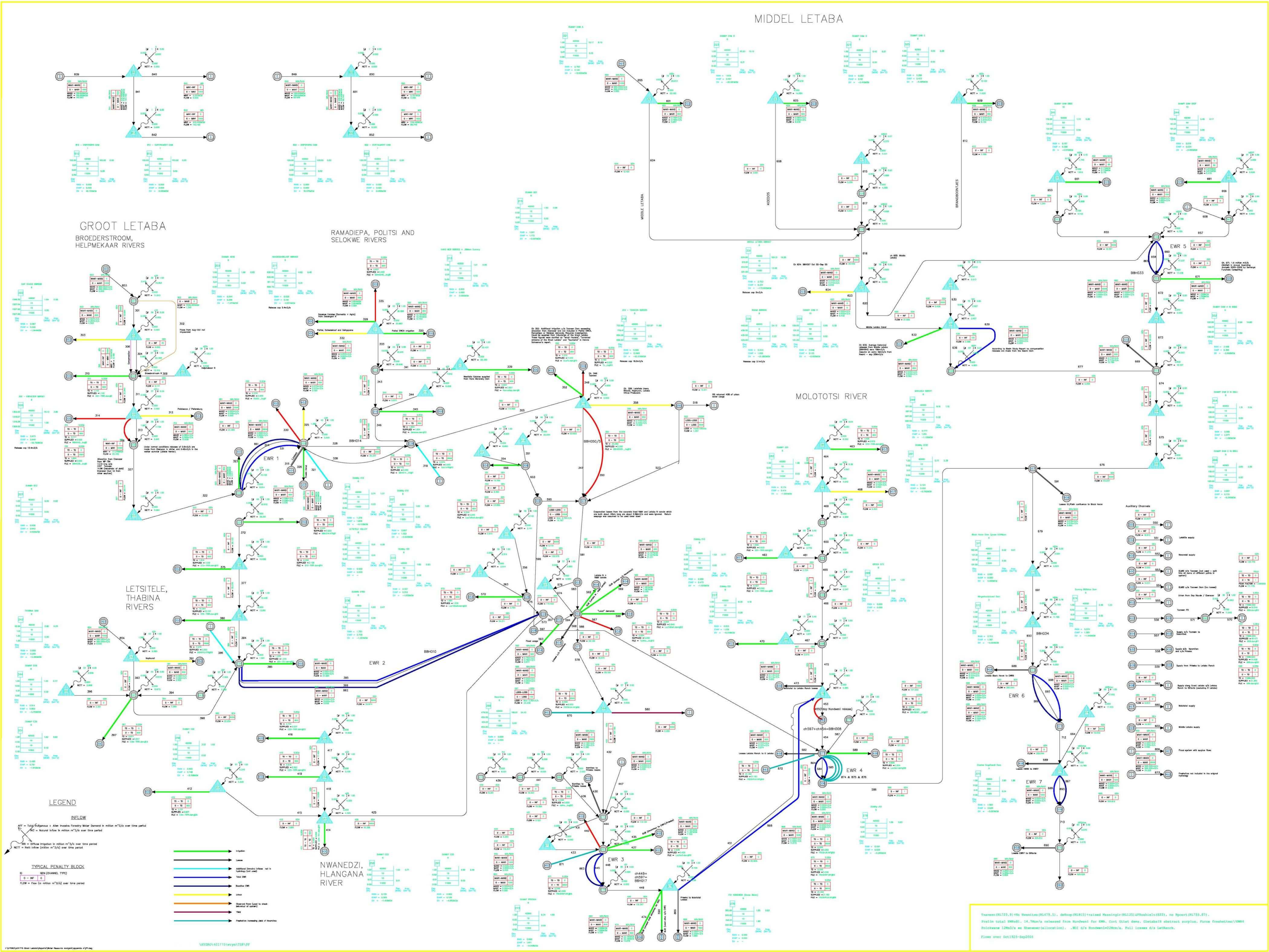
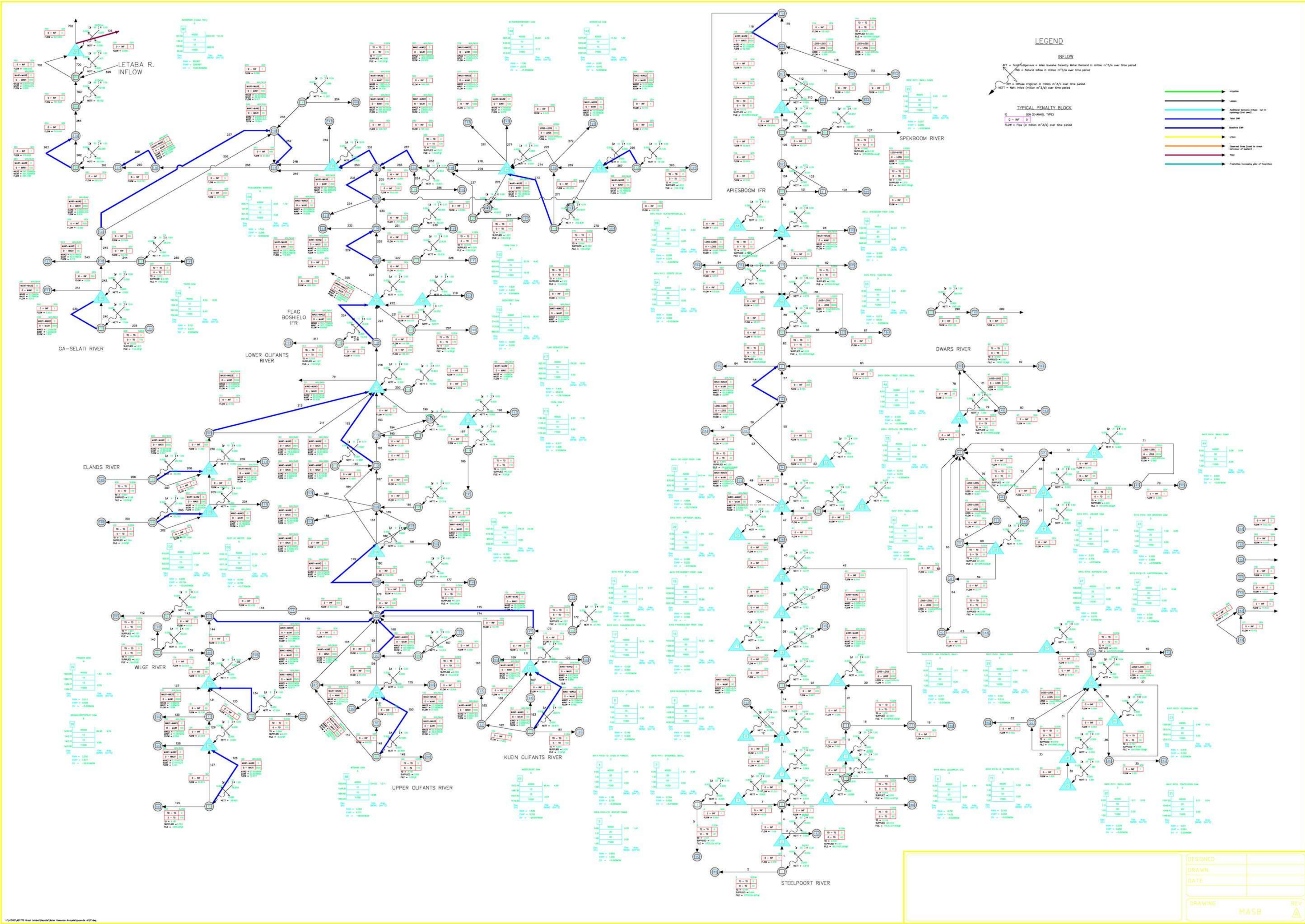
APPENDIX A : System Diagram


MIDDEL LETABA
GROOT LETABA
BROEDERSTROOM, HELPMEKAAR RIVERS
RAMADIEPA, POLITSI AND SELOKWE RIVERS
MOLOTOTSI RIVER
LETSITELE, THABINA RIVERS
NWANEDZI, HLANGANA RIVER
EWR 1
EWR 2
EWR 3
EWR 4
EWR 5
EWR 6
EWR 7
LEGEND
INFLOW
TYPICAL PENALTY BLOCK


LETABA R. INFLOW
LEGEND
INFLOW
TYPICAL PENALTY BLOCK
SPEKBOOM RIVER
APIESBOOM IFR
GA-SELATI RIVER
FLAG BOSHIELO IFR
LOWER OLIFANTS RIVER
DWARS RIVER
ELANDS RIVER
WILGE RIVER
UPPER OLIFANTS RIVER
KLEIN OLIFANTS RIVER
STEELPOORT RIVER

APPENDIX B : Details of Compliance with EWR at Sites 3-7

APPENDIX B

DETAILS OF COMPLIANCE WITH EWR AT SITES 3 - 7

1. EWR SITE 3

The analysis assumed that the proposed supply of about 22 Mm^3/a to emerging farmers downstream of Nondweni had been implemented. This development would shift the usage of water downstream so that more water flowed past EWR Site 3. Should the development not proceed then the streamflow at the site would reduce by the approximately 14 Mcm/a that was assumed to be supplied to these emerging farmers. The analysis also assumed that freshets between Nwamitwa and EWR Site 3 contribute 5 Mm^3/a to the EWR flows at Site 3.

Under these assumptions, the streamflow at Site 3 appears to be adequate prior to the construction of Nwamitwa Dam. The streamflow for scenarios p0 (black solid) and p7770 (black dashed) are above the required streamflow (solid blue line). The two scenarios modelling the situation after the construction of Nwamitwa Dam (t7_0 and tt_0) both assume that releases are made to supply the total preliminary reserve requirement at Site 3. These releases, together with the additional inflows from downstream of the dam, ensured that the requirements at Site 3 were satisfied.

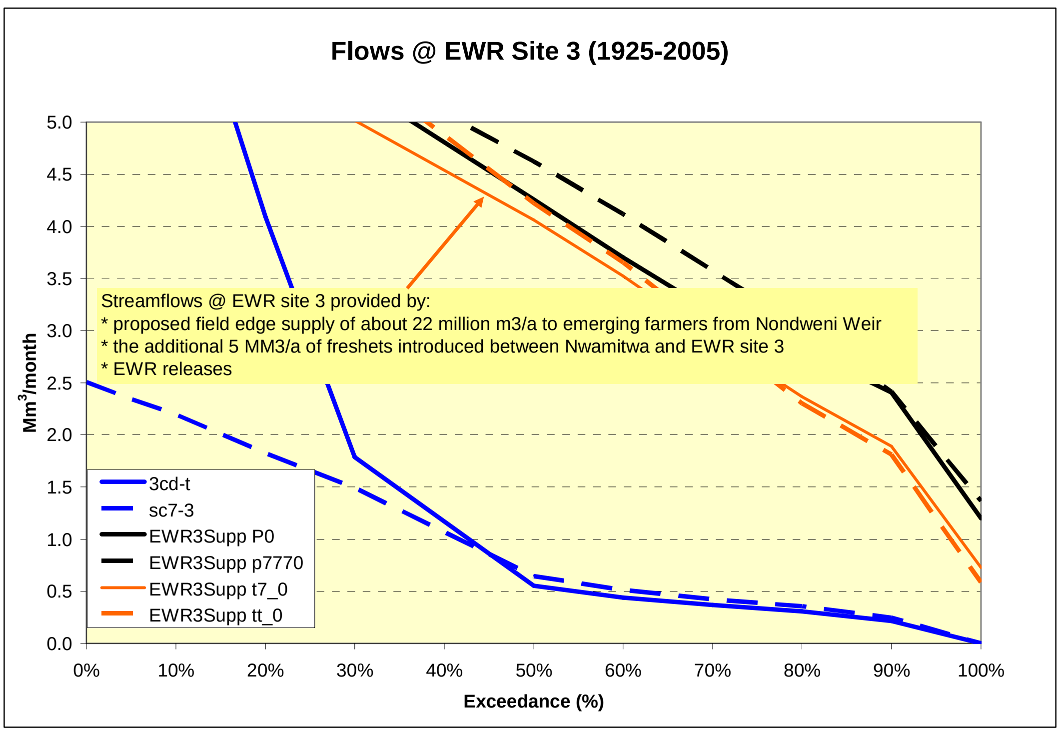


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Figure 1 Simulated streamflows and EWR requirements at EWR Site 3

2. EWR SITE 4

EWR Site 4 near the Letaba Ranch in the WRYM was assumed to have no demands located downstream and did not benefit from this baseflow (unlike Site 3). However, EWR Site 4 does receive accruals from tributaries such as the Molototsi (28 Mm^3/a). Because the streamflows generated by the WRYM did not reflect the freshets in the system, an additional 21 Mm^3/a was assumed to accrue between EWR Site 3 (near Prieska) and EWR Site 4. The freshets were assumed to contribute directly to the EWR requirements at Site 4 and the additional inflow sequence of these freshets was in fact obtained by factoring the flood component of the EWR requirement sequence.

Figure 2 shows that before the construction of Nwamitwa Dam, the total EWR at Site 4 appear to be satisfied. After the construction of Nwamitwa Dam the EWR requirements at Site 4 appear to be satisfied if the total EWR requirements at Site 3 are satisfied. However, this relies on the significant contribution of the additional freshets introduced into the system. If this contribution is removed then the streamflow associated with this scenario (short dashes in **Figure 2**) is significantly less than the EWR (solid blue line).

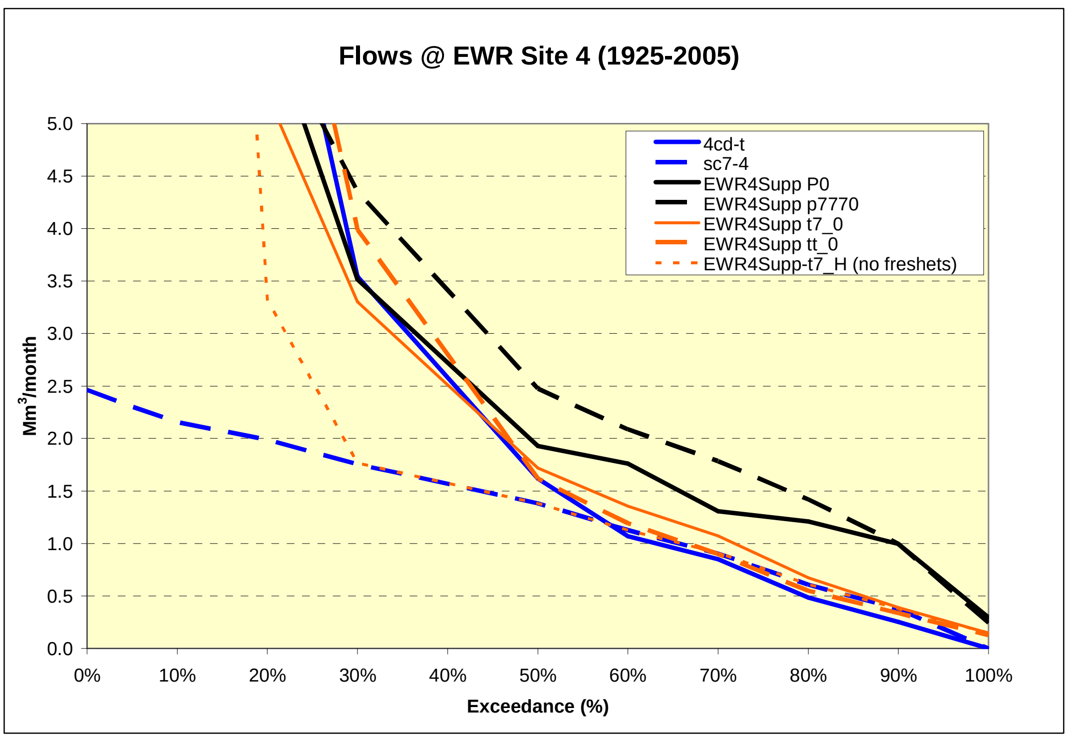

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Figure 2 Simulated streamflows and EWR requirements at EWR Site 4

3. EWR SITE 5

EWR Site 5 is located on the Klein Letaba River downstream of the confluence of the Middle and Klein Letaba Rivers. The reliability of the hydrology and demands is low. Over-allocation in the Middle Letaba results in the dam failing and not being able to supply the EWR for about 50% of the time. Nevertheless, the reach is currently classified as a Category C river, possibly due to the contribution from the less regulated Klein Letaba River. A comprehensive review of the hydrology and water allocations in the Middle and Klein Letaba Rivers is required to determine a fair contribution from this river to the EWR.

Consequently, the Middle Letaba at present cannot be relied on to support the Groot Letaba in meeting the EWR requirements downstream of their confluence.

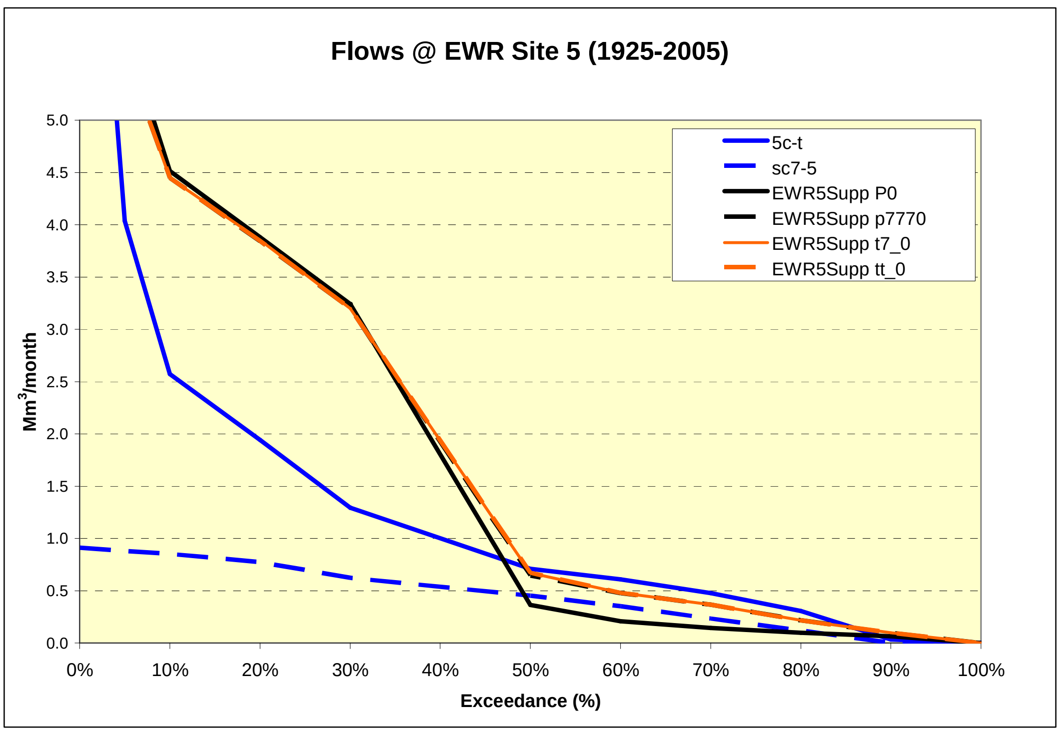

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Figure 3 Simulated streamflows and EWR requirements at EWR Site 5

4. EWR SITE 6

The streamflows generated at Site 6 also assume that the additional freshets introduced in the Groot Letaba are realistic. Prior to the construction of Nwamitwa Dam, if a volume of 14.7 Mm^3/a is released from Nondweni (Scenario p0), or if the Scenario 7 requirement area is supplied throughout the system (Scenario p777), then the EWR requirements at Site 6 will also be satisfied.

The baseflow requirements at Sites 6 and 7 are greater than those at Sites 3 and 4 (see **Figure 4**). This means that after the construction of Nwamitwa Dam, the scenarios that meet the EWR requirements at Sites 3 and 4, on the Groot Letaba upstream of the Klein Letaba confluence, could result in shortfalls at Sites 6 and 7, if there are insufficient contributions from the Klein Letaba. For this reason, Scenarios t7_0 and tt_0 (solid and dashed orange line) drop below the required flow (solid blue line) at exceedance probabilities above 65%.

The same trend is evident for the scenario supplying the total EWR requirement at Sites 3 and 4 u/s of the KNP. Interestingly, because the "Scenario 7" is obtained by factoring the baseflow component of the total EWR requirement by 114%, the low flow requirement of the Scenario 7 is larger than the total EWR requirement.

The hydrology in the KNP may also be missing freshets that would help to increase the streamflows in the KNP and reduce the reliance on the Groot Letaba. This should be checked and the system recalibrated if necessary.

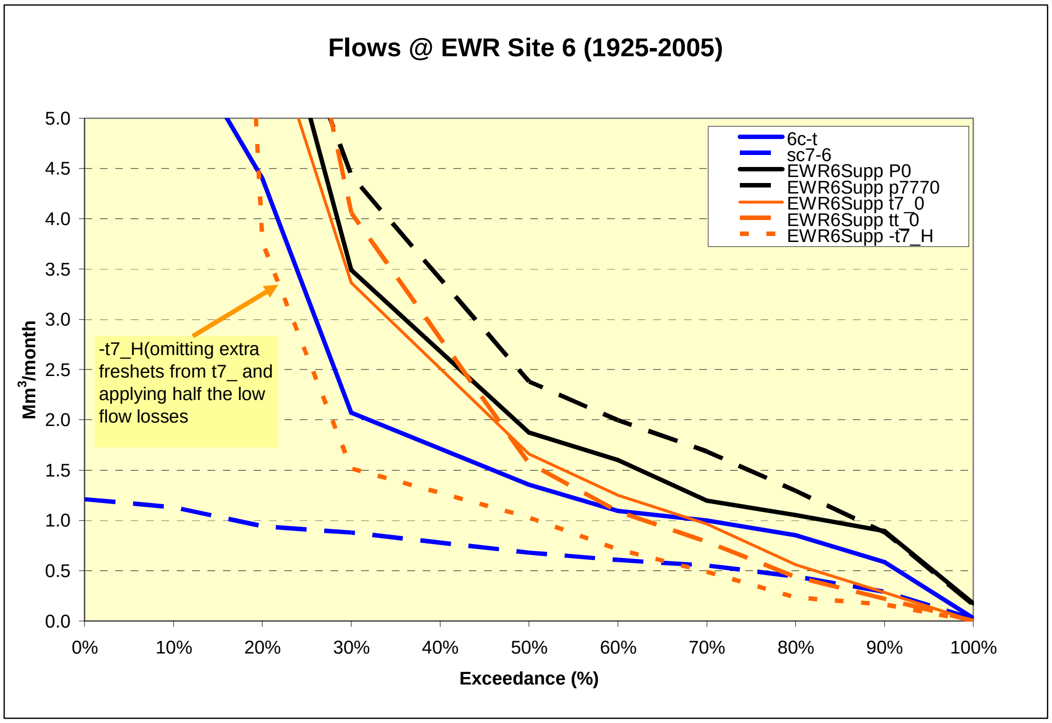

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Figure 4 Simulated streamflows and EWR requirements at EWR Site 6

If the river channel losses in the KNP are taken into account then the streamflows at the sites drop further below the requirement. For instance, for the case when the total EWR requirement is supplied at Site 3 and the "Scenario 7" requirement is supplied at Site 4, then **Figure 5** shows how increasing the losses from 0 (Scenario t7_0 : solid orange line) to half (Scenario t7_h : solid red line) to one times (Scenario t7_f : solid brown line) the measured low flow losses draws the supply further and further below the required volume.

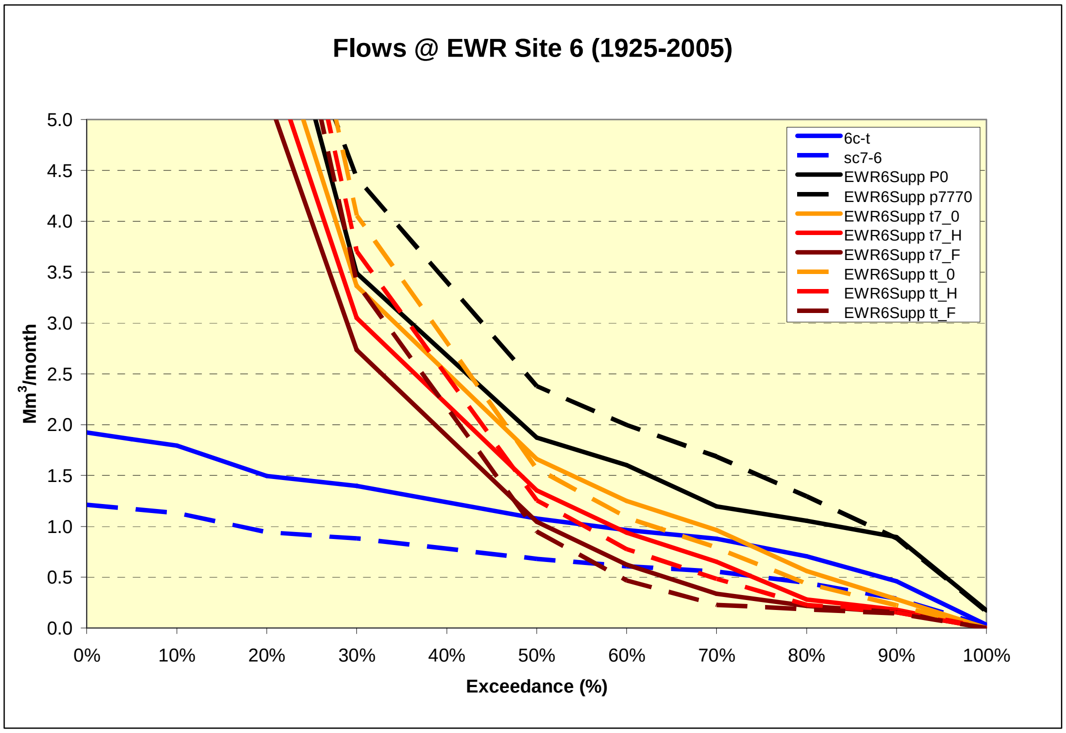

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Figure 5 Simulated streamflows and EWR requirements at EWR Site 6 for scenarios before and after the construction of Nwamitwa. The Nwamitwa scenarios (t7_,tt_,-t7_) focus on meeting EWR requirements upstream of the Klein Letaba confluence – not downstream

If the releases are made from the Groot Letaba to meet the "Scenario 7" requirements at EWR Site 6 and 7 in the KNP, then the total streamflows at Site 6 appear to exceed the requirements – see Scenarios t77H and t77F in **Figures 6** and **7**, respectively.

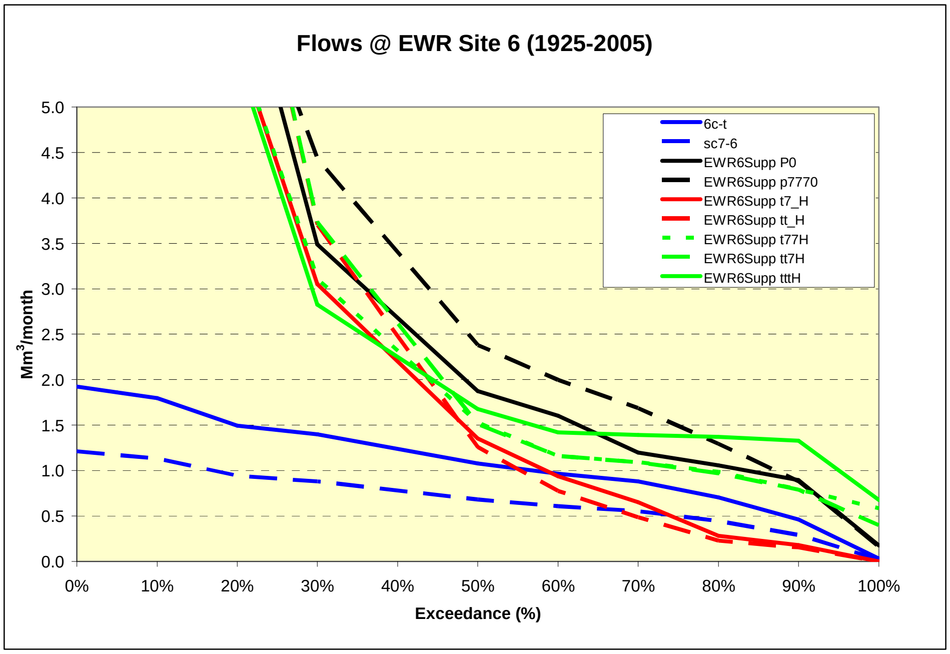

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Figure 6 Simulated streamflows and EWR requirements at EWR Site 6 assuming low flow losses are factored by 0.5 to obtain average losses over critical period

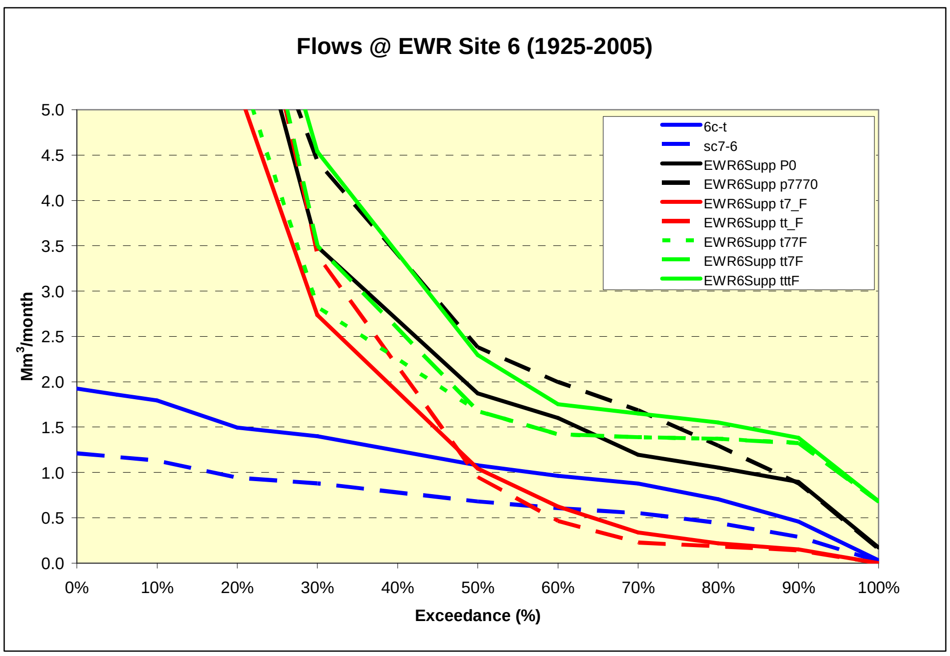

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Figure 7 Simulated streamflows and EWR requirements at EWR Site 6 assuming low flow losses are factored by 1.0 to obtain average losses over critical period

5. EWR SITE 7

The conditions at EWR Site 7 are similar to Site 6 except that some additional accruals and especially losses occur along the intervening river reach. Again the EWR requirements (solid blue line in **Figure 8**) appear to be supplied under present day conditions (Scenarios p0 and p7770 shown using solid and dashed black lines in **Figure 8**). If Nwamitwa is constructed then additional releases may be necessary for the reach downstream of the Groot and Klein Letaba as the scenarios without additional supplements (solid and long-dashed orange lines representing Scenarios t7_0 and tt_0 in **Figure 8**) are less than the required volume about 30-40% of the time. If the assumed freshets introduced between Nwamitwa and the Klein Letaba confluence are omitted (short-dashed orange line in **Figure 8**) then the supply is less than the required volume about 70% of the time.

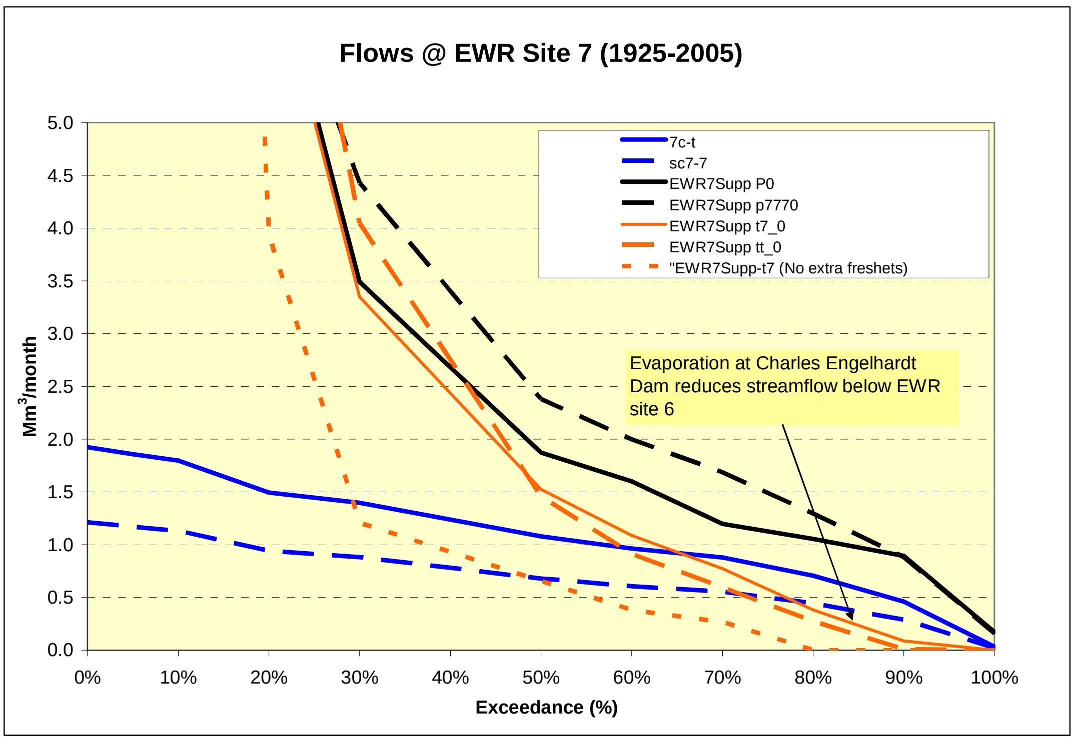

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Figure 8 Simulated streamflows and EWR requirements at EWR Site 7 with the impact of omitting the extra freshetts shown with the short orange dashed line

If the streamflows downstream of the confluence of the Groot and Klein Letaba are monitored and additional releases are made from the Nwamitwa Dam then the streamflows at Site 7 increase. **Figure 9** shows the streamflows at Site 7 if the average losses in the critical period are assumed to be half the observed low flow losses. If releases are made to meet "Scenario 7" at Site 7 then a slight shortfall still occurs at the site because the Scenario 7 requirements used are slightly less than the total EWR requirements. Recalibration of the hydrology downstream of the Letaba Ranch might introduce additional freshets that would help to sustain the ecology. Also, the natural flow sequences on which the EWR requirements are based have not been reduced to account for the losses. If the total EWR requirements at Sites 3 and 4 are met in addition to Scenario 7 at Sites 6 and 7, then the modelled stream flow (long-dashed green line in **Figure 9**) is above the requirement (solid blue line in **Figure 9**).

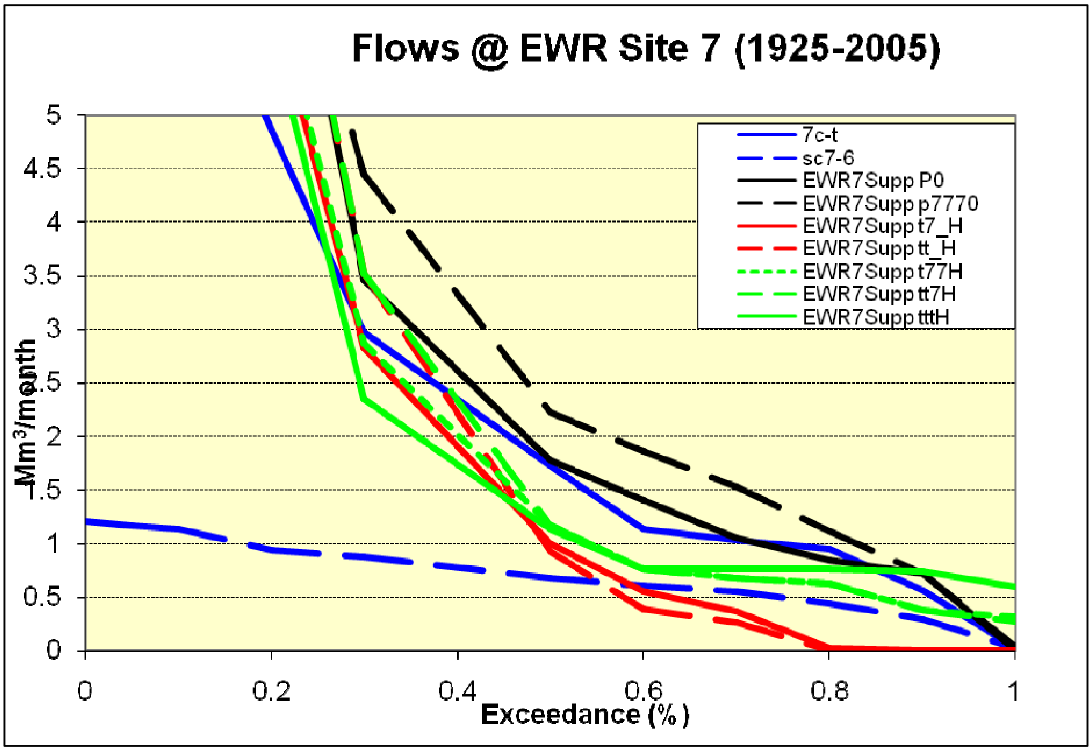

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Figure 9 Simulated streamflows and EWR requirements at EWR Site 7 assuming that the average loss during the critical period is half the low flow losses loss

Figure 10 shows the further reduction in the streamflows that occurs when the average loss rate over the critical period equals the observed low flow loss rate.

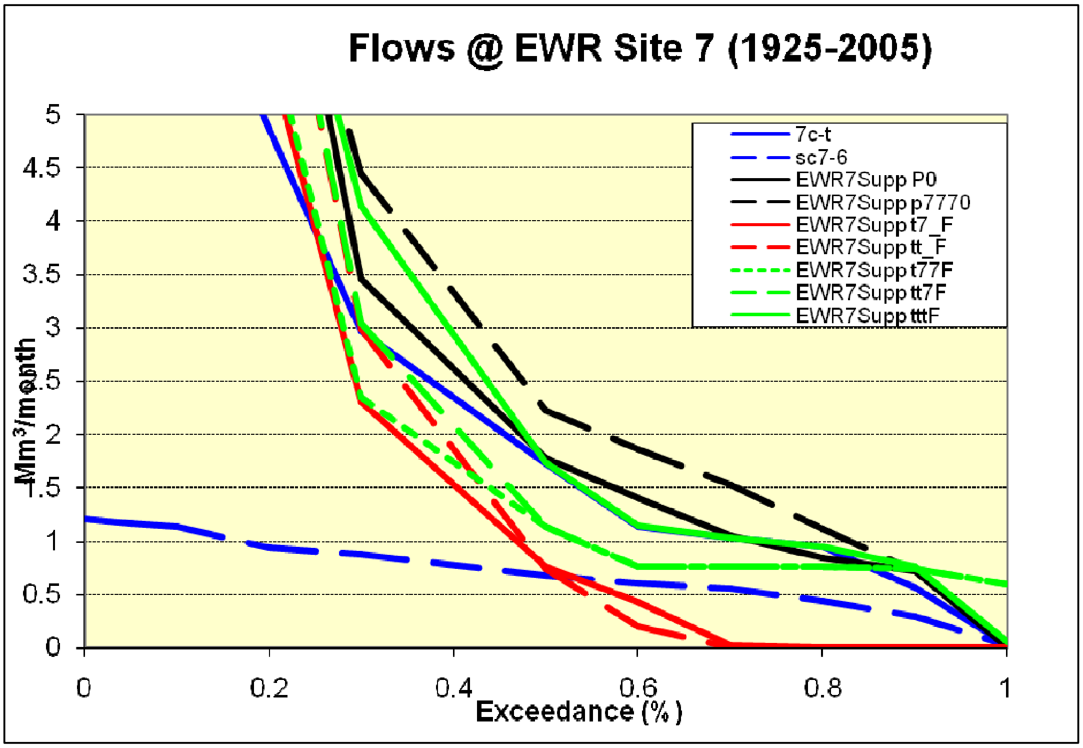

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Figure 10 Simulated streamflows and EWR requirements at EWR Site 7 assuming that the average loss during the critical period is equal to the low flow loss

Figure 11 compares the Preliminary Reserve at EWR site 7 with the streamflow under natural, present day (no Nwamitwa) and future conditions (with Nwamitwa) during the protracted dry period from 1961 to 1971 when the Tzaneen/Nwamitwa Dam would not have spilt. The present day summer streamflows in 1963/64 and in 1967/68 appear to be negligible, and result in a very stressed environment.

Under future conditions Nwamitwa was assumed to meet the reserve at Site 3 and to make releases to meet "Scenario 7" requirements at EWR Sites 4, 6 and 7.

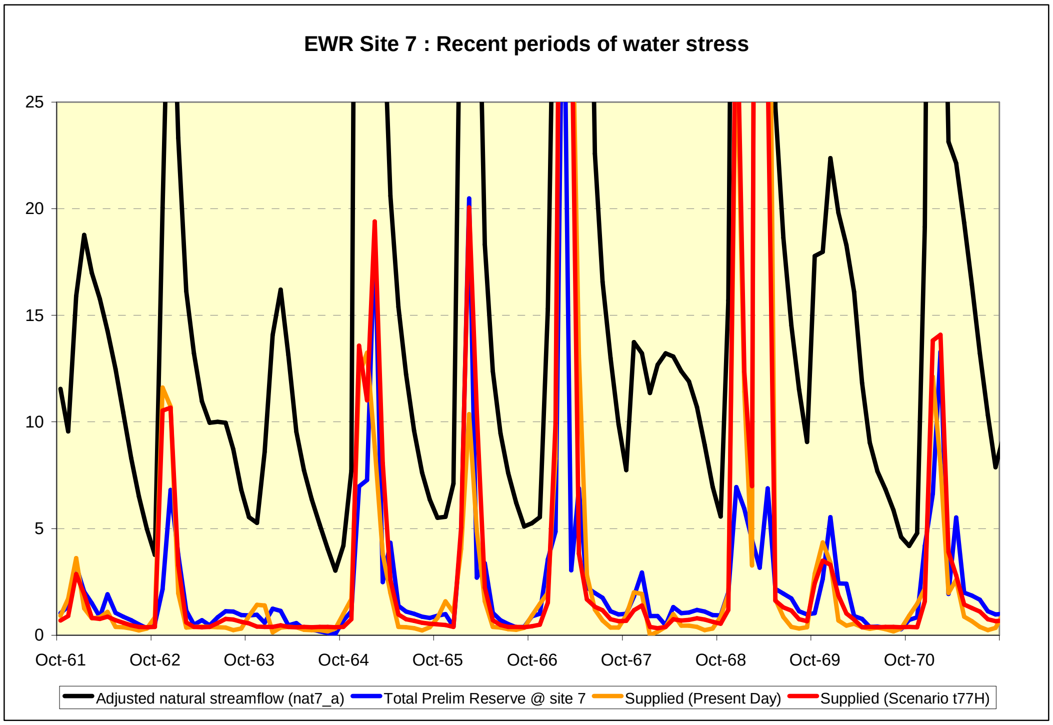

Figure 11 Streamflow at EWR Site 7 from 1961 to 1970 under natural (black), present day (orange) and future (Nwamitwa scenario t77H – red) conditions compared to the EWR requirement (blue)

More recent streamflows at Site 7 are shown in **Figure 12**.

The upstream development of the catchment has meant that the summer streamflows in 1991/92 and 2002/3 were very low and the behaviour of this site during these recent events should provide a valuable insight into its environmental water requirements. According to the Preliminary Reserve these streamflows can drop to almost zero for about five to seven sequential months during the droughts in 1964 and 1992. Should the environmental releases from the Tzaneen Dam rather be aimed at providing relief during these extreme events rather than providing supplementary freshets during average summers?

Note from 1996 to 2001, the Tzaneen and Nwamitwa Dams would have spilt as they were fairly full.

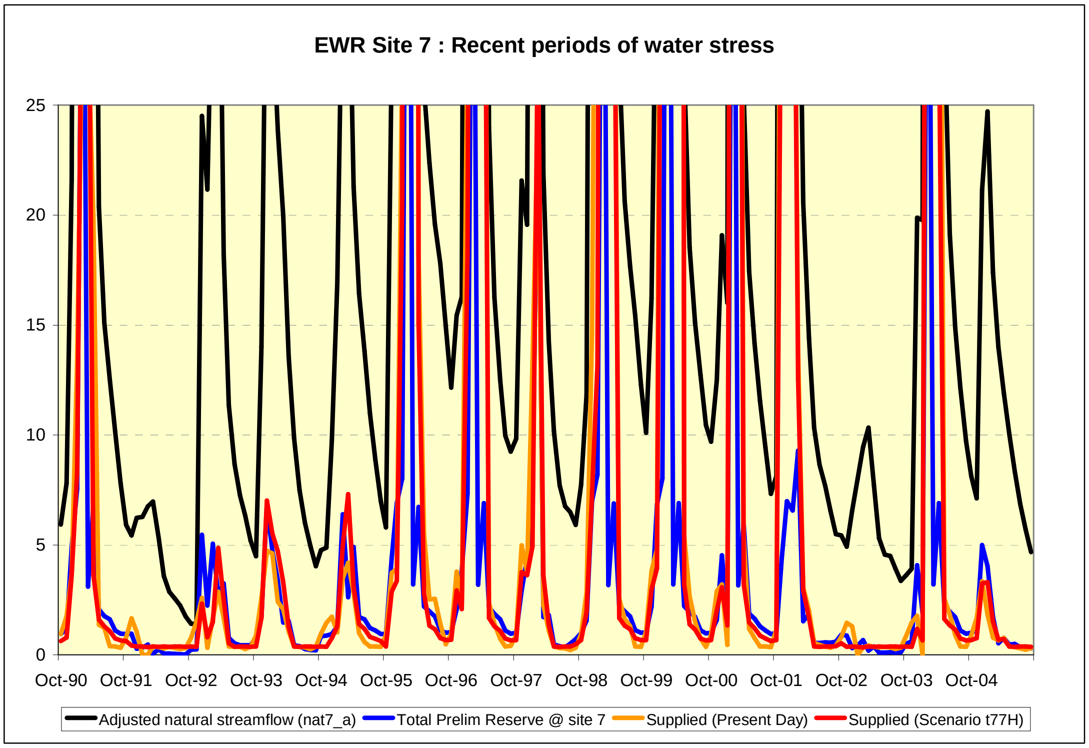

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Figure 12 Streamflow at EWR Site7 from 1990 to 2004 under natural (black), present day (orange) and future (Nwamitwa Scenario t77H – red) conditions compared to the EWR requirement (blue)

Figure 13 illustrates how much of the EWR requirements at Site 7 are supplied from the additional freshets introduced downstream of Nwamitwa and by the supplementary releases from the Nwamitwa Dam. If these components are omitted then the streamflow at the site (dashed red line) is significantly less than the required ecological streamflow (solid blue line).

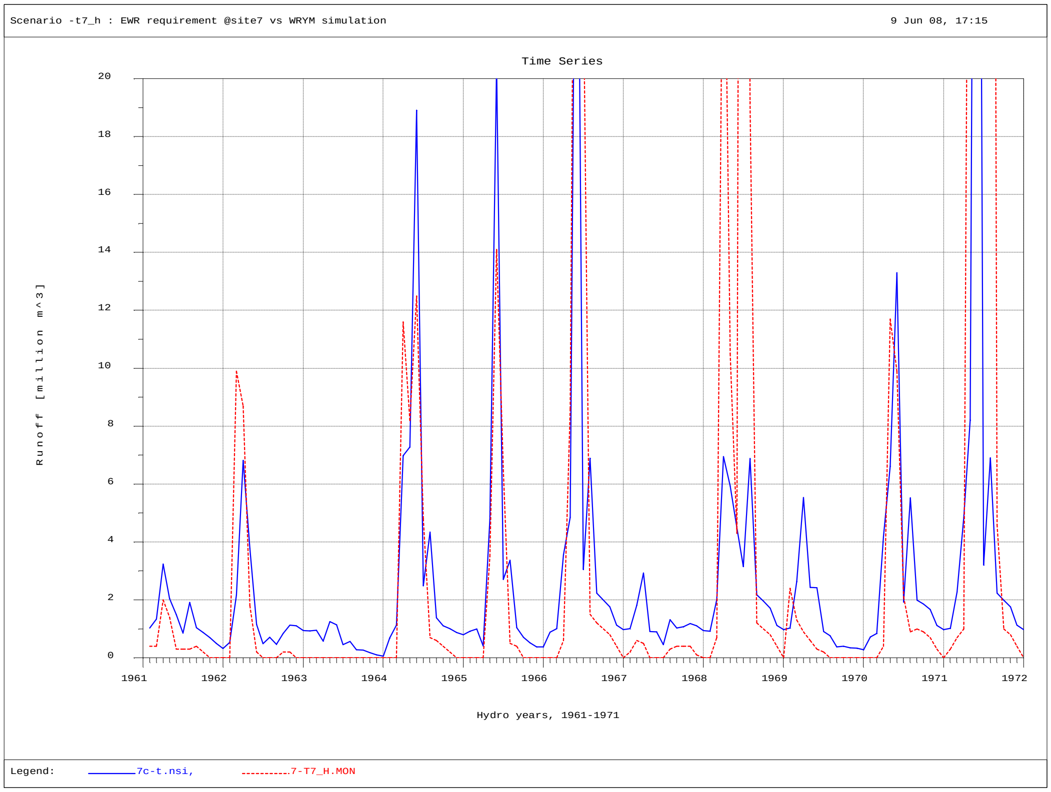

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Figure 13 Scenario –t7_h. Required (blue) with simulated (red dashed) streamflow sequence from 1961 to 1971 at EWR Site 7 assuming no additional freshets and no explicit releases for EWR sites located downstream of the Groot Letaba/Klein Letaba confluence

Figure 14 compares the environmental requirements (blue) and stream flows under the t77 (green) and t7_ (red) scenarios at EWR Site 7 using flow duration curves for each month. Both the t77 and t7_ scenarios provide the total EWR requirement at EWR Site 3 and meet "Scenario 7" requirements at EWR Site 4. However, the t77 scenario also tries to meet the requirements of "Scenario 7" at EWR Sites 6 and 7. Note that the EWR requirement specifies a flood in February while the two scenarios provide stream flows throughout the year. The low flows in winter for scenario t77H, which are driven by the "Scenario 7" requirements, are slightly less than the required baseflows.

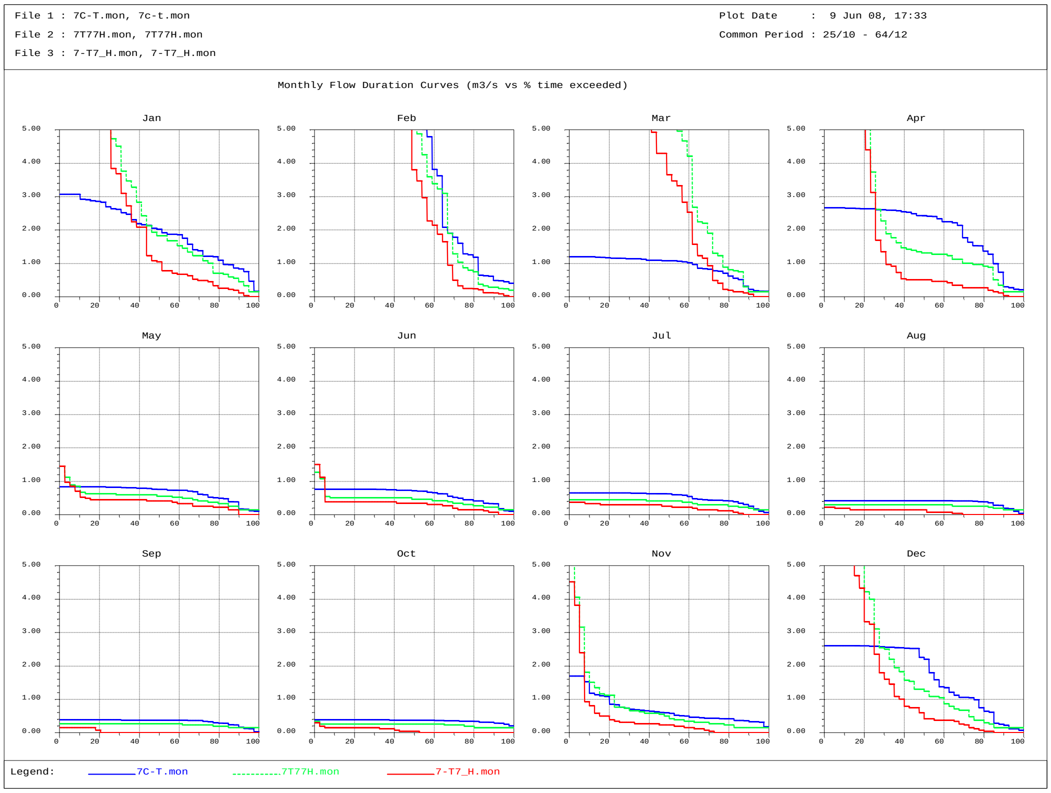

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Figure 14 Flow duration plots for Site 7 for each month comparing the total required streamflow (blue) with the water supplied under Scenarios T77H (green) and –T7_H (red)

APPENDIX C : Demands used in WRYM

Domestic use		Allocation	Usage (Mm3/a)	Feasibility study – Water Requirements and System Analysis (Note 3): 1995	aggregated 1995	2020	aggregated 2020	aggregated	Interpolated: 2007	aggregated 2007	Main Report: 2020 (Tables 5.3, 5.4 and 5.5) - Note 5	Bridging study WRYM	Aggregated Bridging WRYM	Source	Aggregated Bridging WRYM by source	Channel	Avg req (m3/s)
Polokwane (previously Pietersburg) (from Dap Naude)		6.5	4.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	6.5	6.5	Dap Naude	6.5	303	0.207
Polokwane (from Ebenezer)		12.0	18.8	13.5	13.5	13.5	13.5	13.0	13.5	13.5	12.9	12.0	12.0	Ebenezer	12.0		
Haenertsburg			0.0								0.1	0.00		Ebenezer		312	0.380
Politsi											1.2			Magoebaskloof			
Duiwelskloof		2.0	2.1	1.52	1.5	5.16	5.2	2.4	2.7	2.7		2.0	2.0	Magoebaskloof/Vergelegen/Hans Merensky	2.0	332	
Ga-Kgapane											1.2			Magoebaskloof/Vergelegen/Hans Merensky			0.063
	Tzaneen u/s WTW	2.4	2.2	3.95		25.53			9.7		18.2	2.4		Ebenezer	2.4	325(reuse)	0.075
	Tzaneen d/s WTW	1.2	1.0									1.2		Tzaneen			
Tzaneen (For Feasibility study this included growth at the Thabina and Modjadji Dams when this exceeded their capacity)	Industrial (Consolidated and Letaba Citrus Processors, Consolidated Murchison, Maranda Mining Co)	3.3	1.5	1.99	13.4	1.99	51.7	38.1	2.0	22.6	1.5	1.5	16.3	Tzaneen	13.9	358	
												0.0		Tzaneen			
Excess demand from Naphuno and Bolebedu shifted to Gt Letaba				0.00		7.34					5.25						
Letsitele		0.4	0.3	0.22		0.76			0.4		0.7	0.3		Tzaneen			
Ritavi 2	Nkowakowa	3.5	8.2	5.60		11.42			7.9		9.8	8.2		Tzaneen			
Ritavi 1	Nwamitwa	0.0	1.9	1.59		4.70			2.7		2.7	1.9		Tzaneen			
Namakgale		0				-						0.0		Tzaneen			
	Nondweni	0	0.8									0.8		Tzaneen			
																	0.440
Naphuno		1.7	1.3	2.02	2.0	6.62	2.9	2.9	3.6	3.6	4.2	2.9	2.9	Thabina	2.9	391	0.090
Assumed Naphuno shifted to Gt Letaba / Tzaneen						-3.76					-1.4						
Bolobedu		0.2	0.2	0.00	0.0	7.95	4.4	4.4	0.2	0.2	8.3	5.1	5.1	Modjaji	5.1	468	0.162
Assume Bolebedu shifted to Gt Letaba / Tzaneen						-3.58					-3.9						
Groot Letaba Total		**33.2**	**42.8**	**36.0**	**36.0**	**83.3**	**83.3**	**66.4**	**48.2**	**48.2**	**66.4**	**44.8**	**44.8**		**44.8**		
Giyani		3.7	3.7									3.7	6.0	Middle Letaba/Nsami	6.0	632 (20Mm^3/a including irrigation+losses)	0.634
Middle Letaba Dam WTW		2.3	2.3									2.3				624	0.073
TOTAL		**39.2**	**48.8**									**50.8**	**50.8**		**50.8**		

Additional agricultural demands

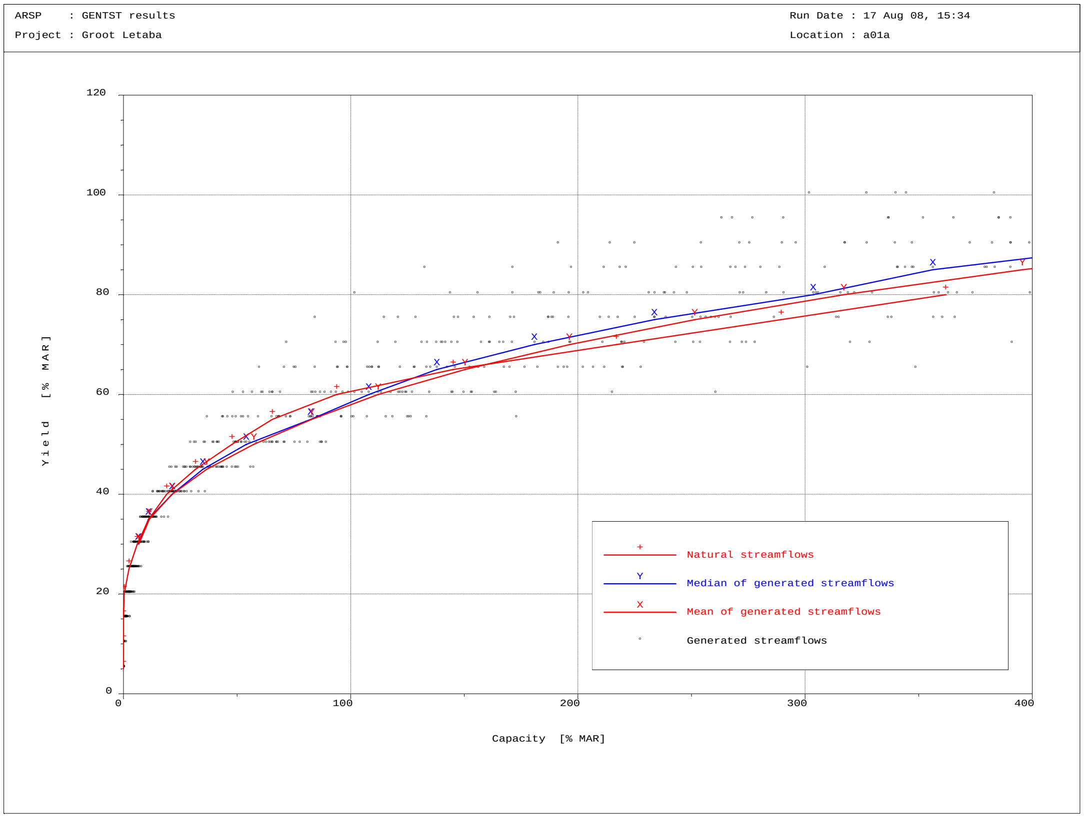
1. **Feasibility Study Report. Volume 2. Water requirements and system analyses. Report PBB810/00/0398 Annexure A : Domestic and Industrial Water Use and Water Demand. Domestic from Table 7.**
2. **0.3 million m^3/a demand of SAPEKOE on the Debengeni R is included with SAPEKOEs agricultural demand**
3. **Feasibility Study Report. Volume 2. Water requirements and system analyses. Report PBB810/00/0398 Annexure A : Domestic and Industrial Water Use and Water Demand. Domestic from Table 9 and 10.**
4. **Excludes Debengeni to SAPEKOE**
5. **In Table 5.4 of the Feasibility Report there is an error and the individual rural domestic requirements add up tp 25.04 instead of the 29.01 quoted for Scenario 1 in 2020 (Possibly the total included Giyani, Lulekani and Namakgale 2).**
   As a result the total industrial/domestic demand of 66.4 is less than the 70.4 reported in Table 5.6 of the Main Report

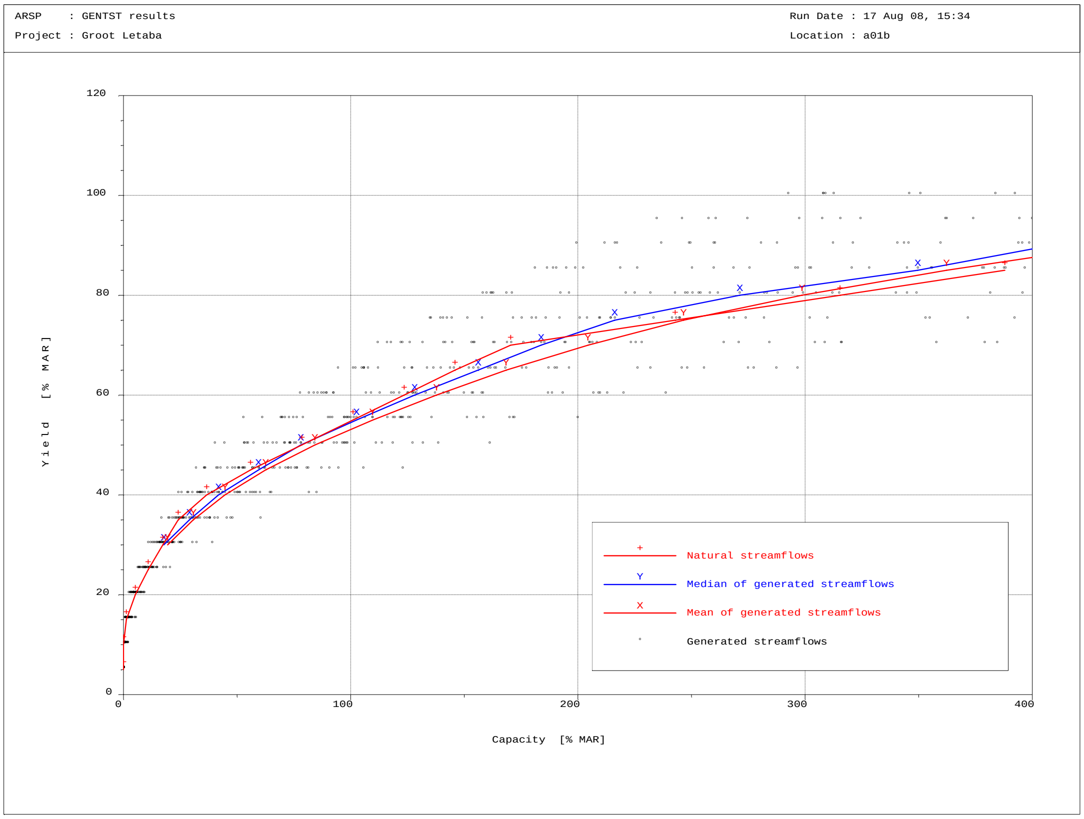
Notes

The actual usage by Polokwane, Nkowakowa and Ritav1 exceeds the allocation by 13.4 million m3/a.
Assume Polokwane demand is limited to its allocation as it is external to the water supply system and might find an alternative water source
The estimate of the actual usage is 4.3 million m3/a less than the projected demand for 2007 and the adopted present day demands are about 2.3 million m3/a less thant the Feasibility Projection
If Thapane was modelled a target draft of 1Mcm/a could act on that dam

APPENDIX D : Comparison of the Yield Characteristics of the Stochastic and Historical Streamflow Sequences (Note : this appears in the digital version only)

Comparison of the yield storage characteristics of each natural historical streamflow sequence with the median/average characteristics for the set of sequences generated using the stochastic parameters adopted for that streamflow sequence.

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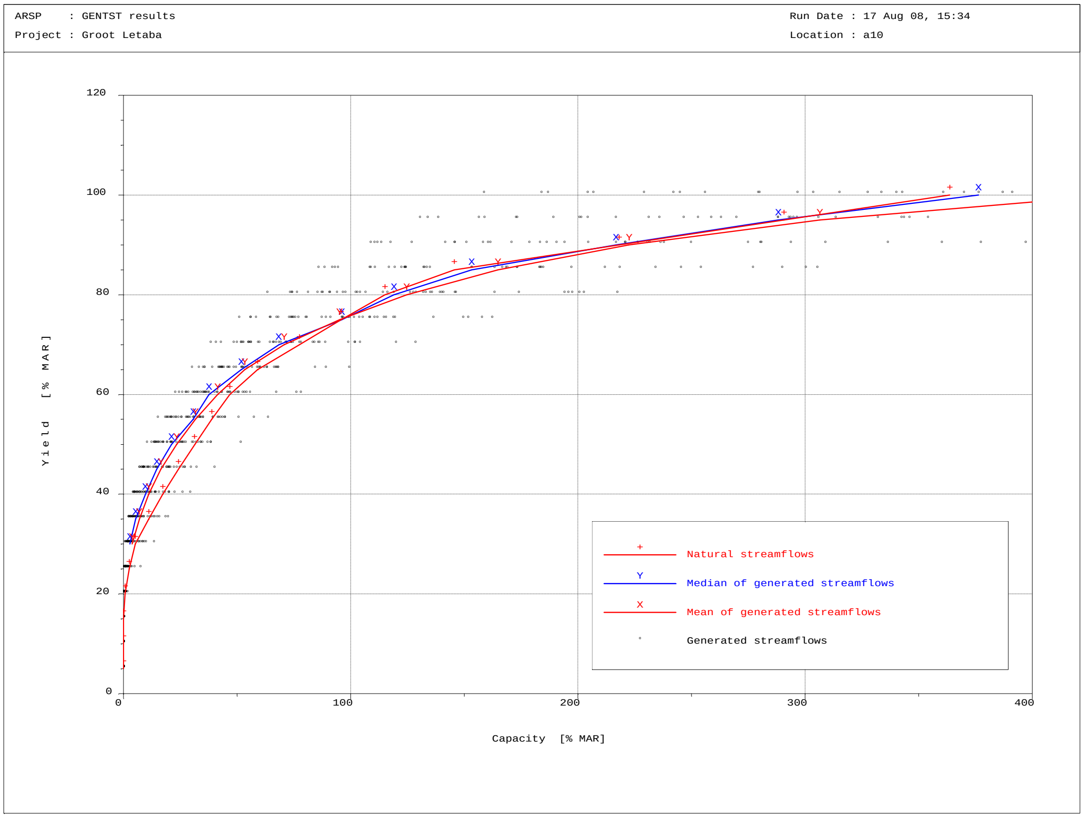
Mean of generated streamflows
Generated streamflows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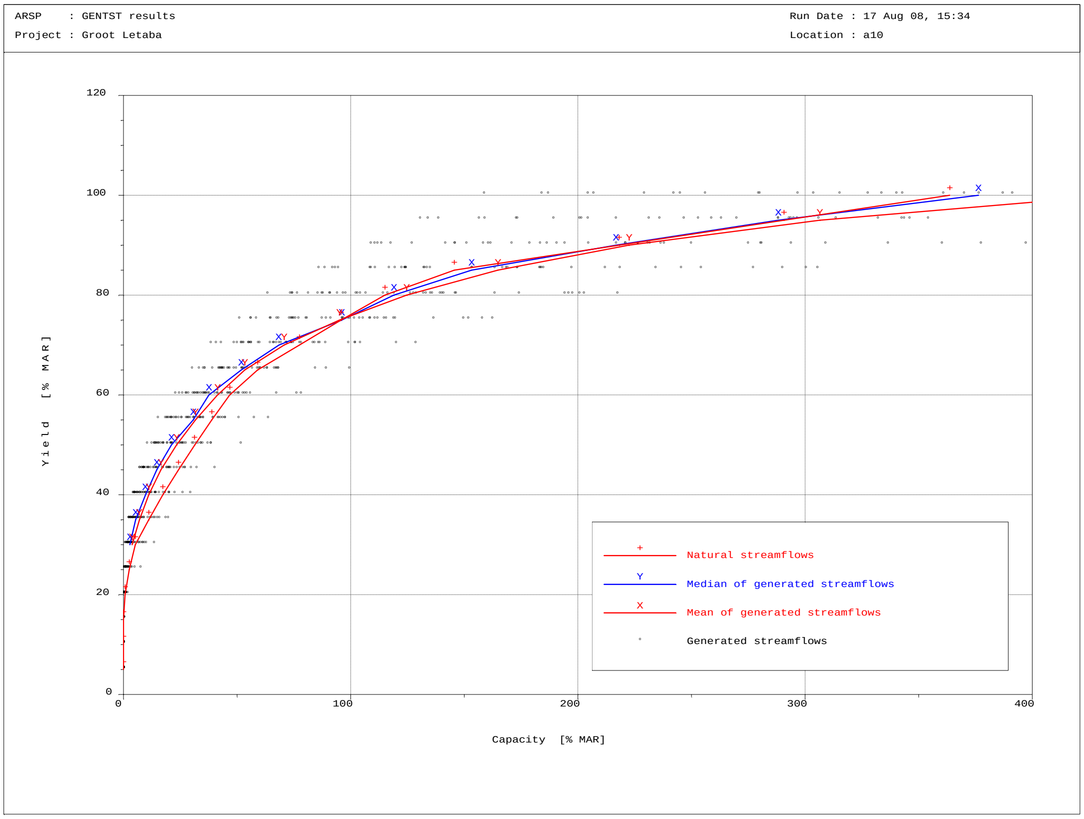
Median of generated streamflows
Mean of generated streamflows
Generated streamflows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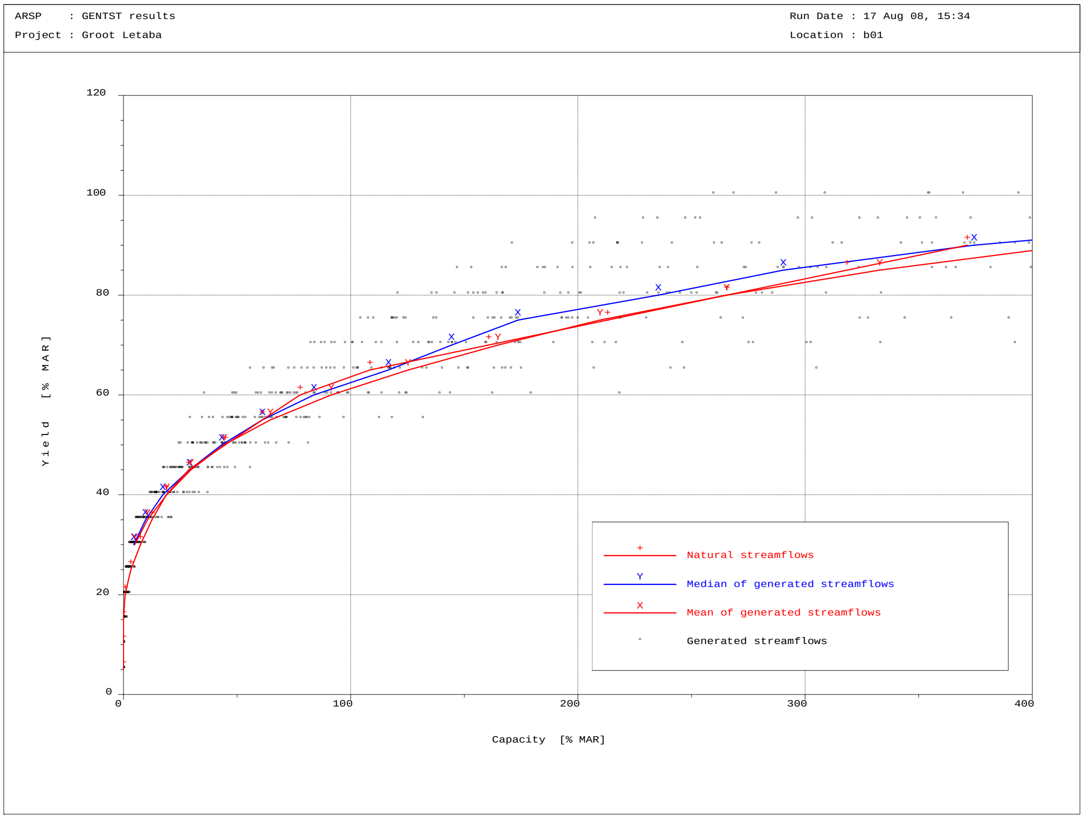
Median of generated streamflows
Mean of generated streamflows
Generated streamflows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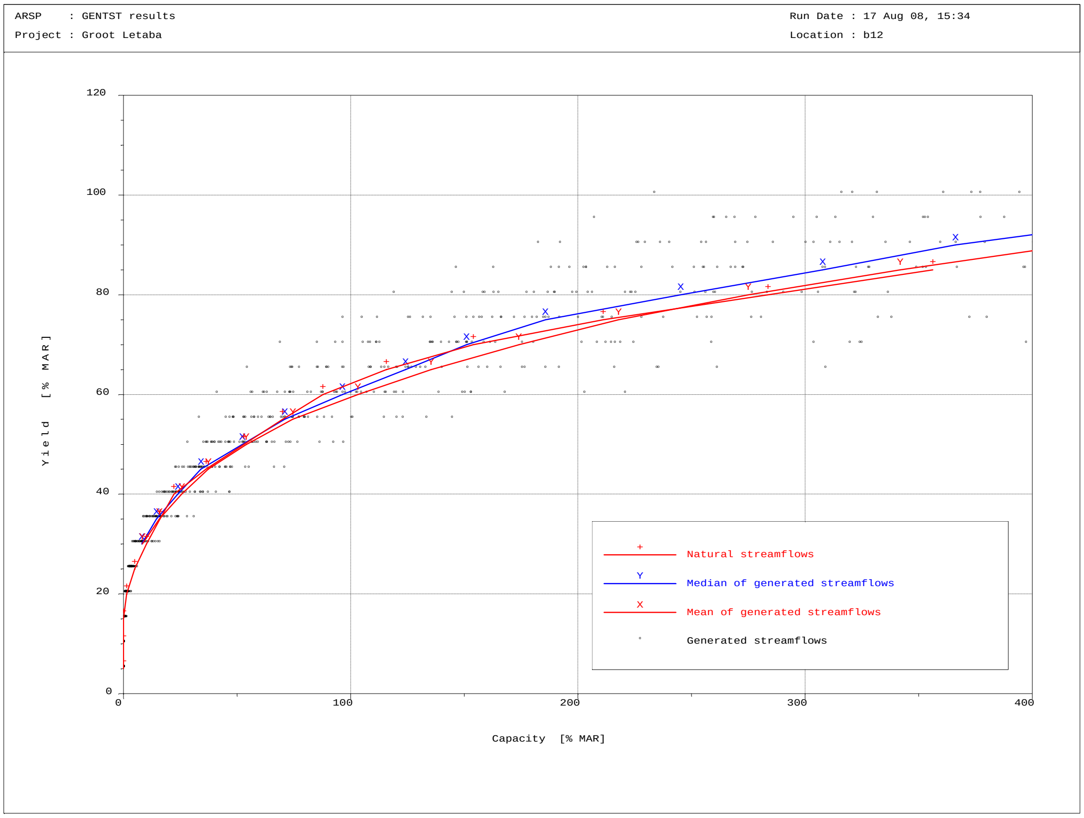
Mean of generated streamflows
Generated streamflows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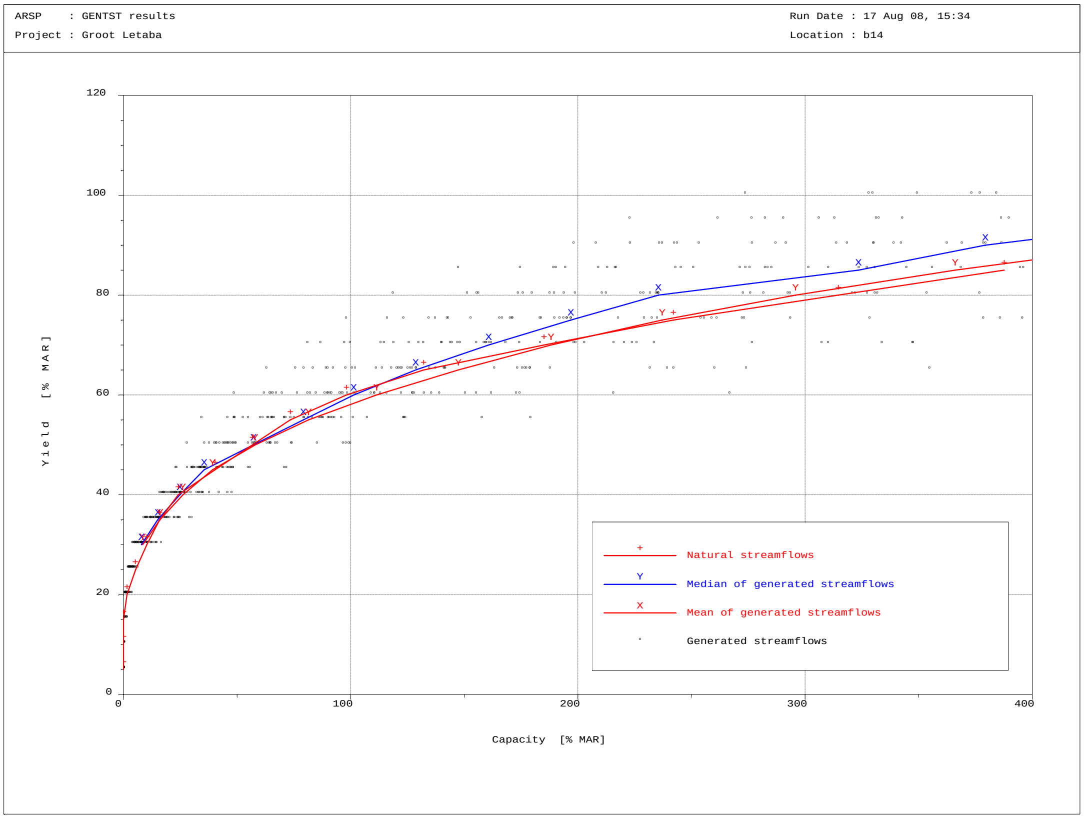
Mean of generated streamflows
Generated streamflows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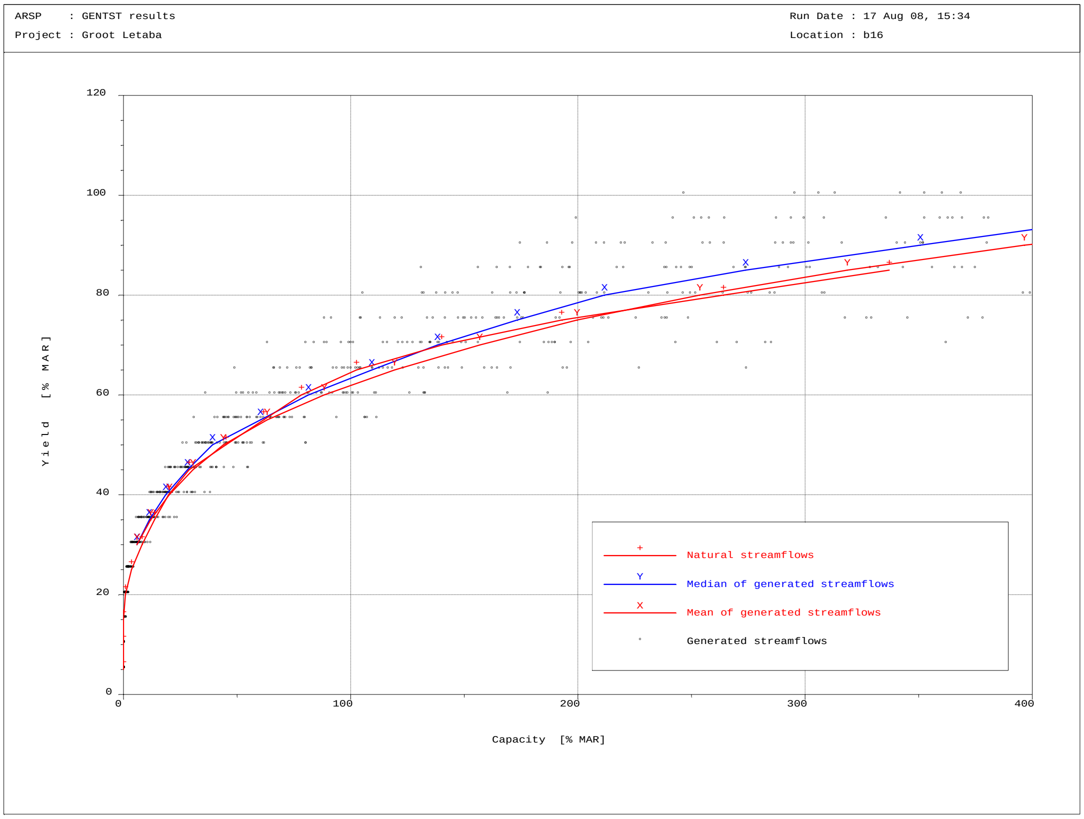
Mean of generated streamflows
Generated streamflows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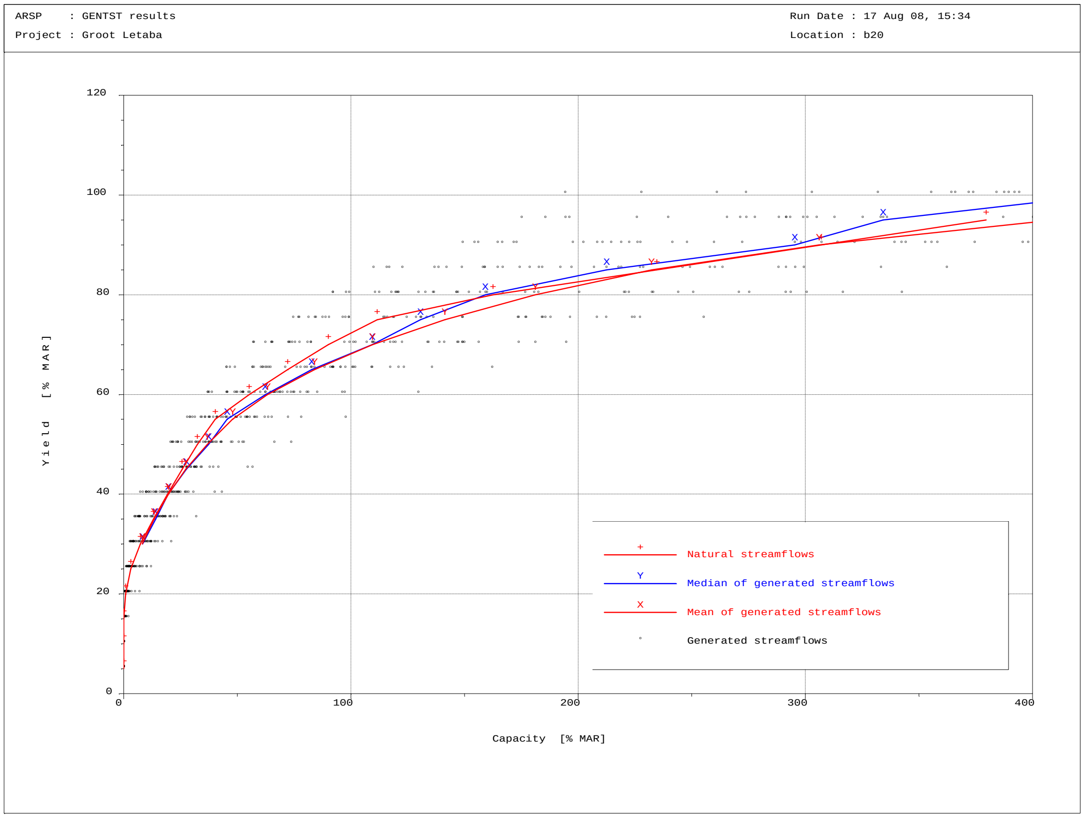
Generated streamflows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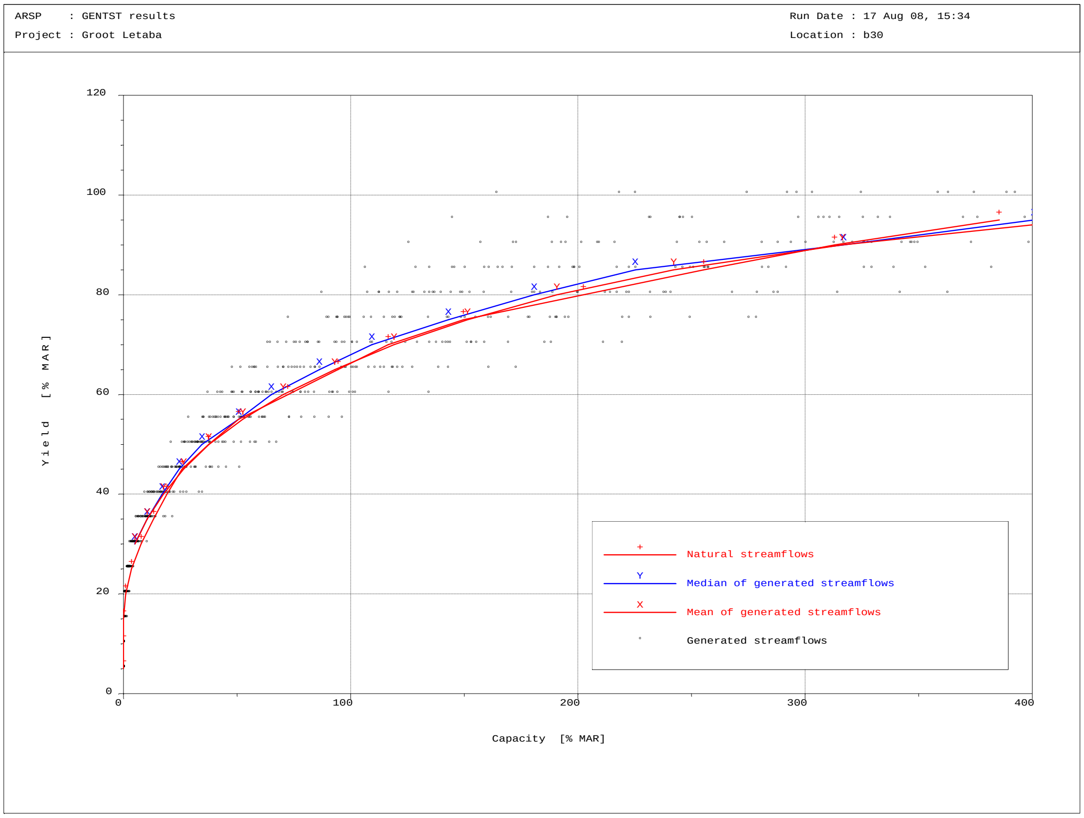
Mean of generated streamflows
Generated streamflows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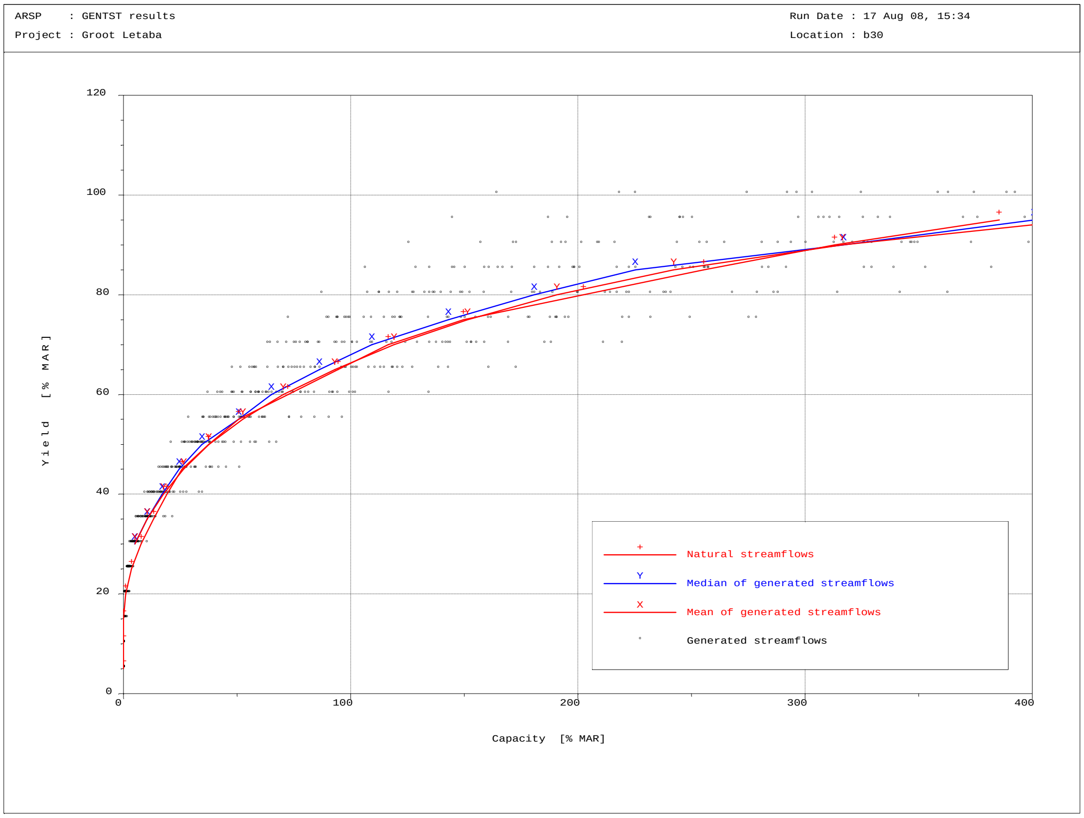
Generated streamflows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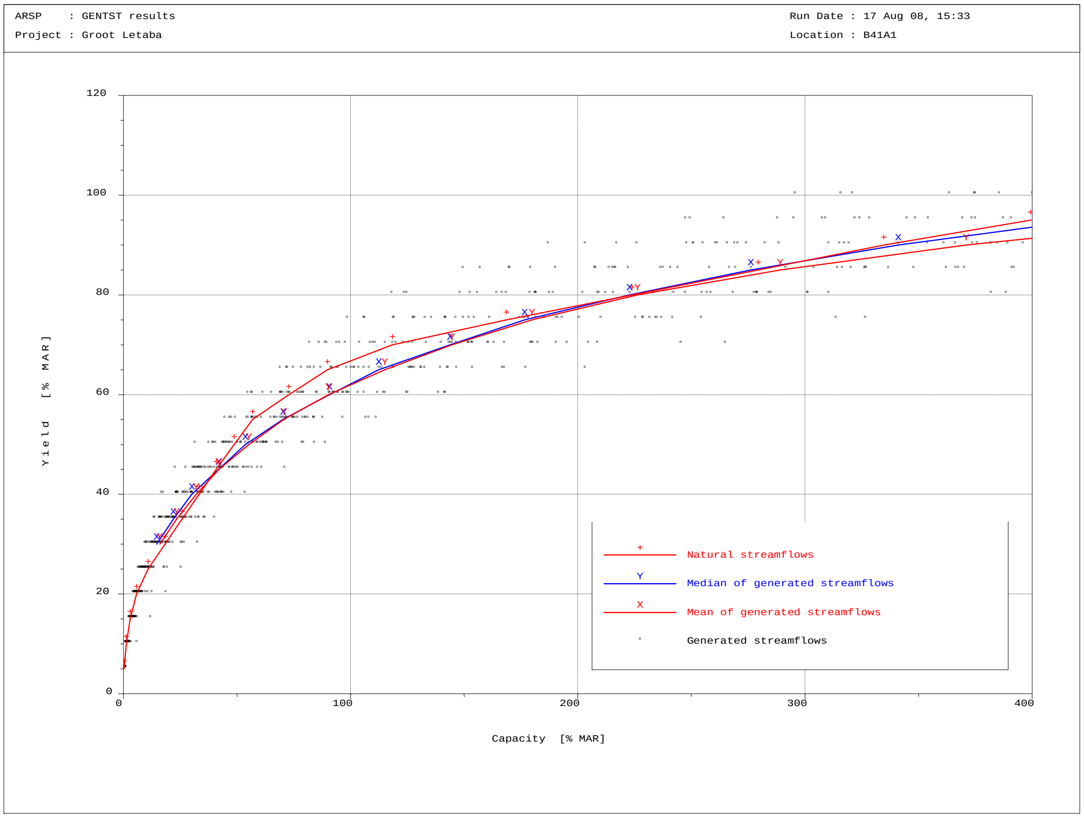
Generated streamflows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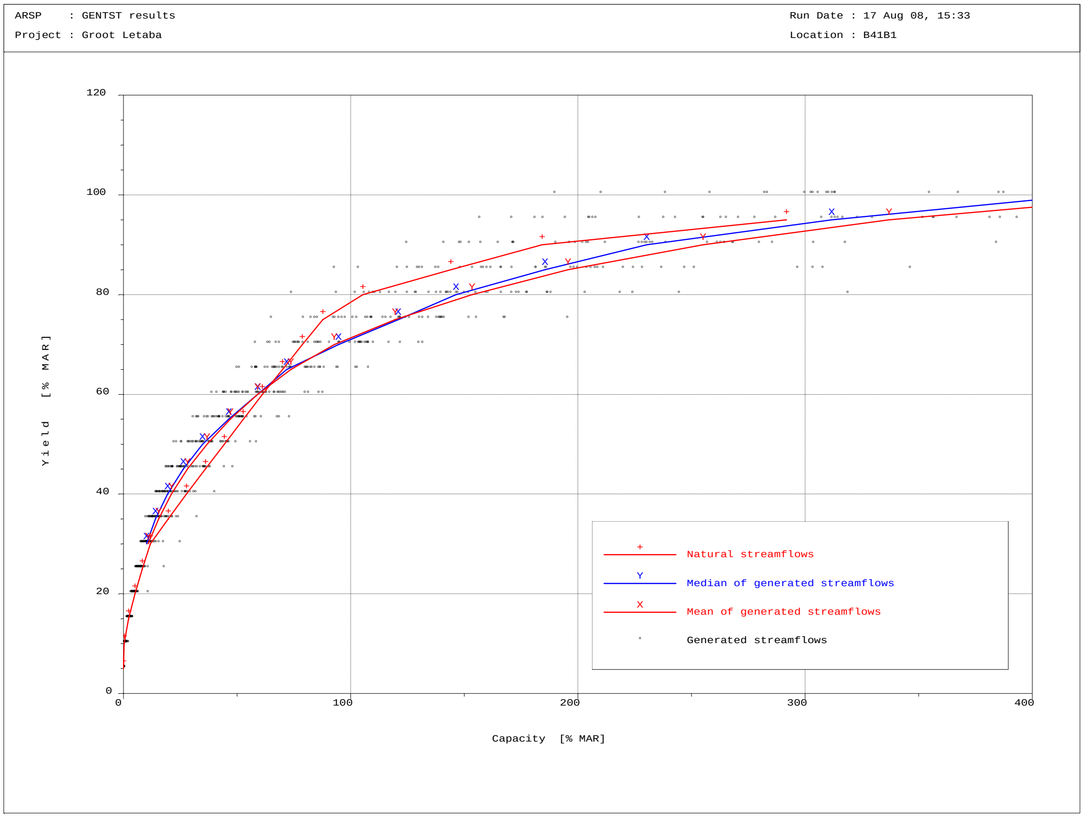
Generated streamflows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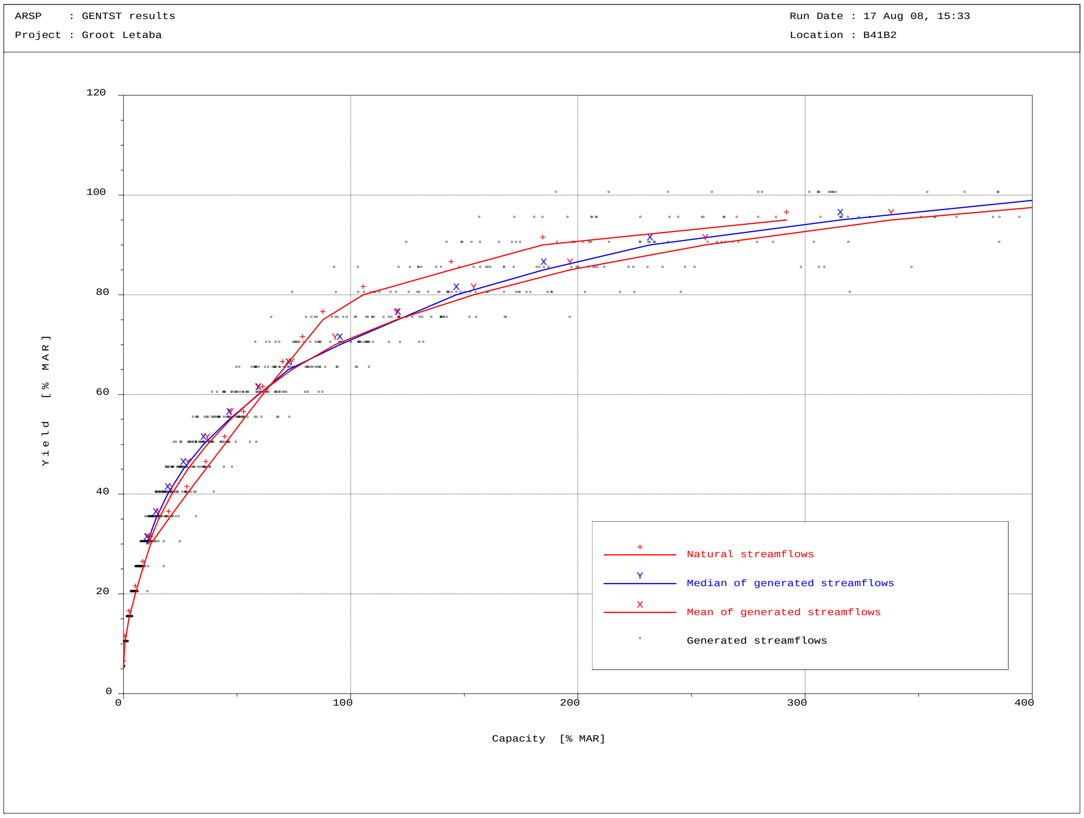
Mean of generated streamflows
Generated streamflows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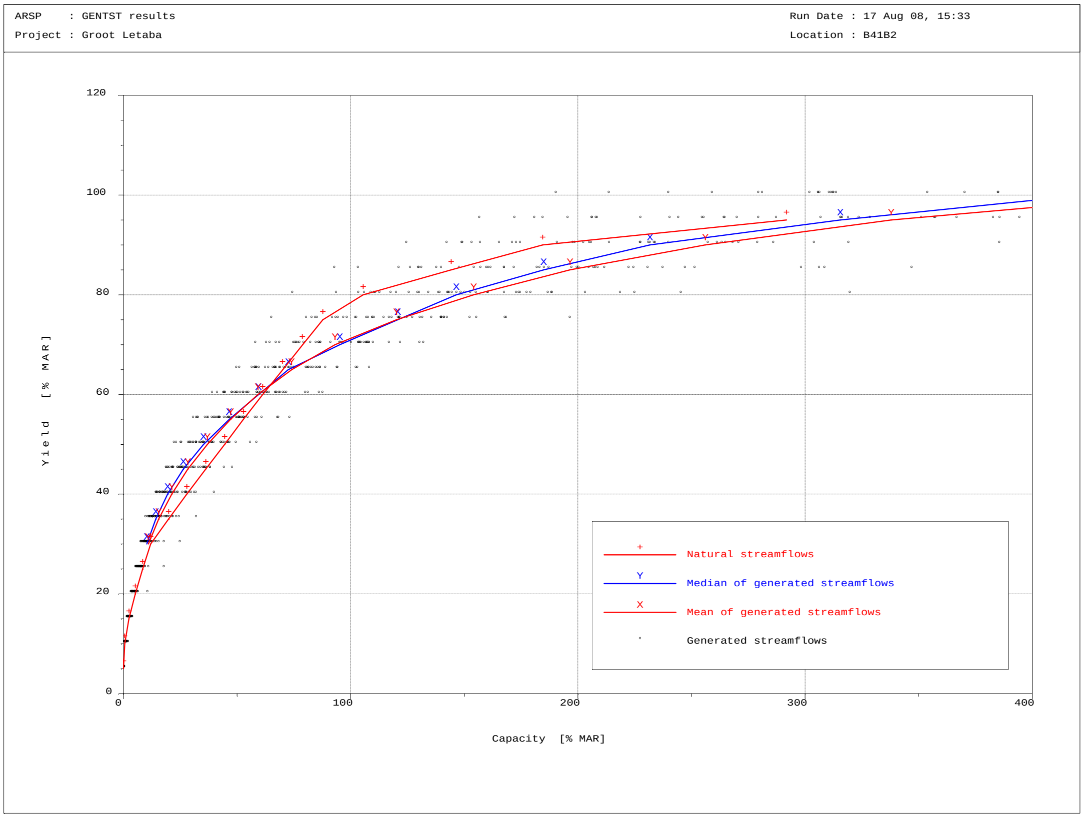
Mean of generated streamflows
Generated streamflows



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Capacity [% MAR]
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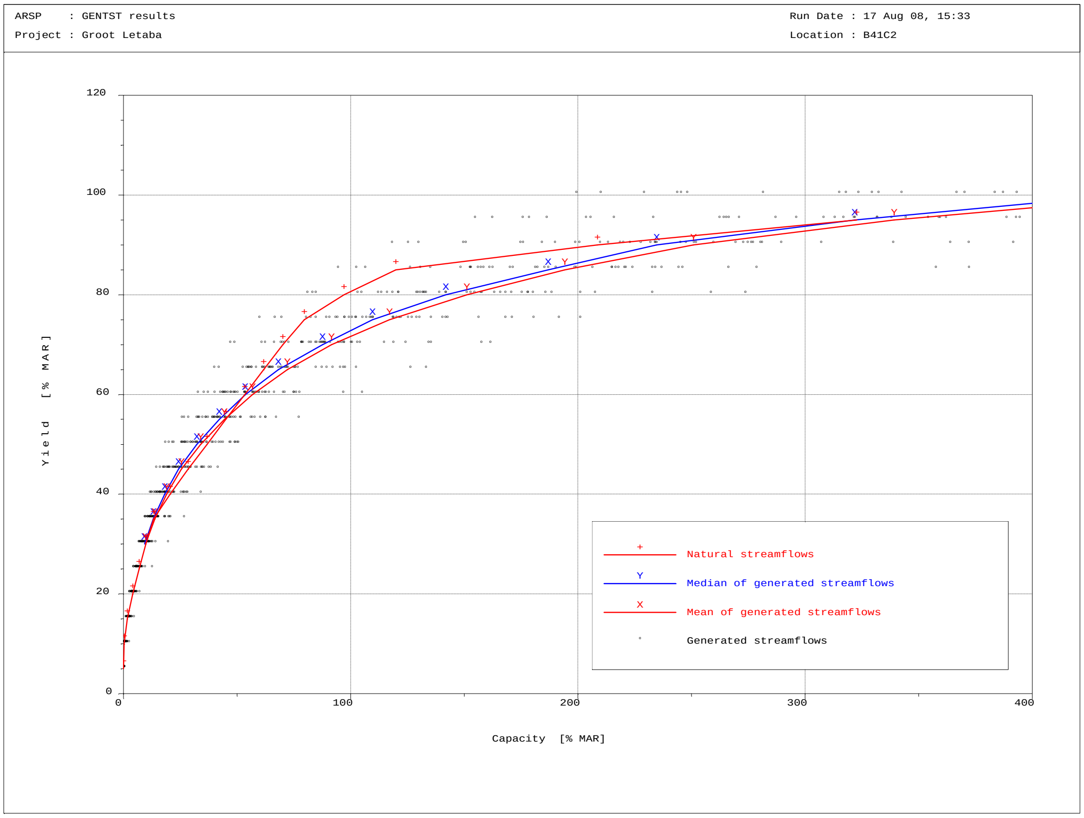
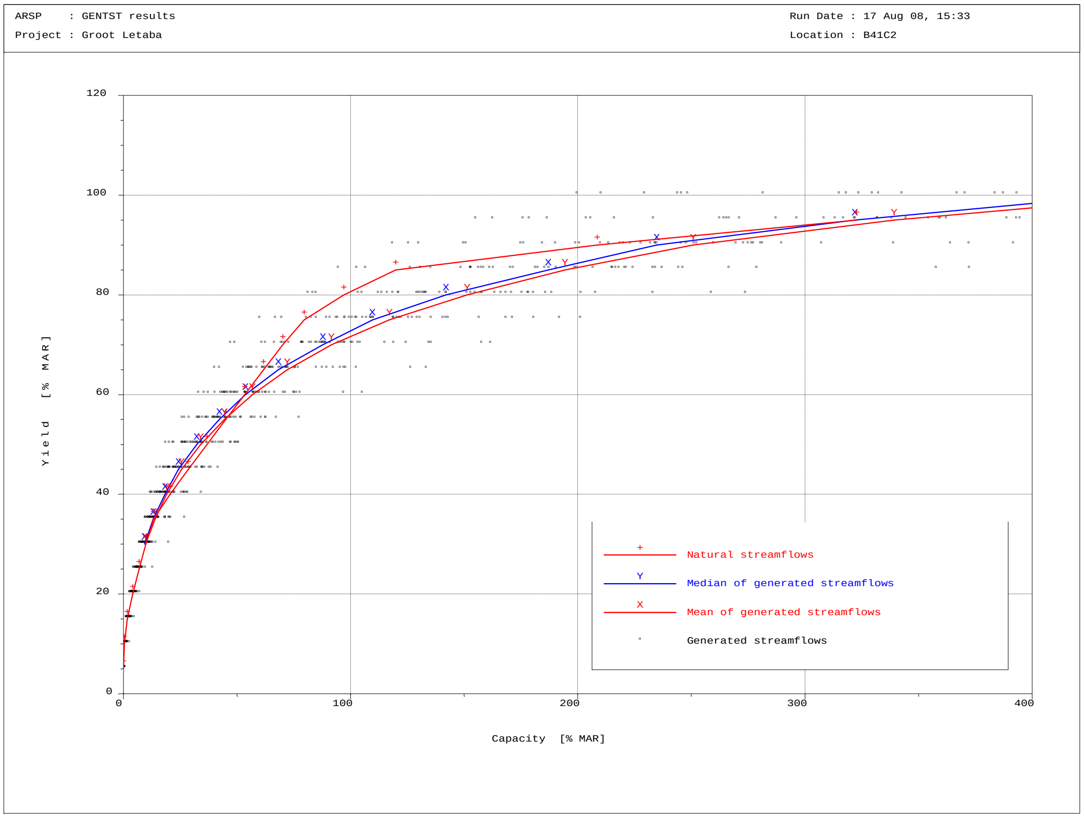
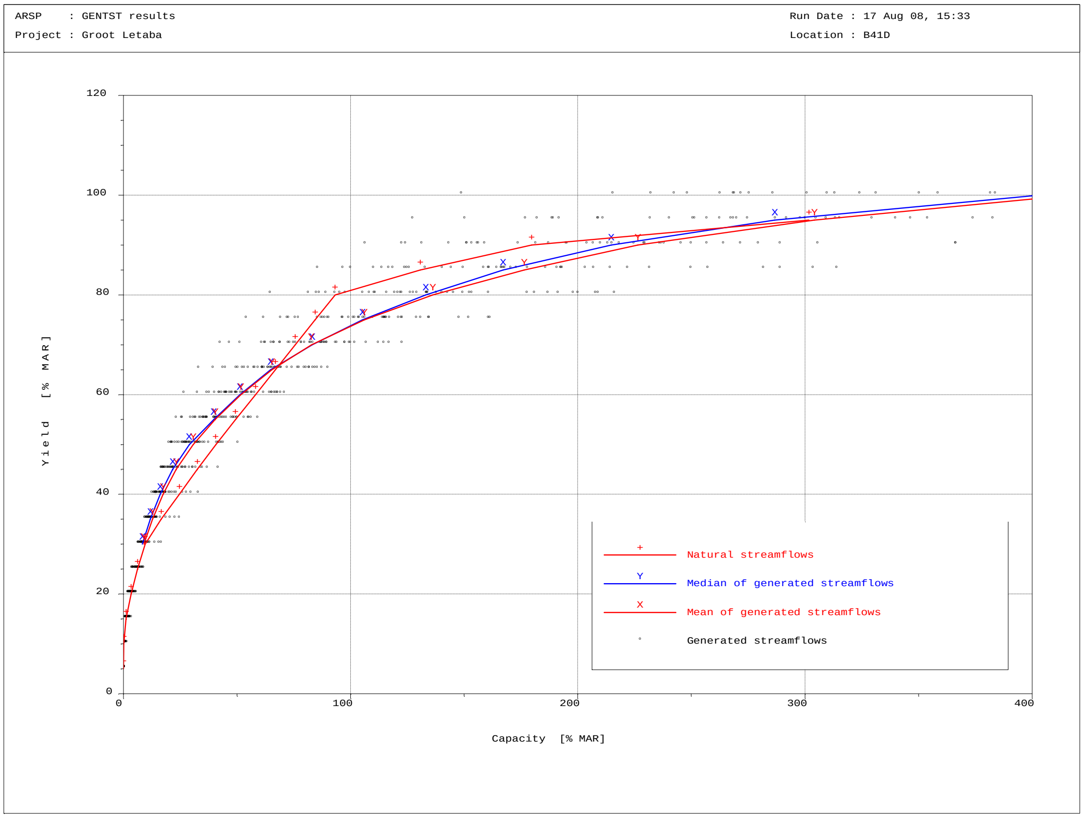
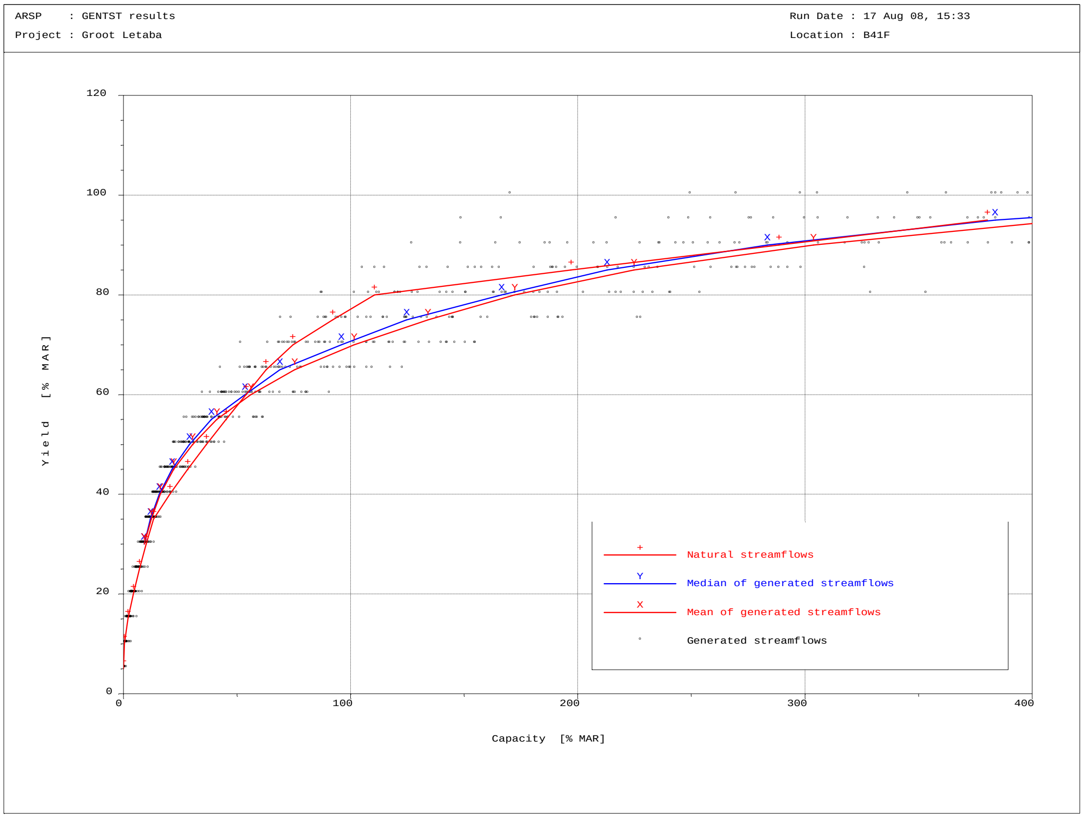
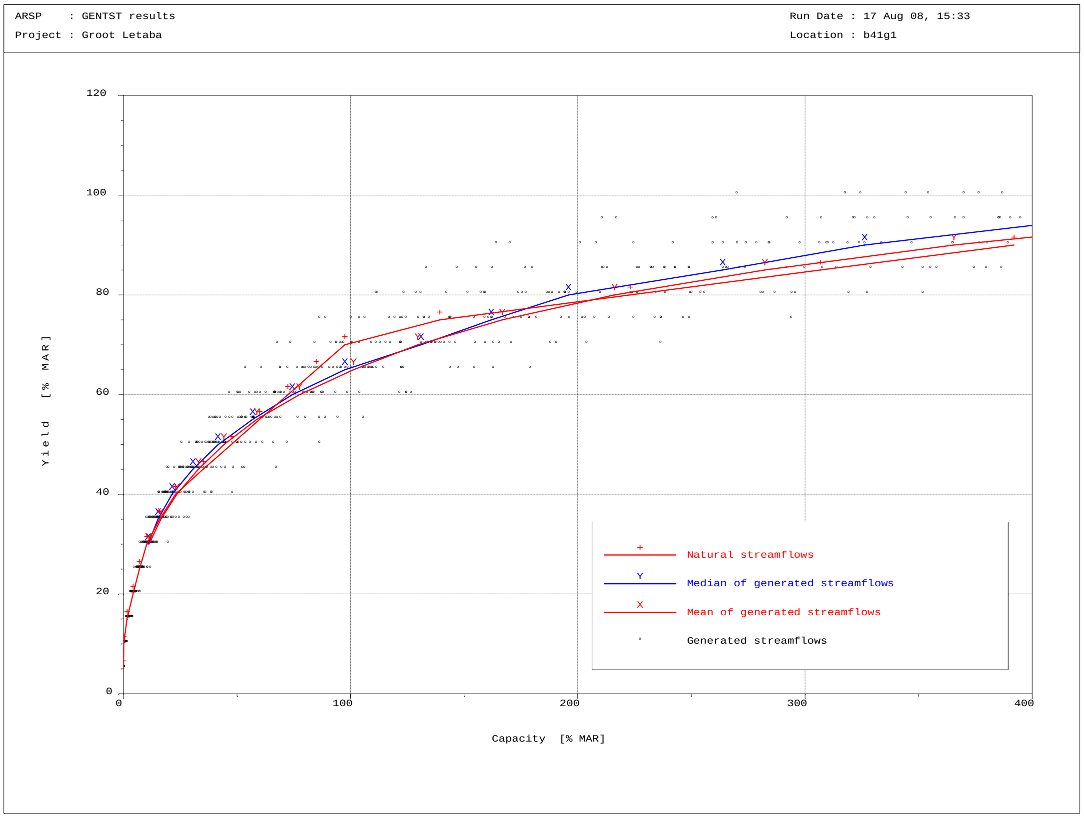
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:33
Location : B41C2
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:33
Location : B41C2
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:33
Location : B41D
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:33
Location : B41F
120
100
80
60
40
20
0
Yield [% MAR]
0
100
200
300
400
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:33
Location : b41g1
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
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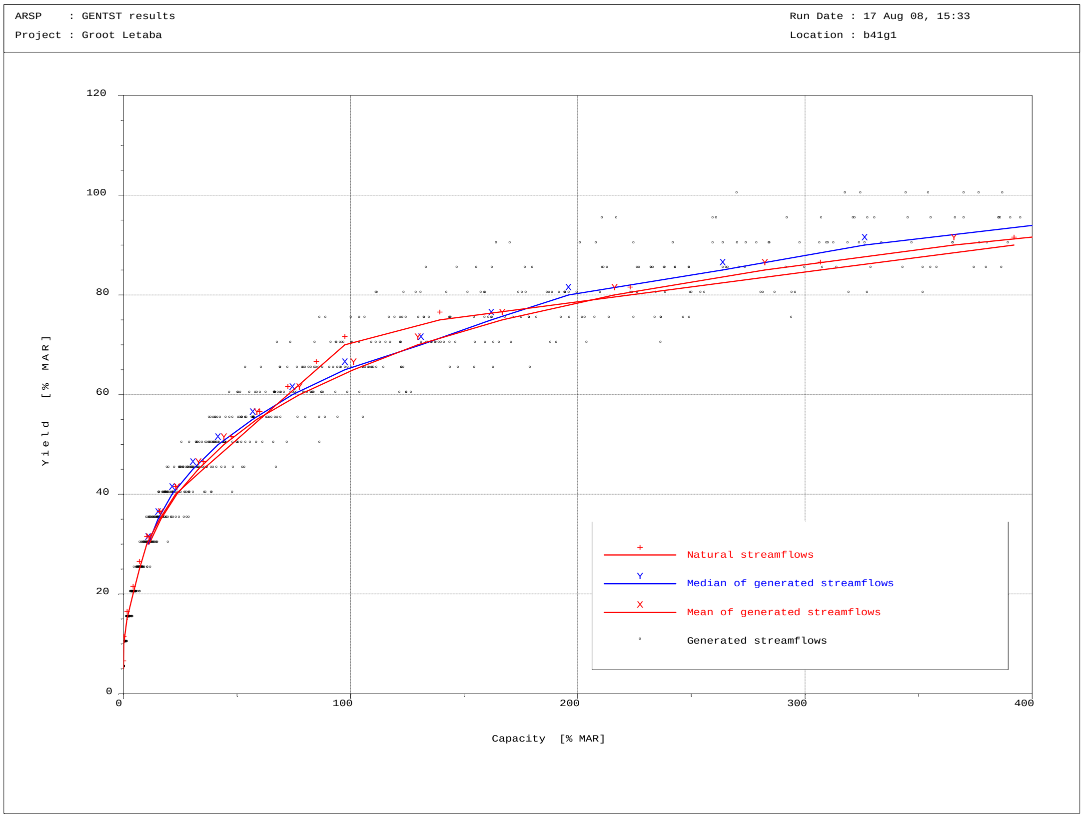
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:33
Location : b41g1
Yield [% MAR]
Capacity [% MAR]
0
20
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60
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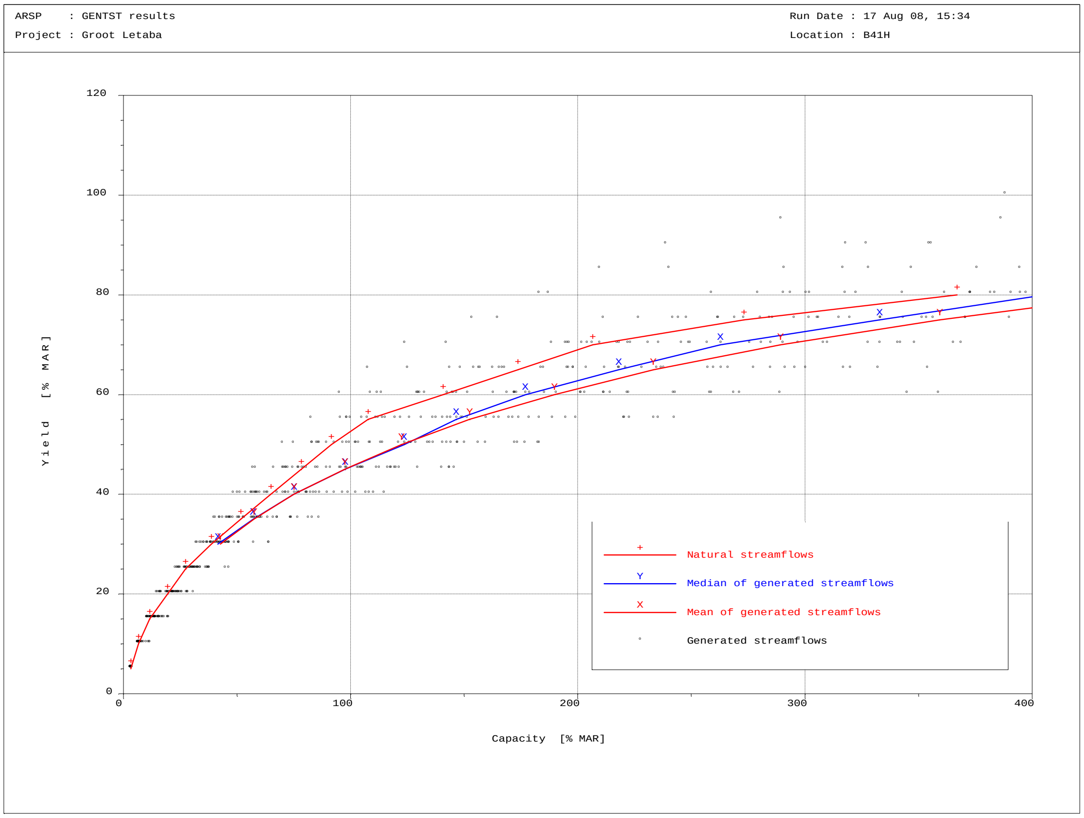
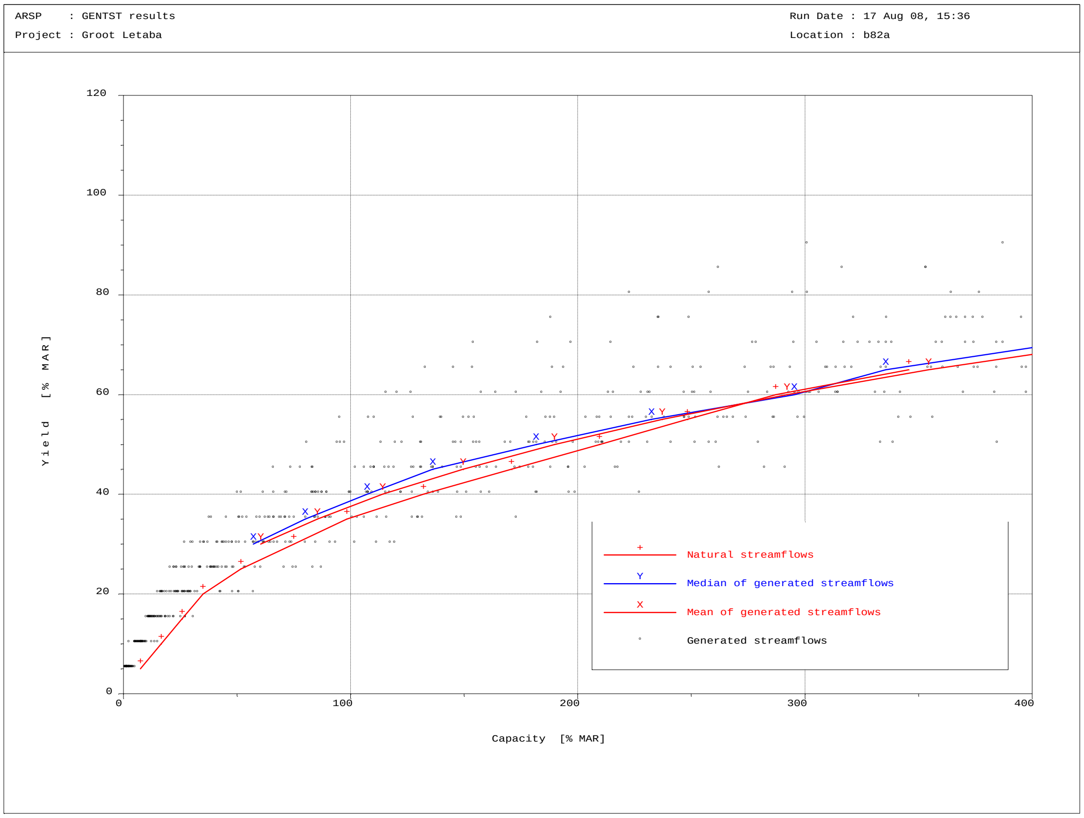
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:34
Location : B41H
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b82a
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
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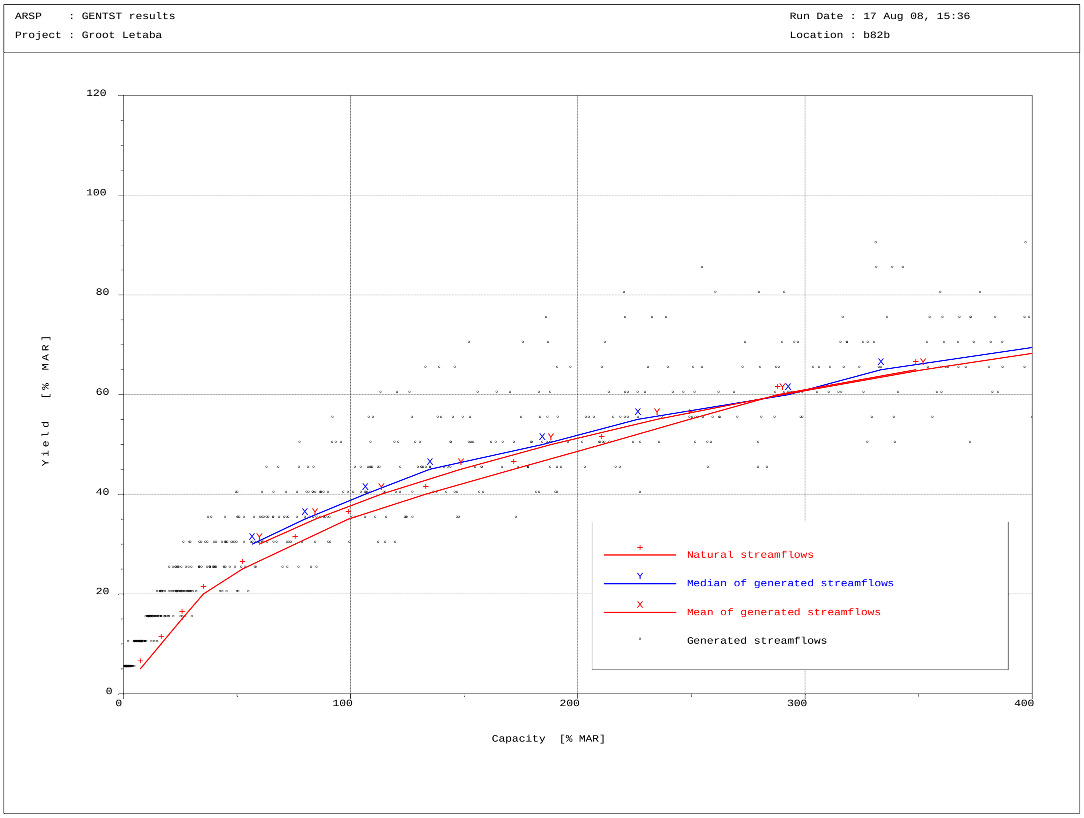
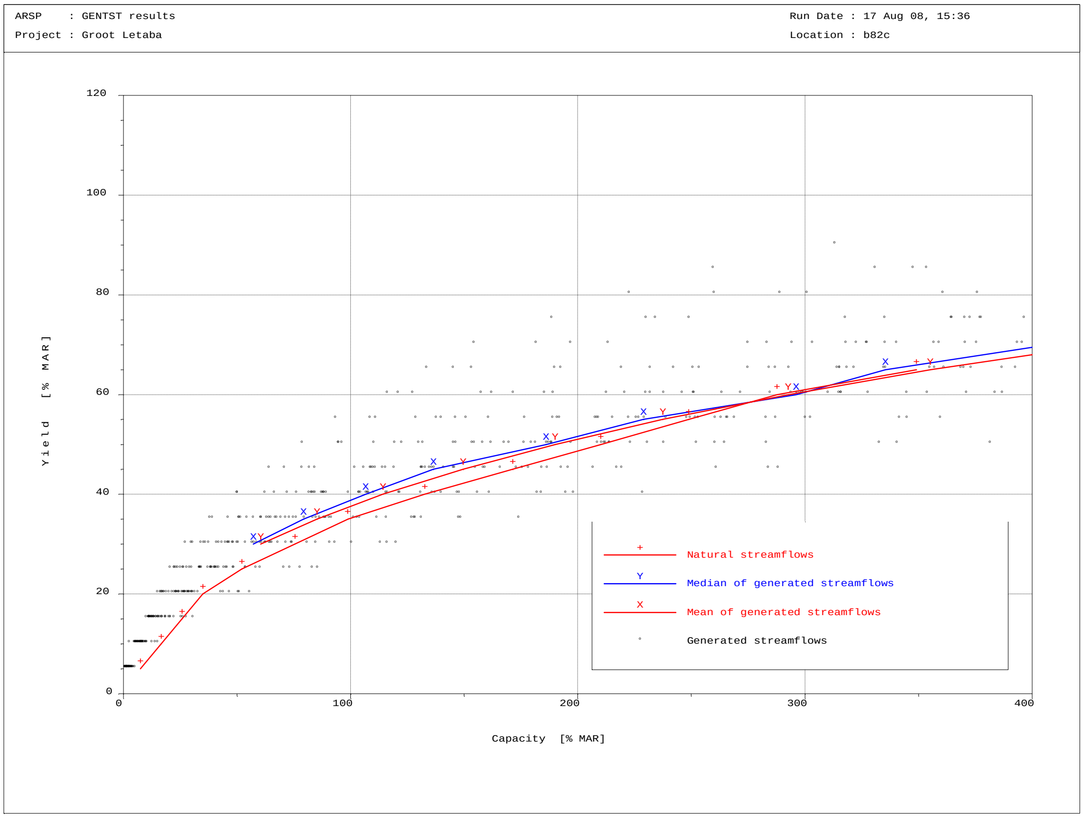
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b82b
120
100
80
60
40
20
0
Yield [% MAR]
0
100
200
300
400
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b82c
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
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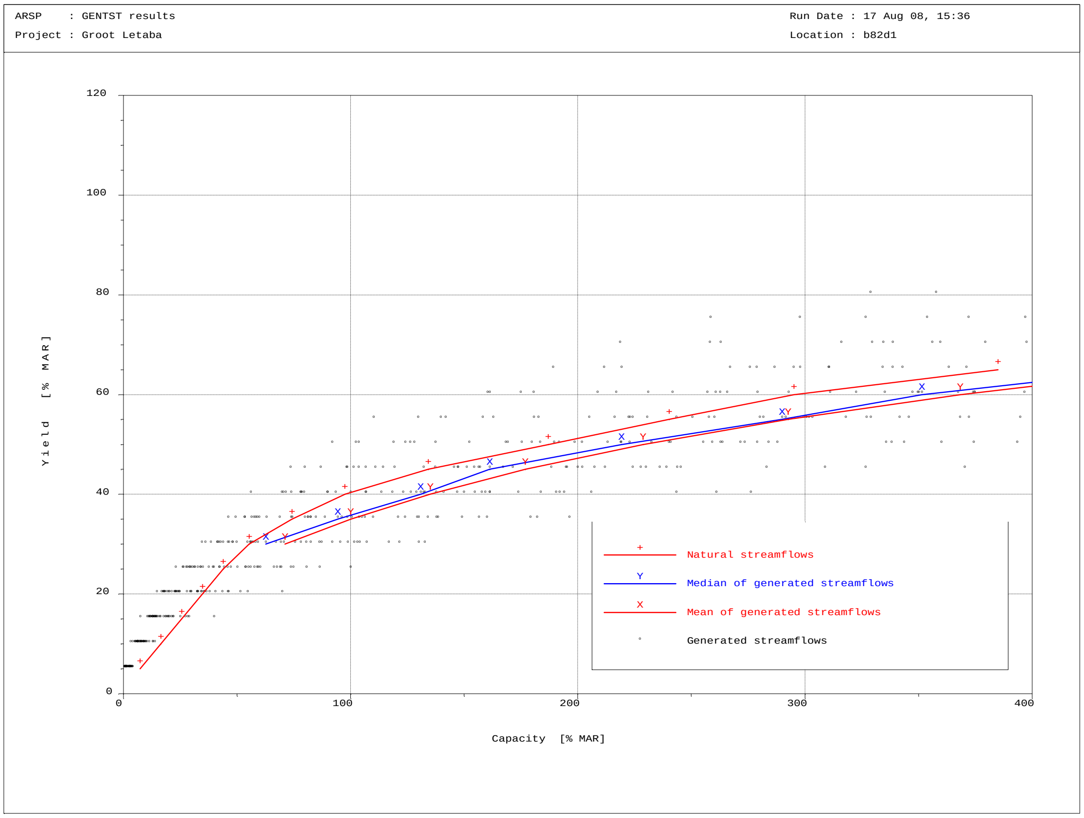
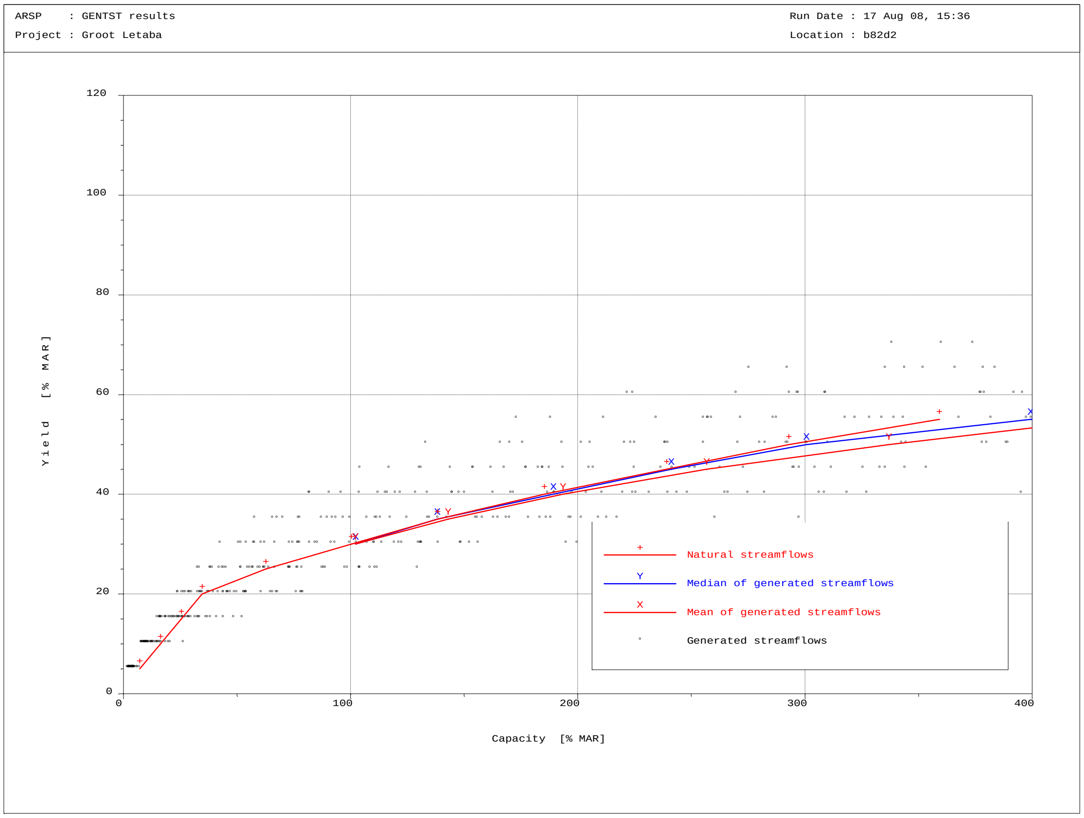
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b82d1
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b82d2
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows
0
20
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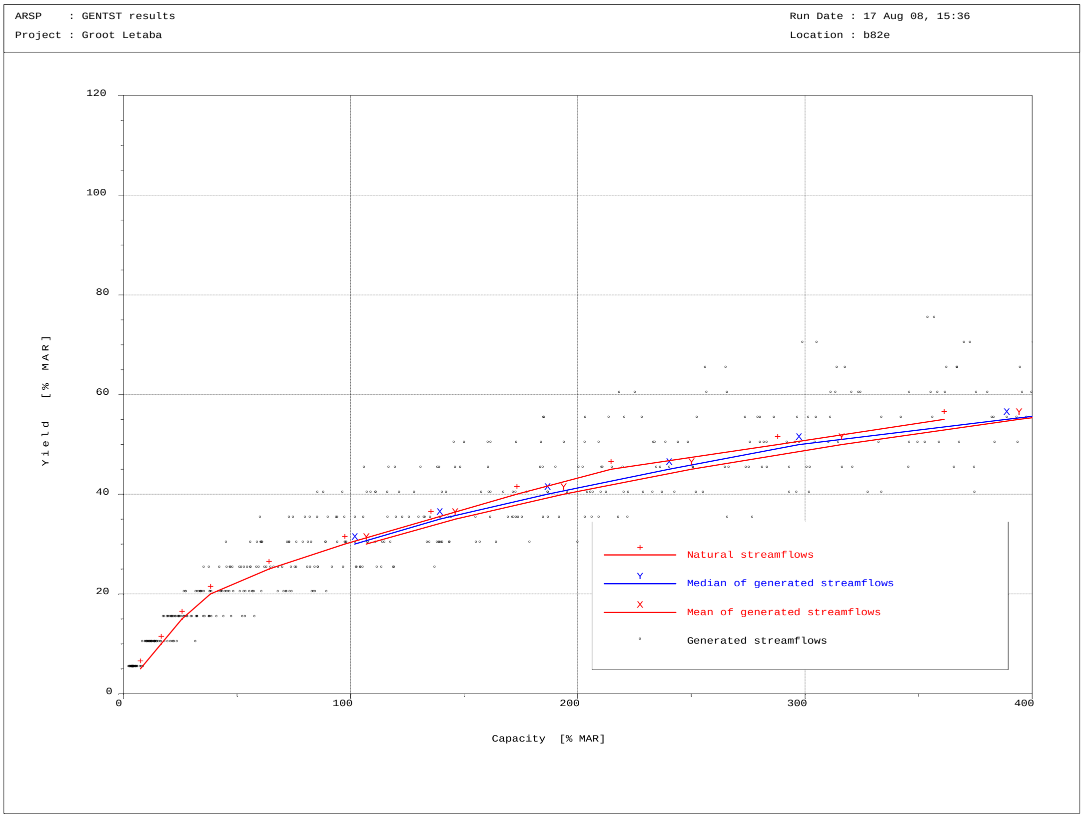
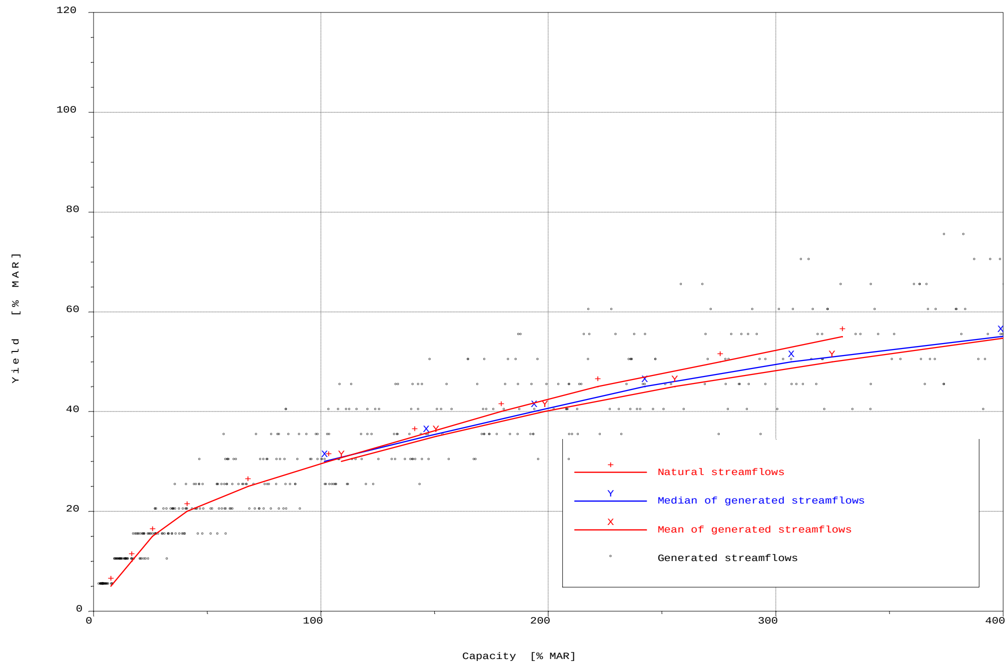
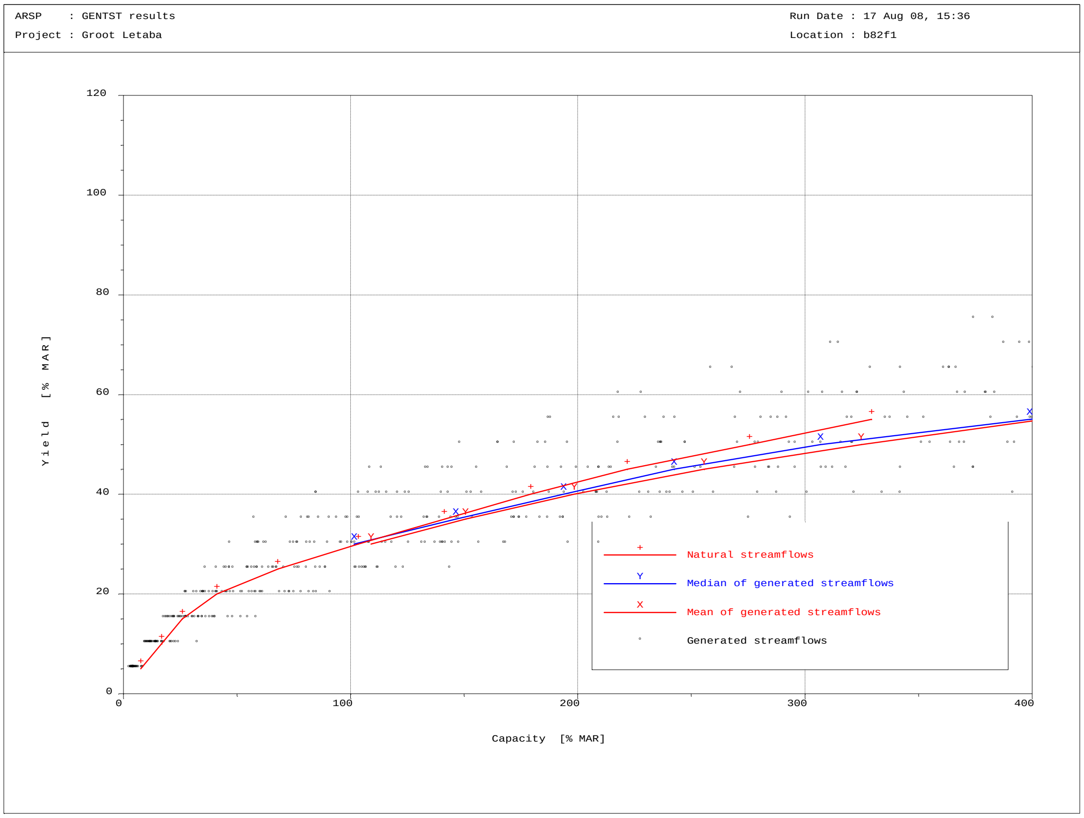
60
80
100
120
0
100
200
300
400


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b82e
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b82f1




ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b82f1
Yield [% MAR]
Capacity [% MAR]
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40
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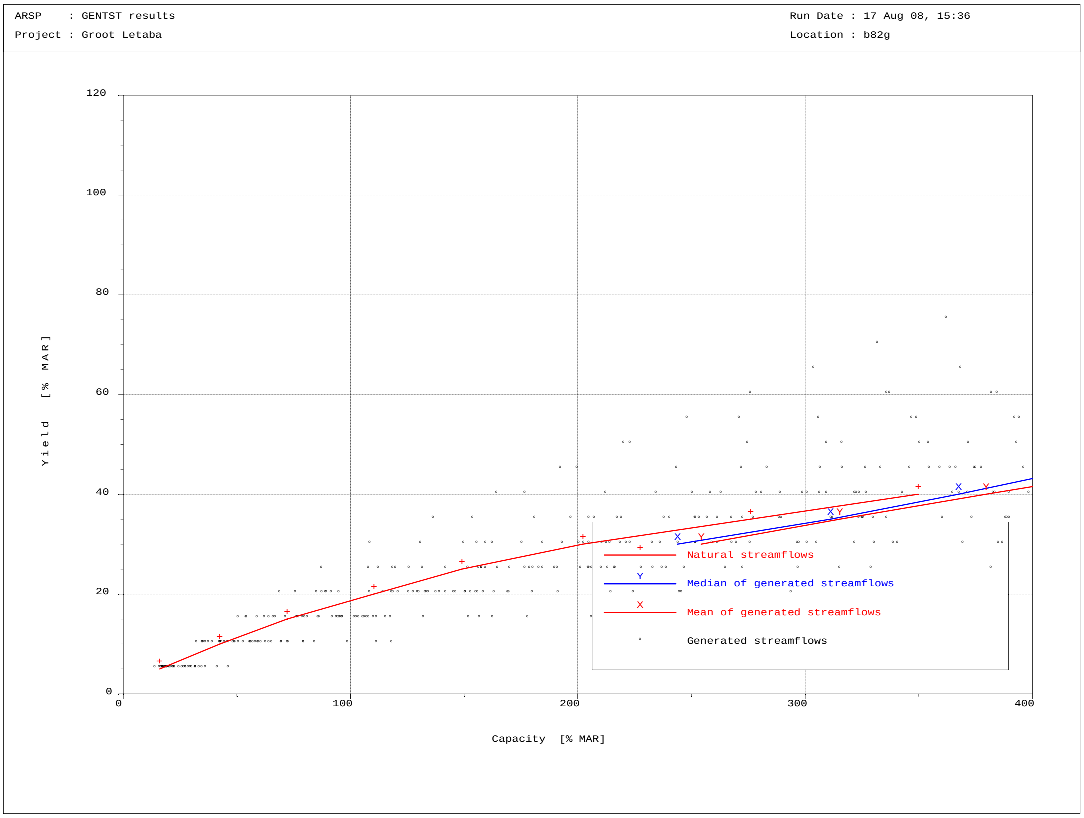
80
100
120
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b82g
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows
0
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40
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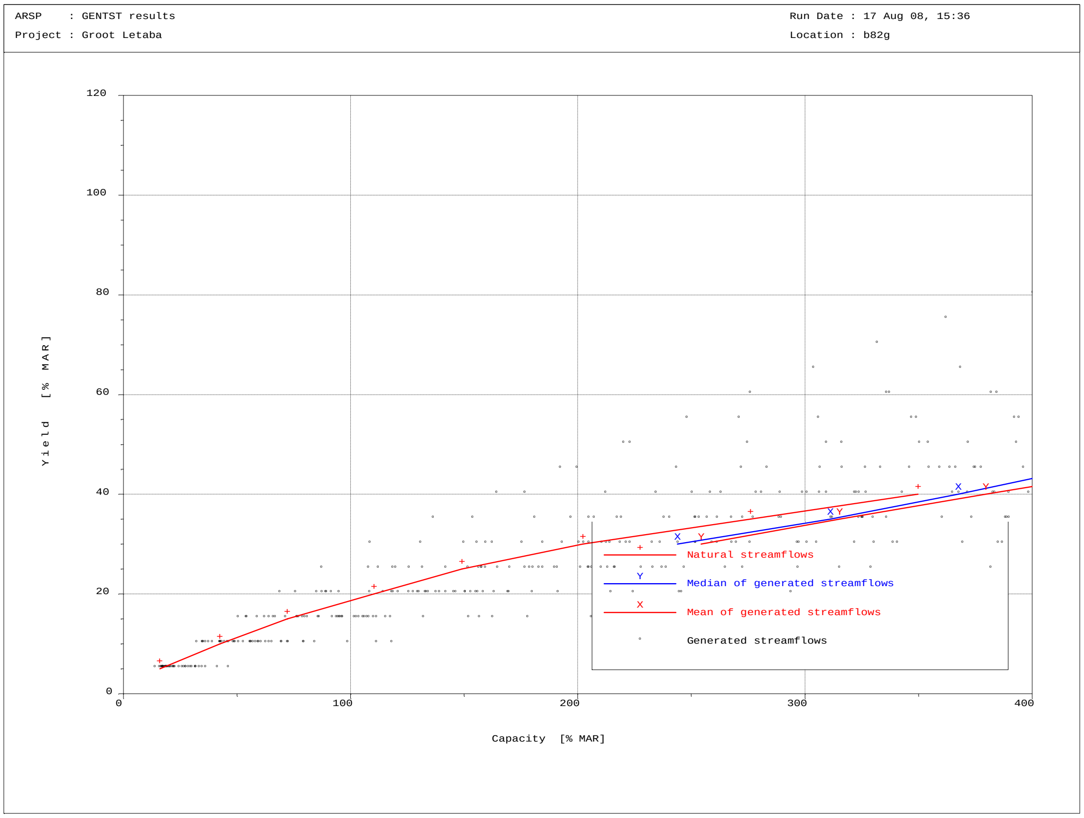
80
100
120
0
100
200
300
400


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b82g
Yield [% MAR]
Capacity [% MAR]
0
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60
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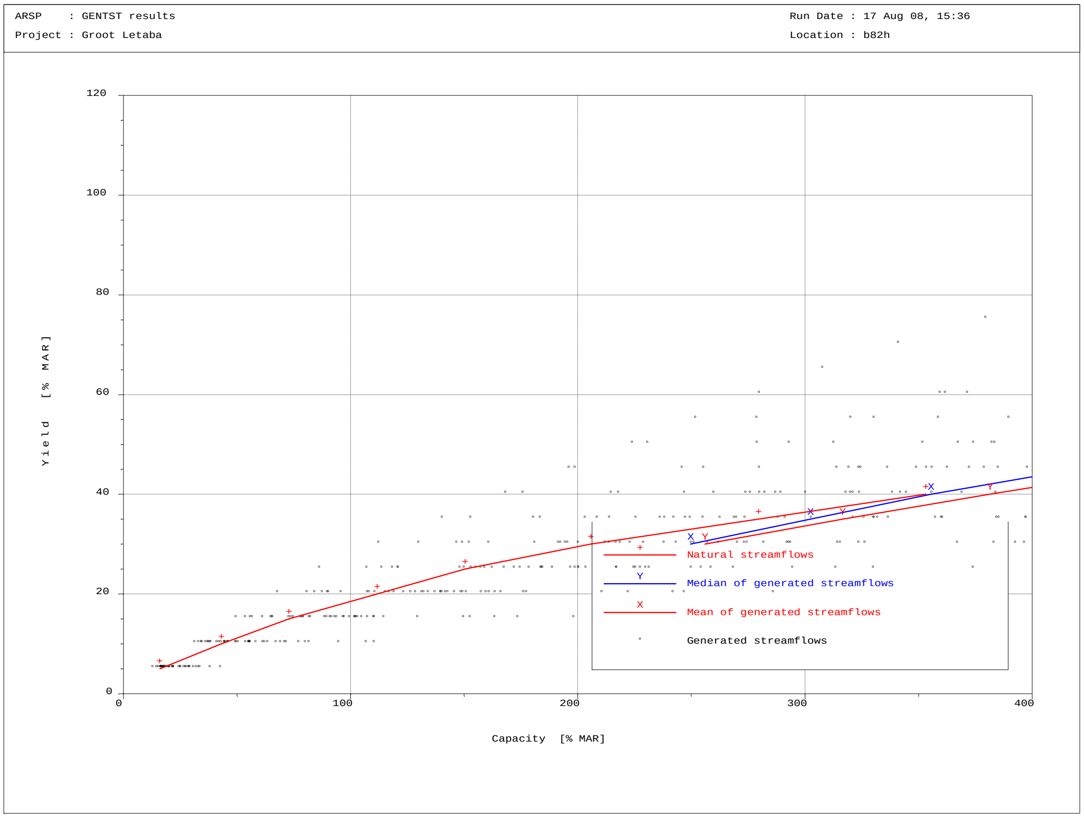
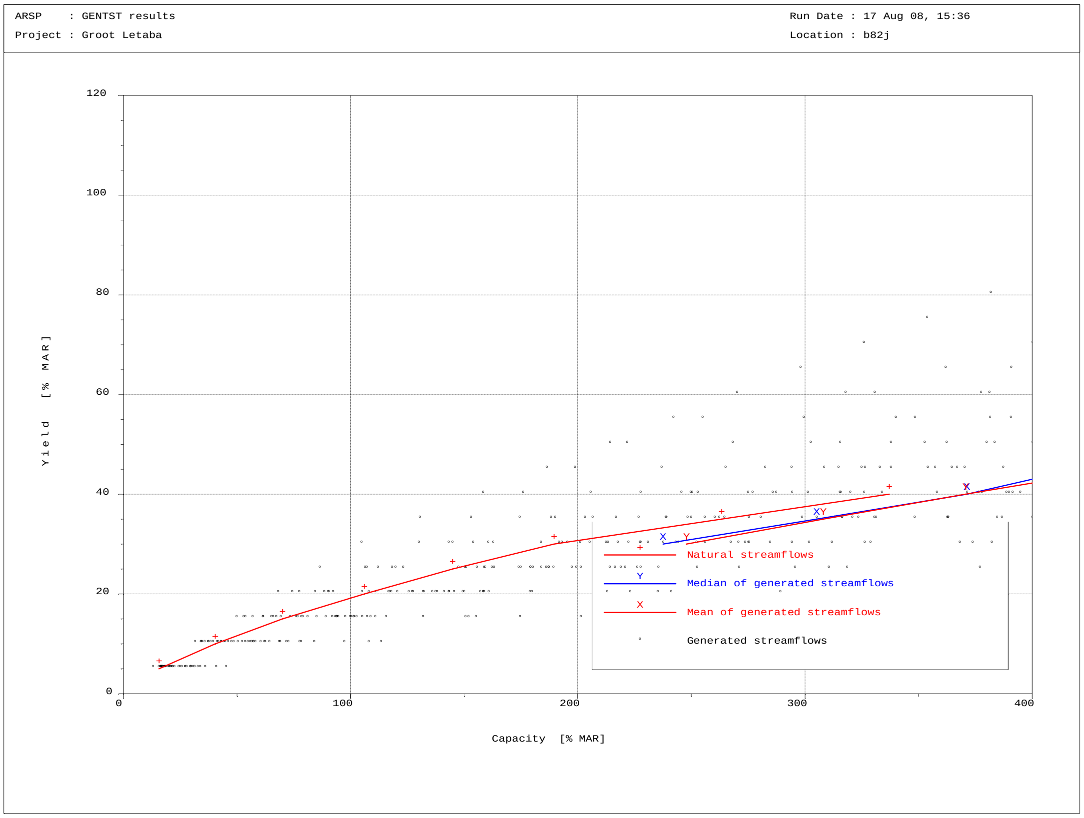
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b82h
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b82j
Yield [% MAR]
Capacity [% MAR]
0
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120
0
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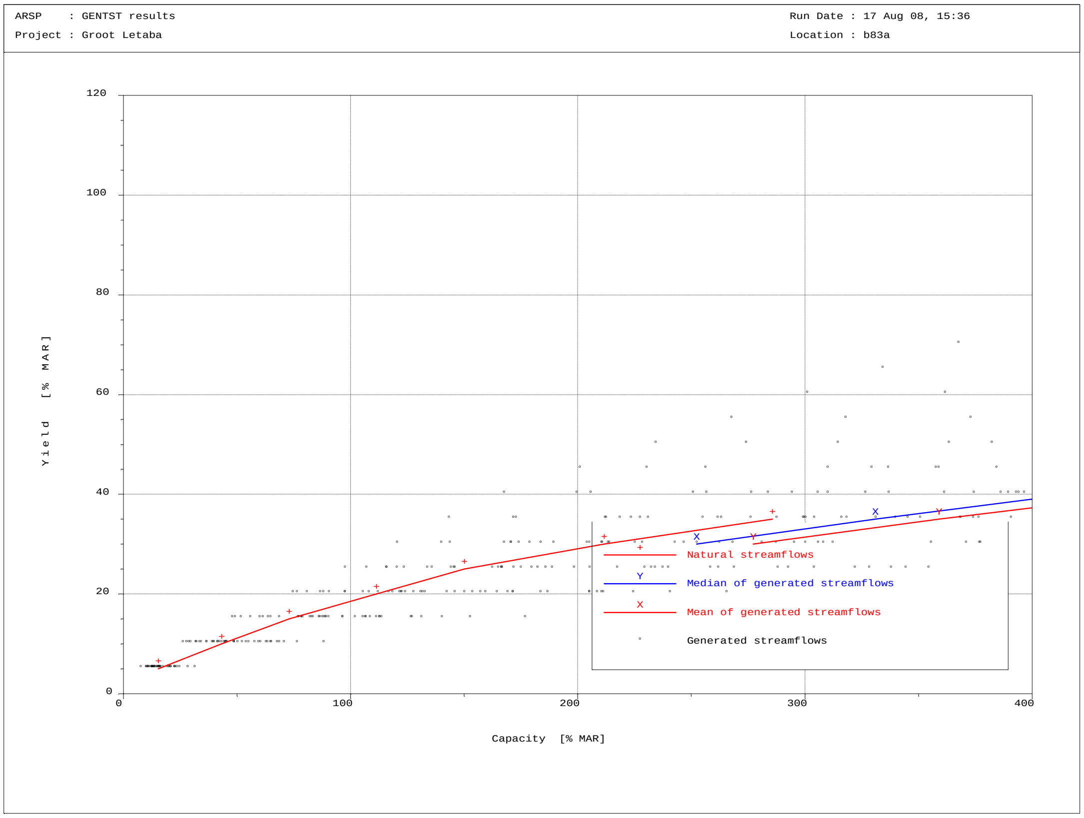
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b83a
Yield [% MAR]
Capacity [% MAR]
0
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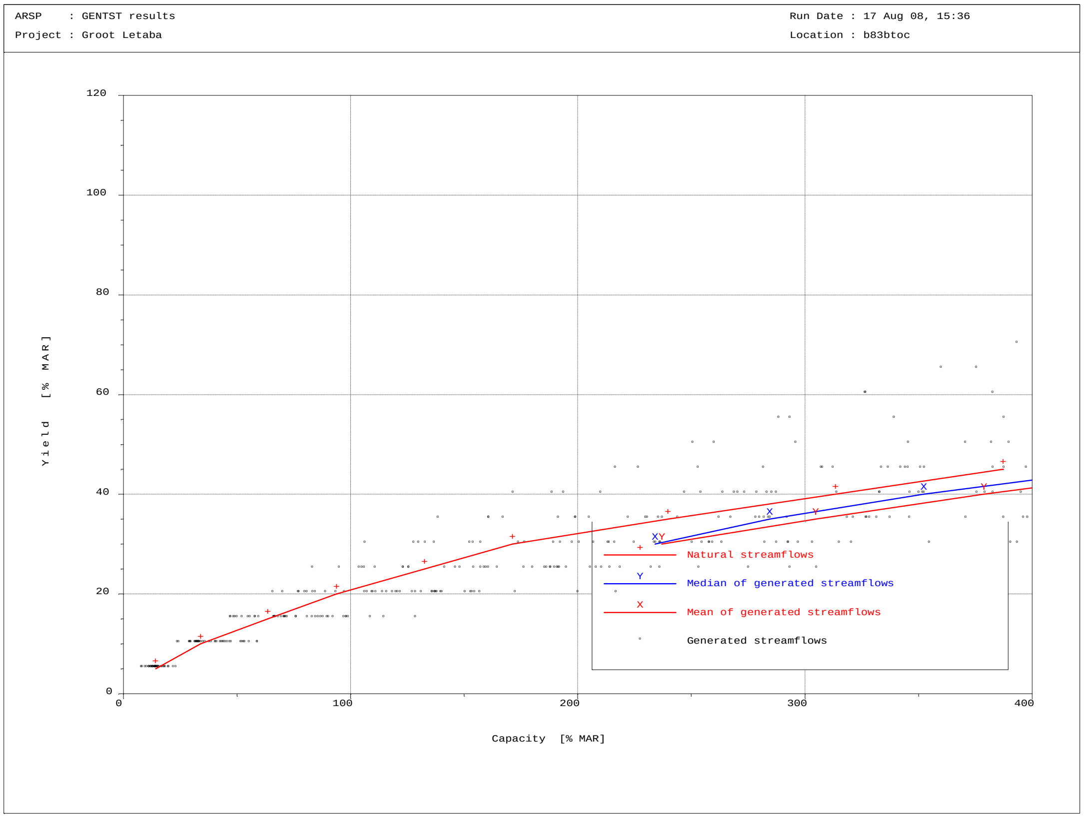
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b83btoc
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
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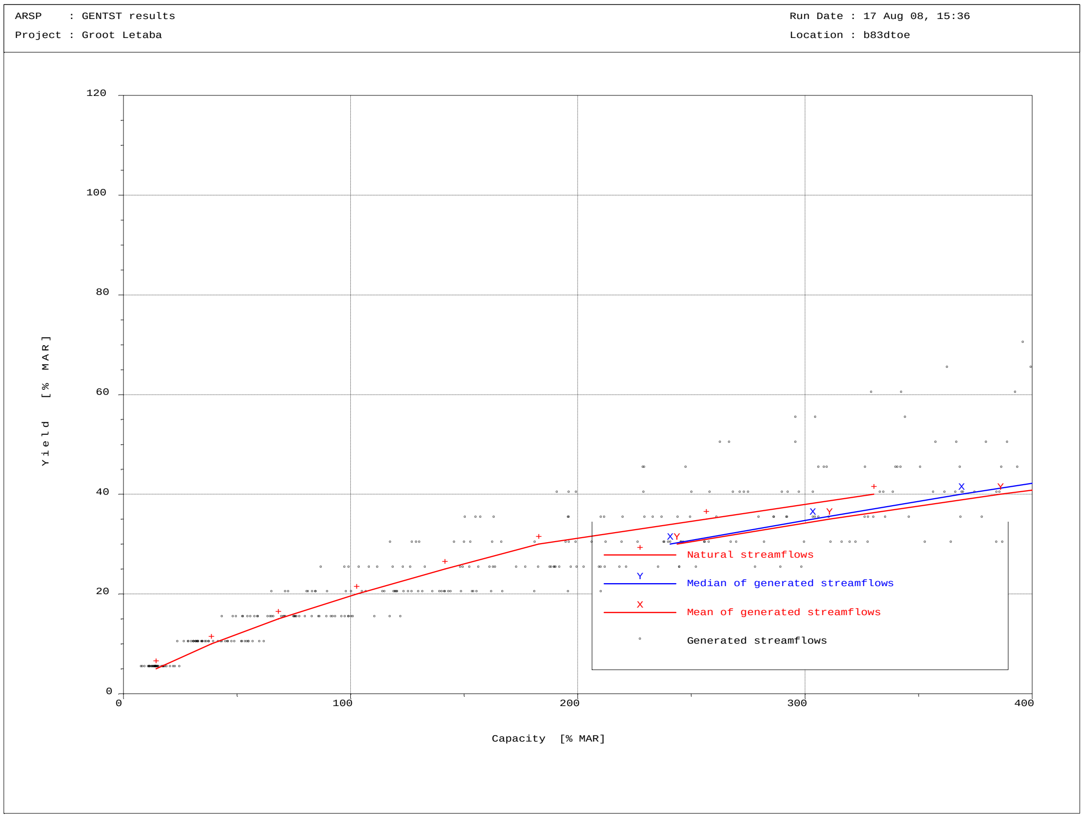
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b83dtoe
Yield [% MAR]
Capacity [% MAR]
0
20
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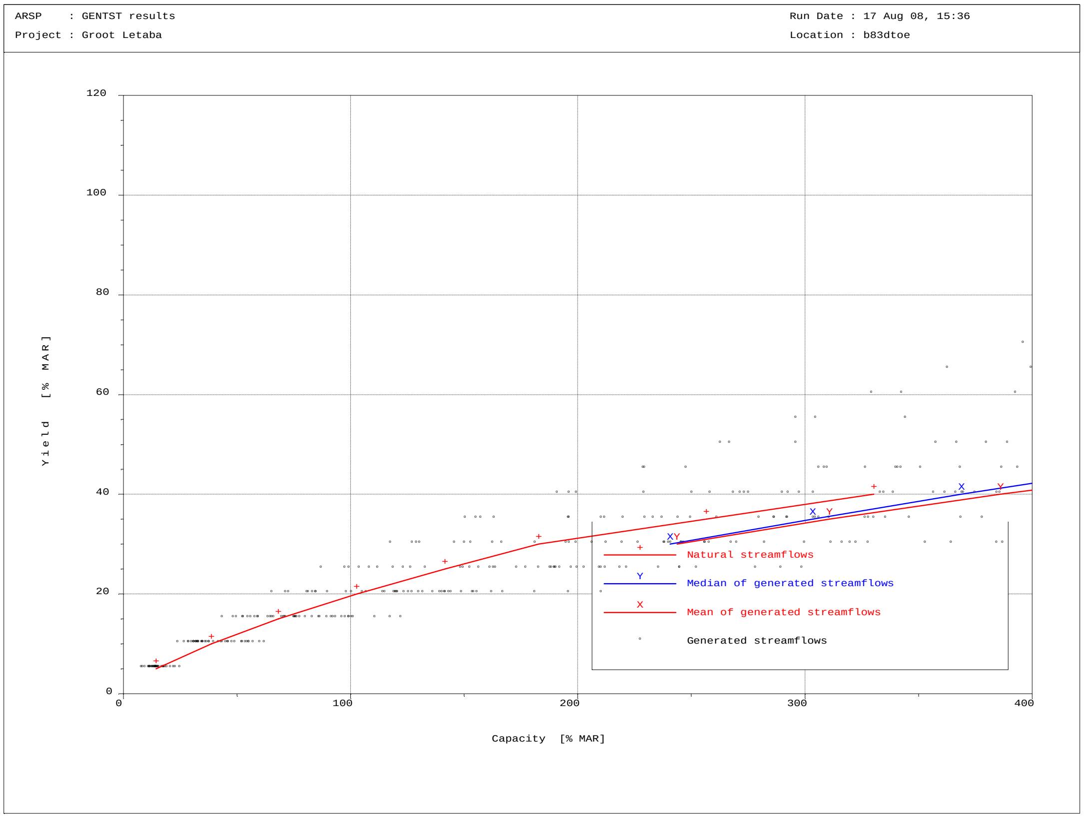
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b83dtoe
Yield [% MAR]
Capacity [% MAR]
0
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120
0
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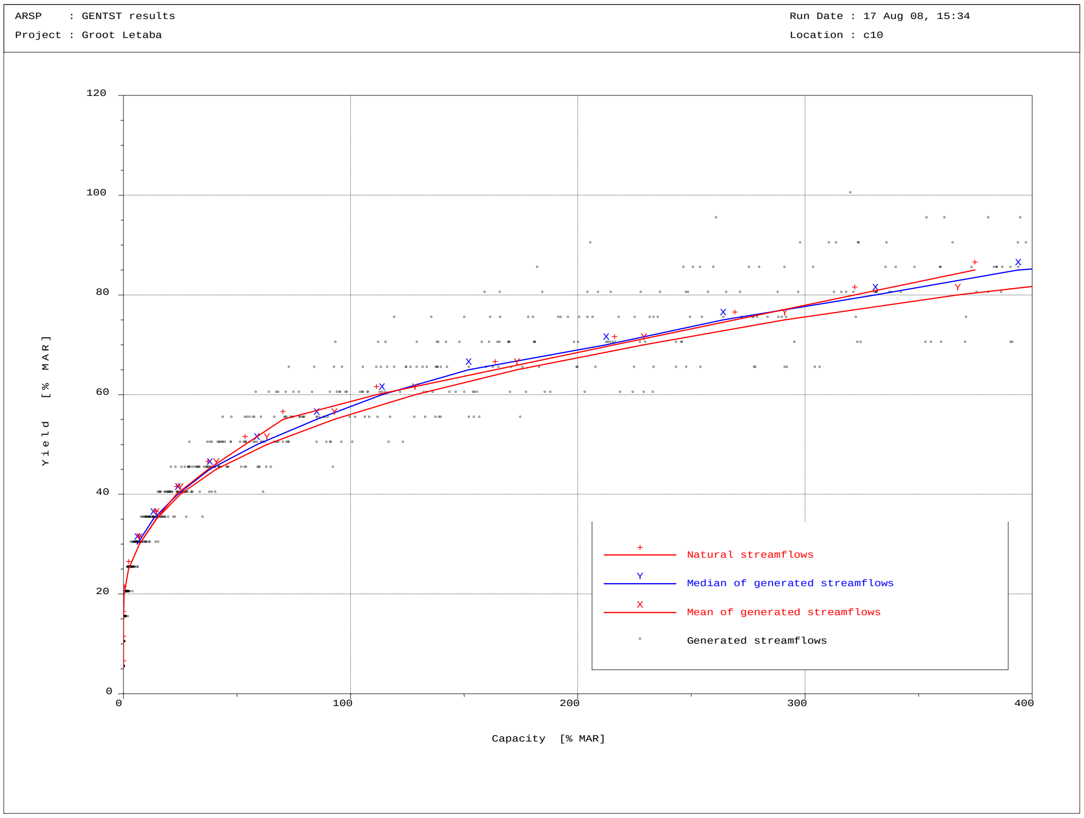
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:34
Location : c10
Yield [% MAR]
Capacity [% MAR]
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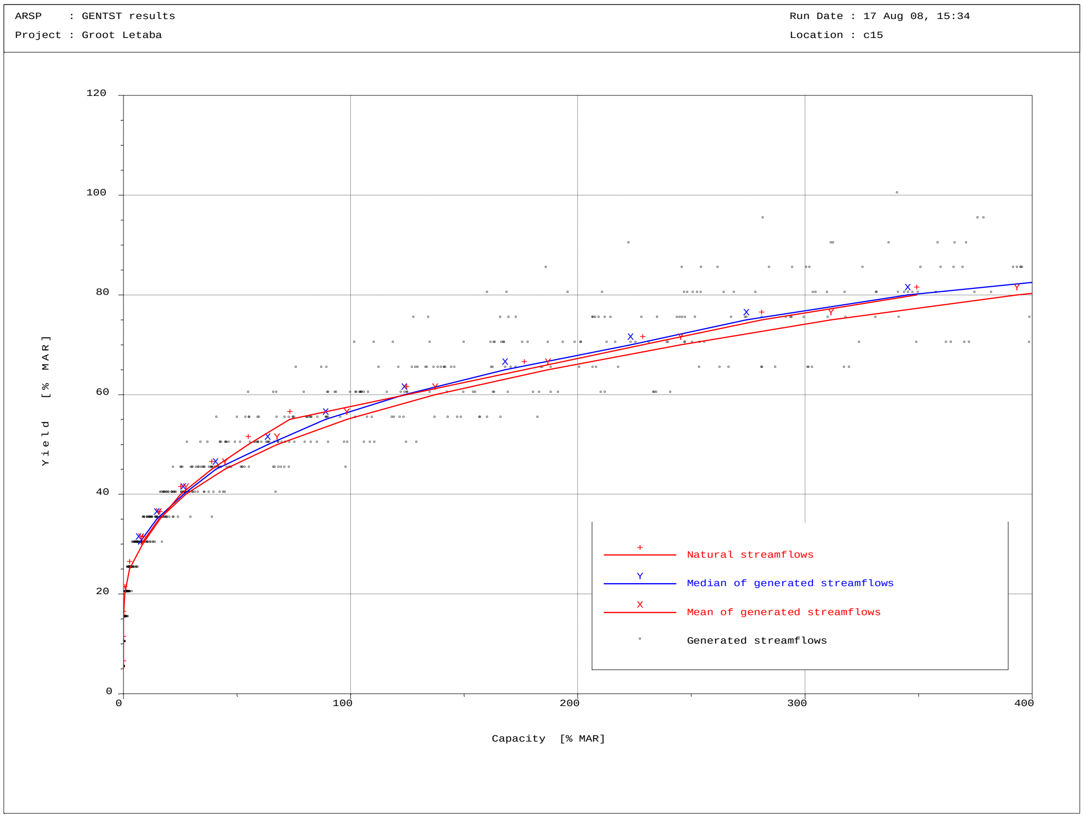
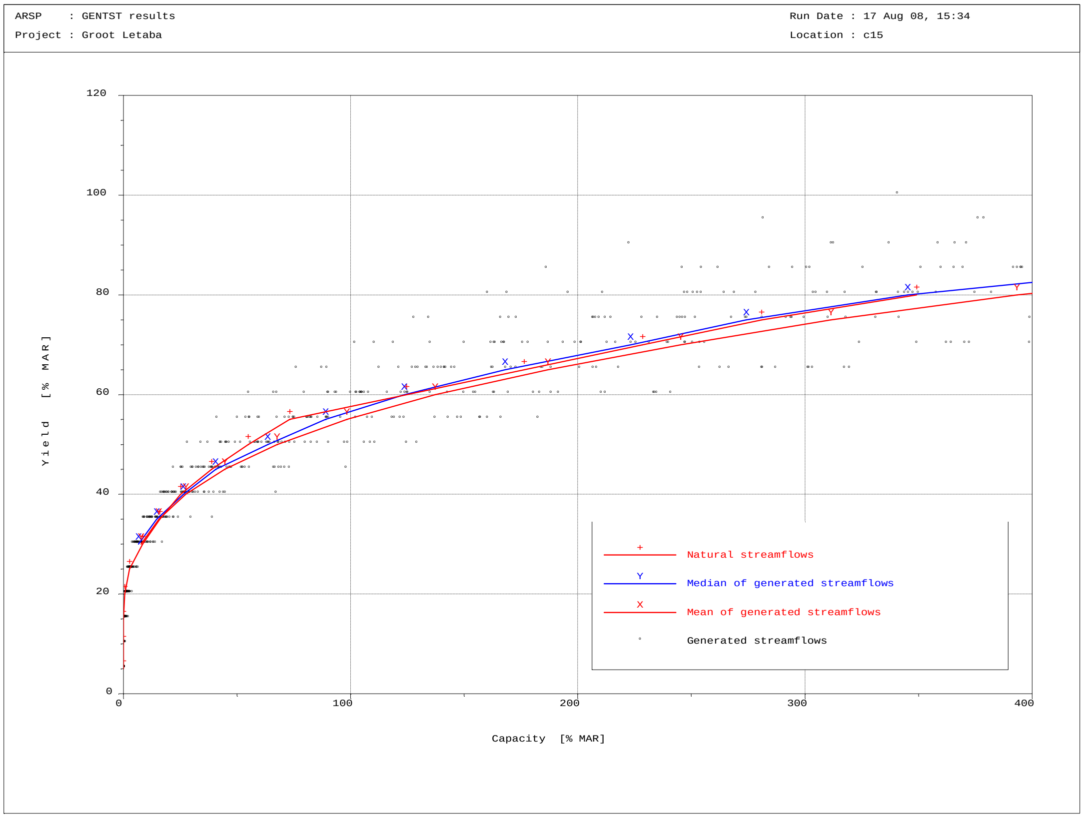
100
120
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:34
Location : c15
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:34
Location : c15
Yield [% MAR]
Capacity [% MAR]
0
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120
0
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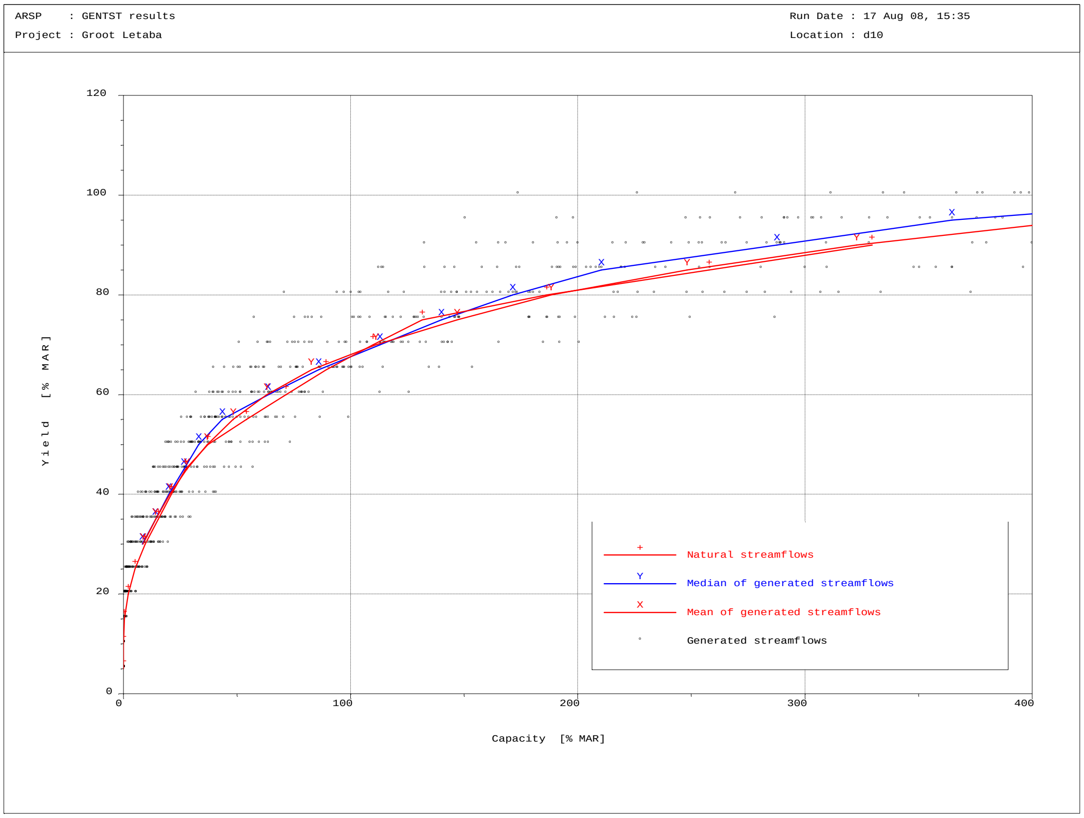
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:35
Location : d10
Yield [% MAR]
Capacity [% MAR]
0
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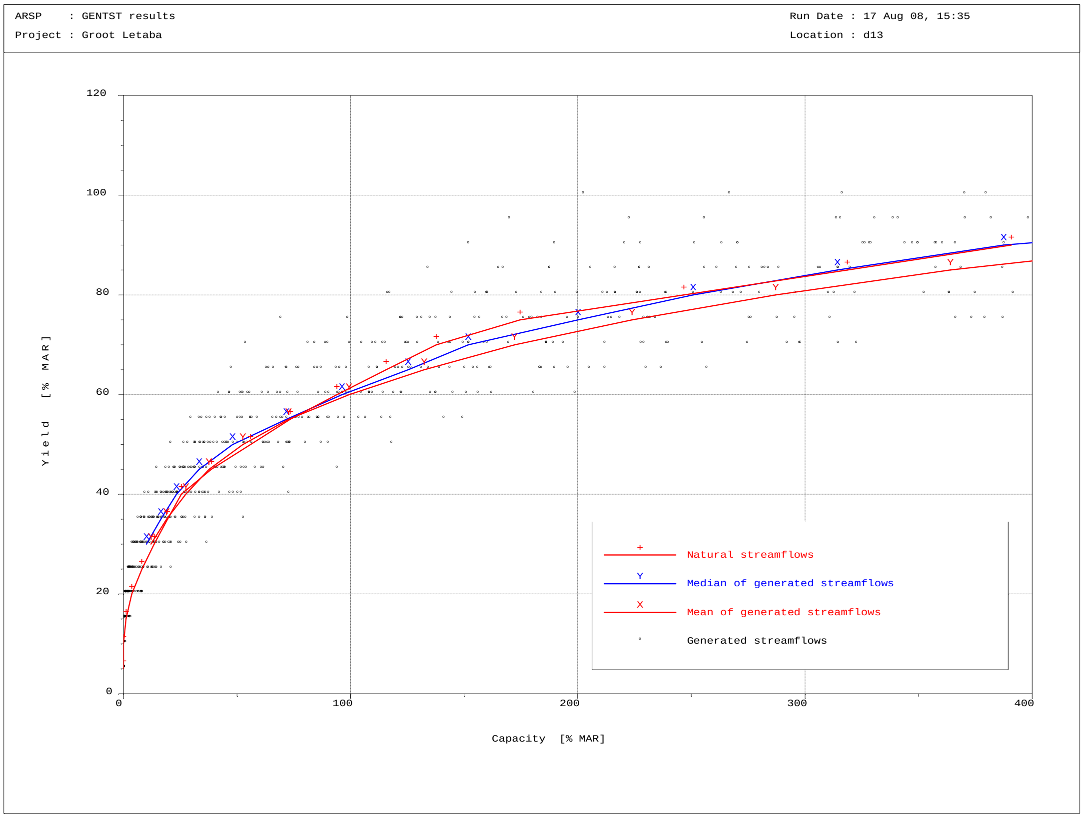
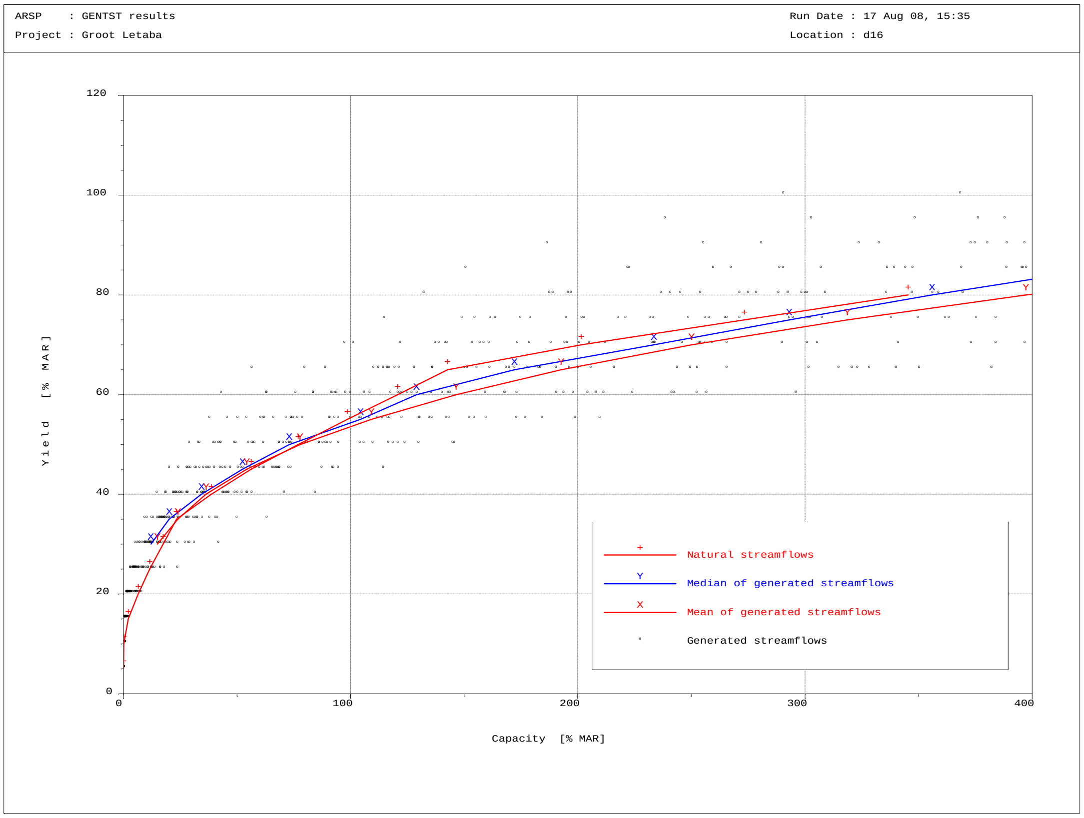
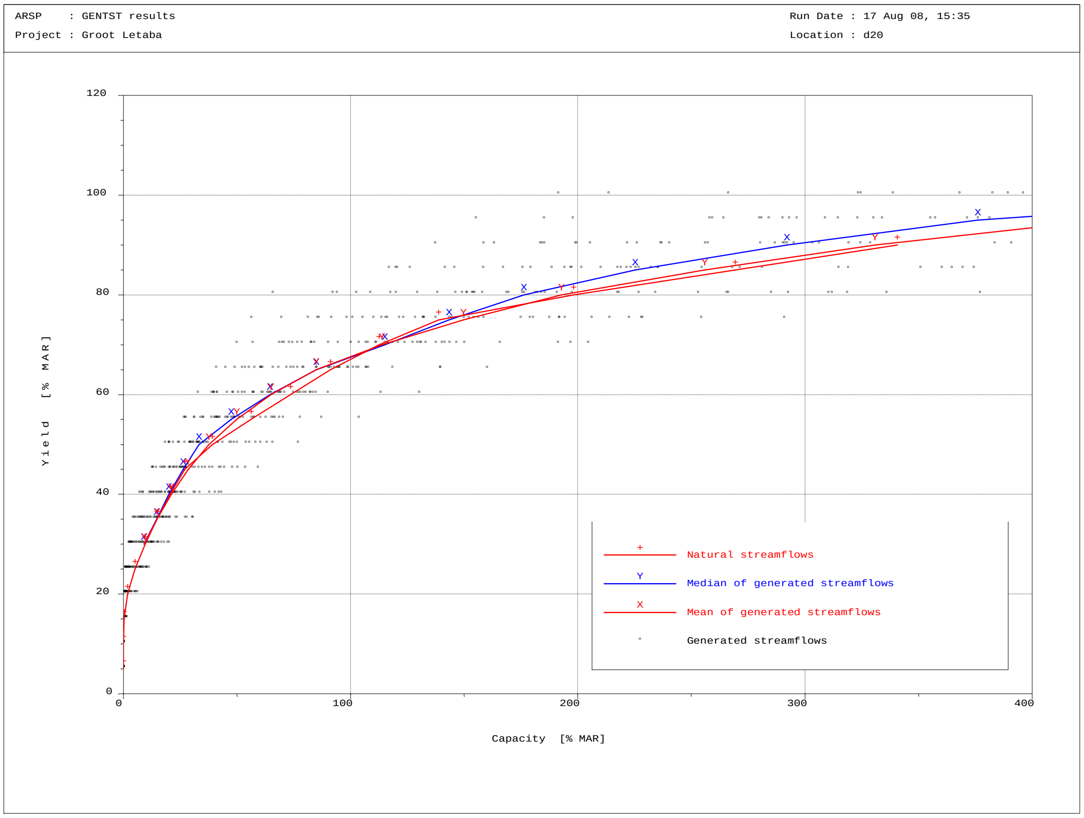
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:35
Location : d13
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows
0
20
40
60
80
100
120
0
100
200
300
400


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:35
Location : d16
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows



ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:35
Location : d20
Yield [% MAR]
Capacity [% MAR]
0
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40
60
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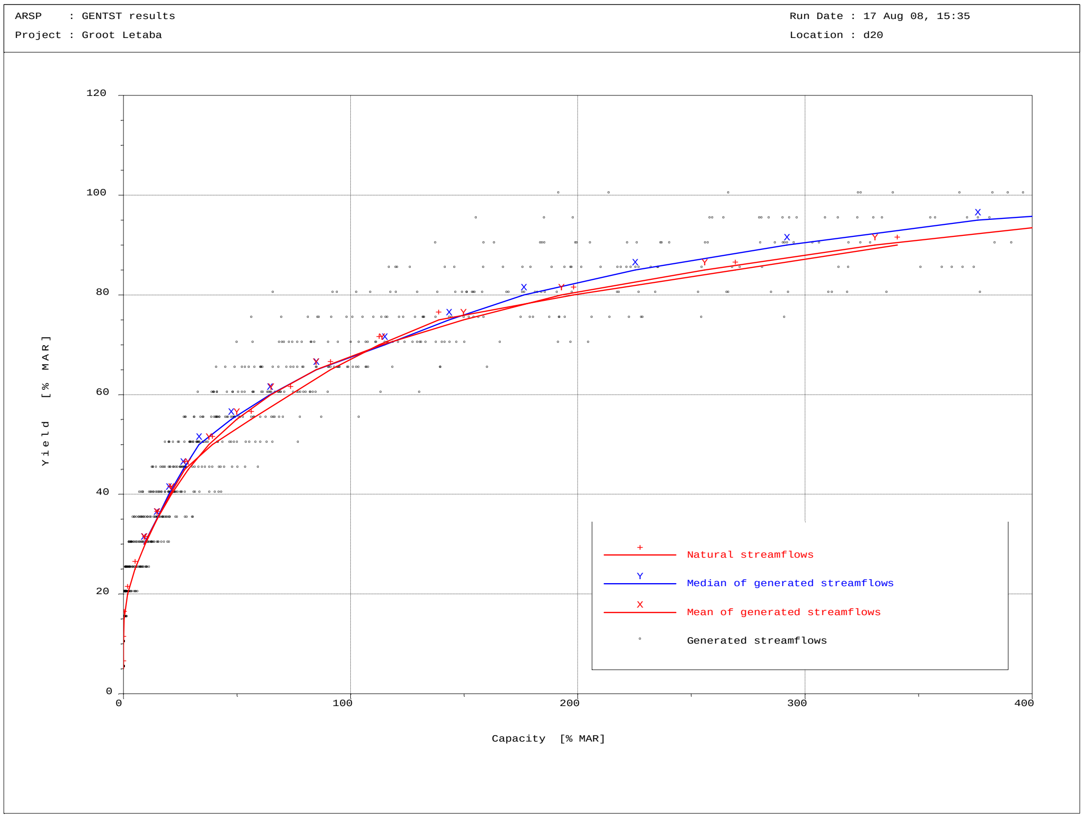
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:35
Location : d20
Yield [% MAR]
Capacity [% MAR]
0
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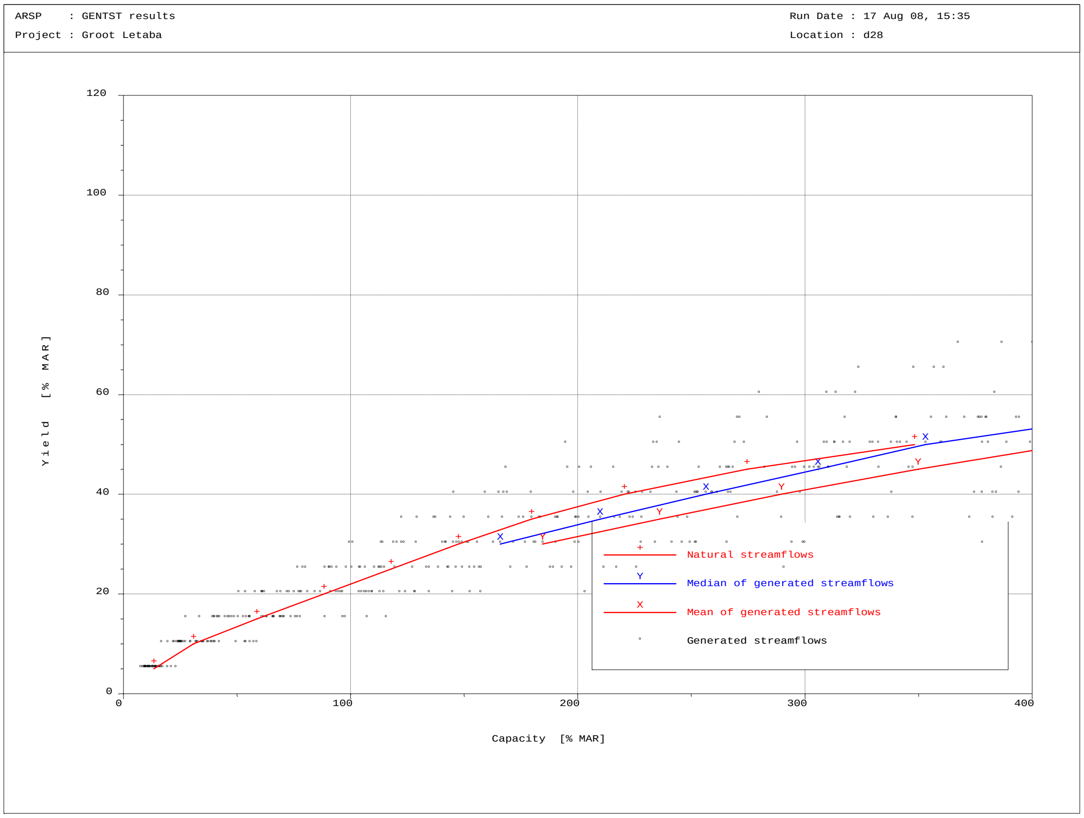
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:35
Location : d28
Yield [% MAR]
Capacity [% MAR]
0
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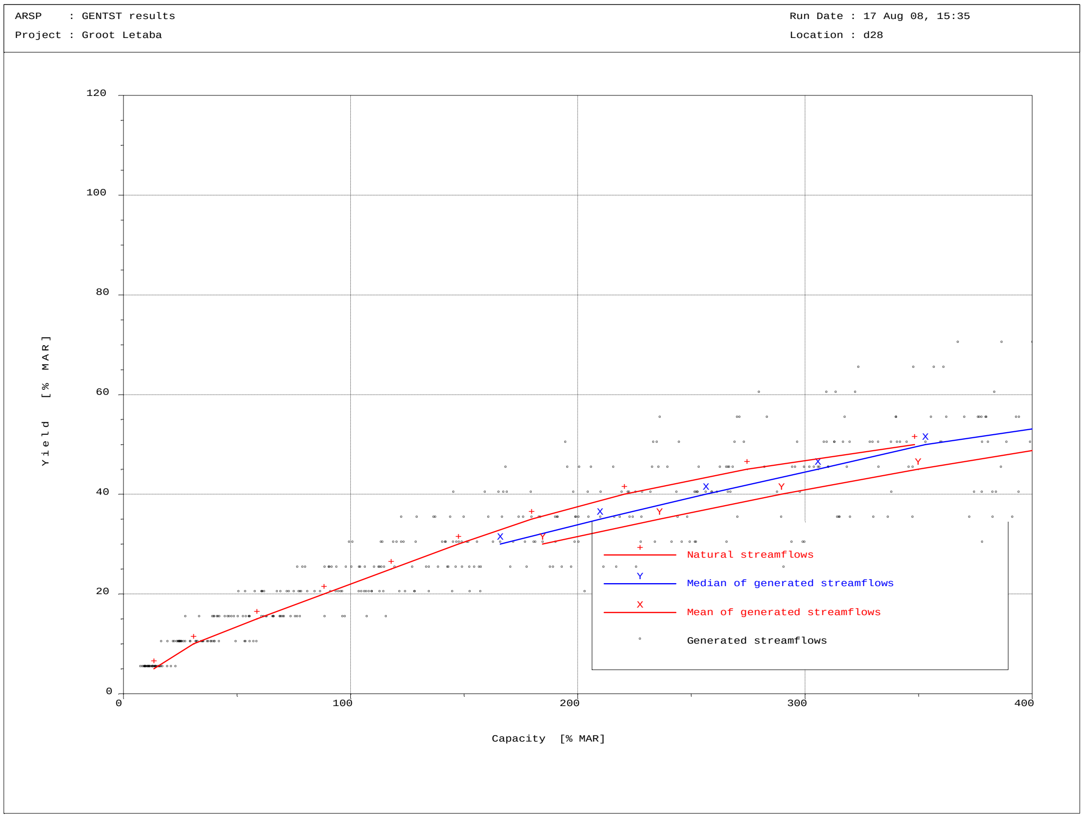
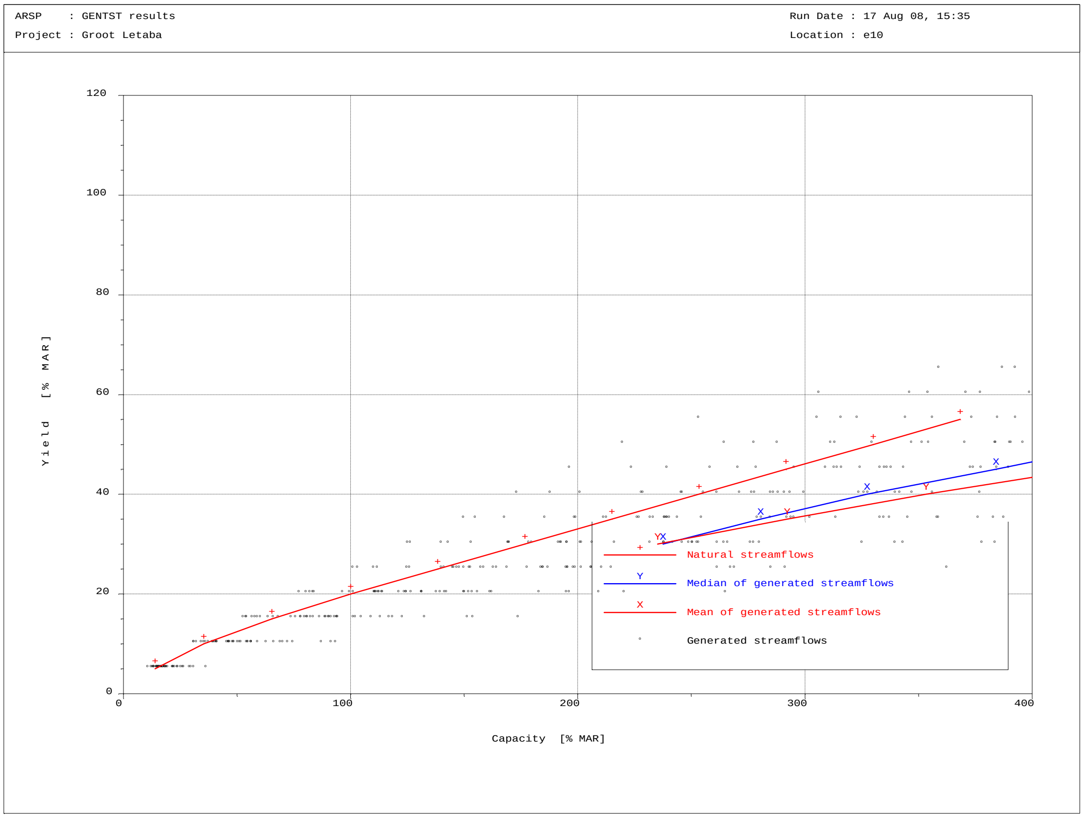
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:35
Location : d28
120
100
80
60
40
20
0
Yield [% MAR]
0
100
200
300
400
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:35
Location : e10
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
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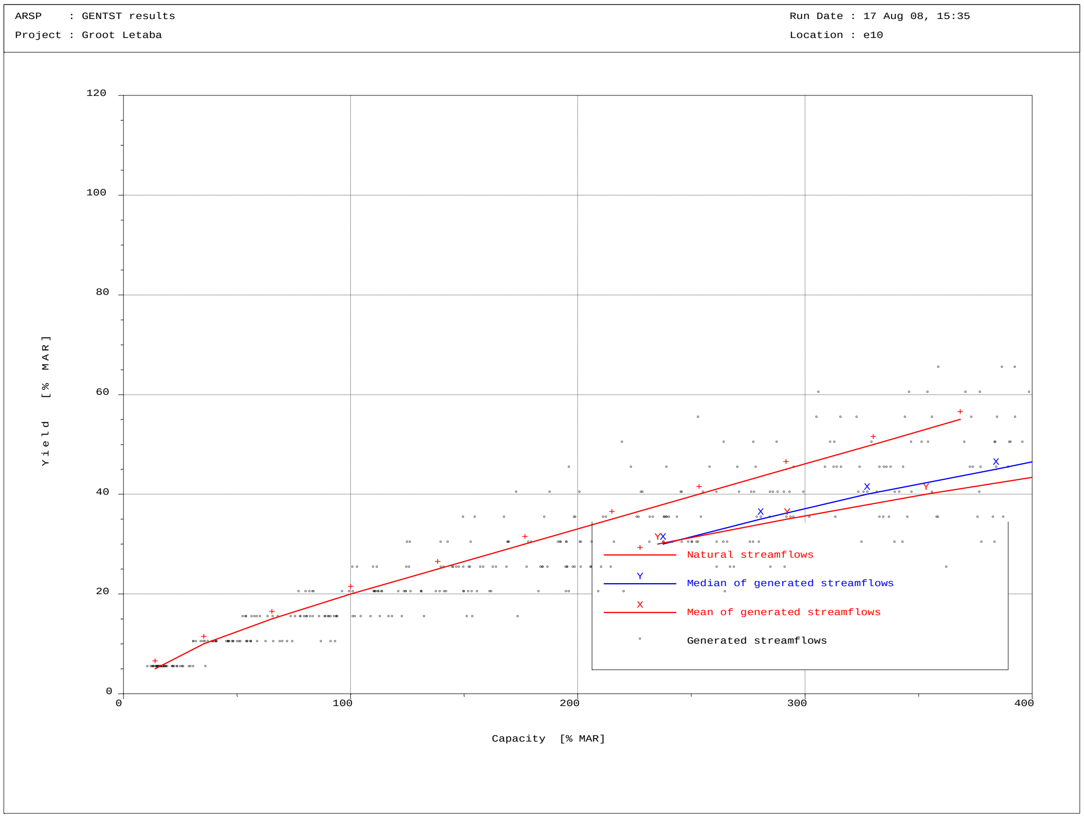
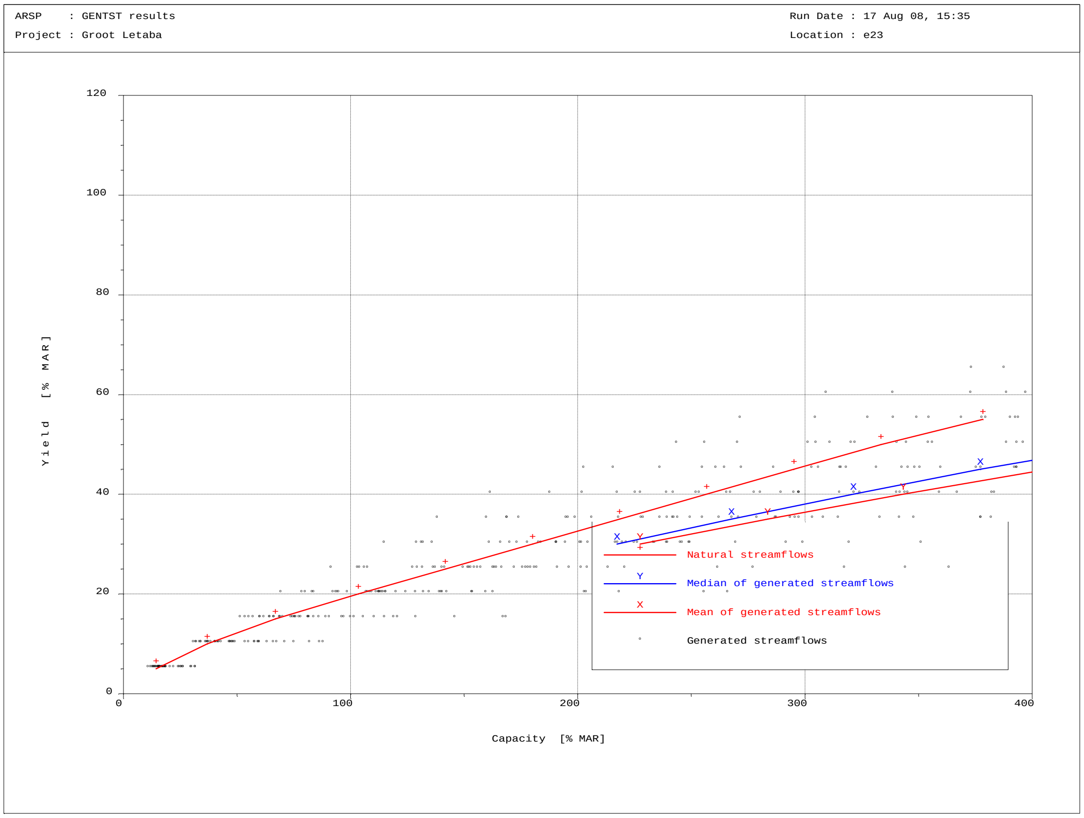
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:35
Location : e10
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:35
Location : e23
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows
0
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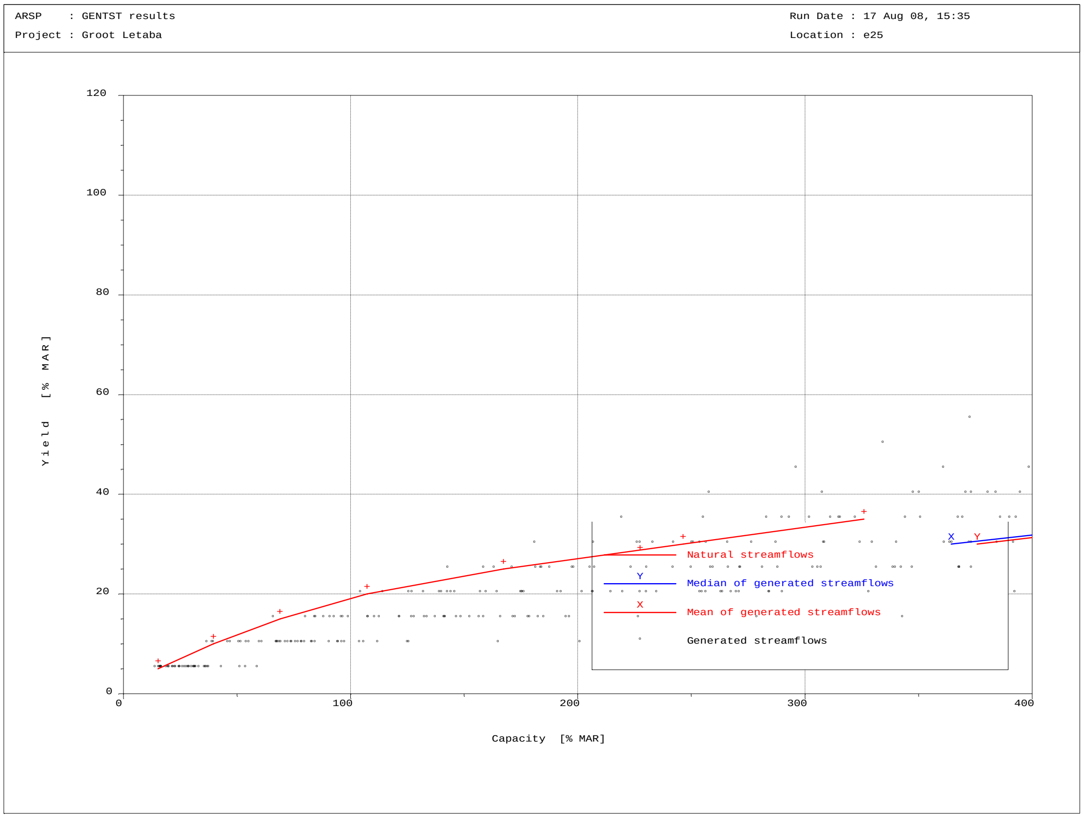
80
100
120
0
100
200
300
400


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:35
Location : e25
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows
0
20
40
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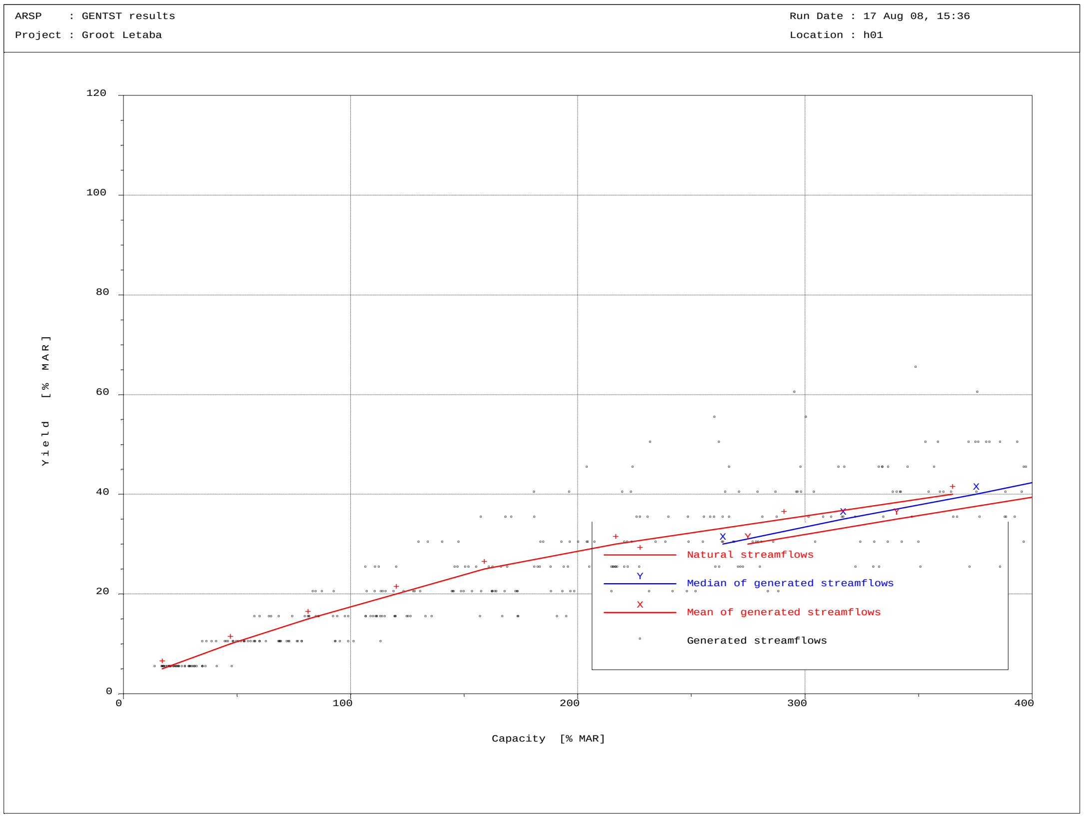
80
100
120
0
100
200
300
400


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : h01
Yield [% MAR]
Capacity [% MAR]
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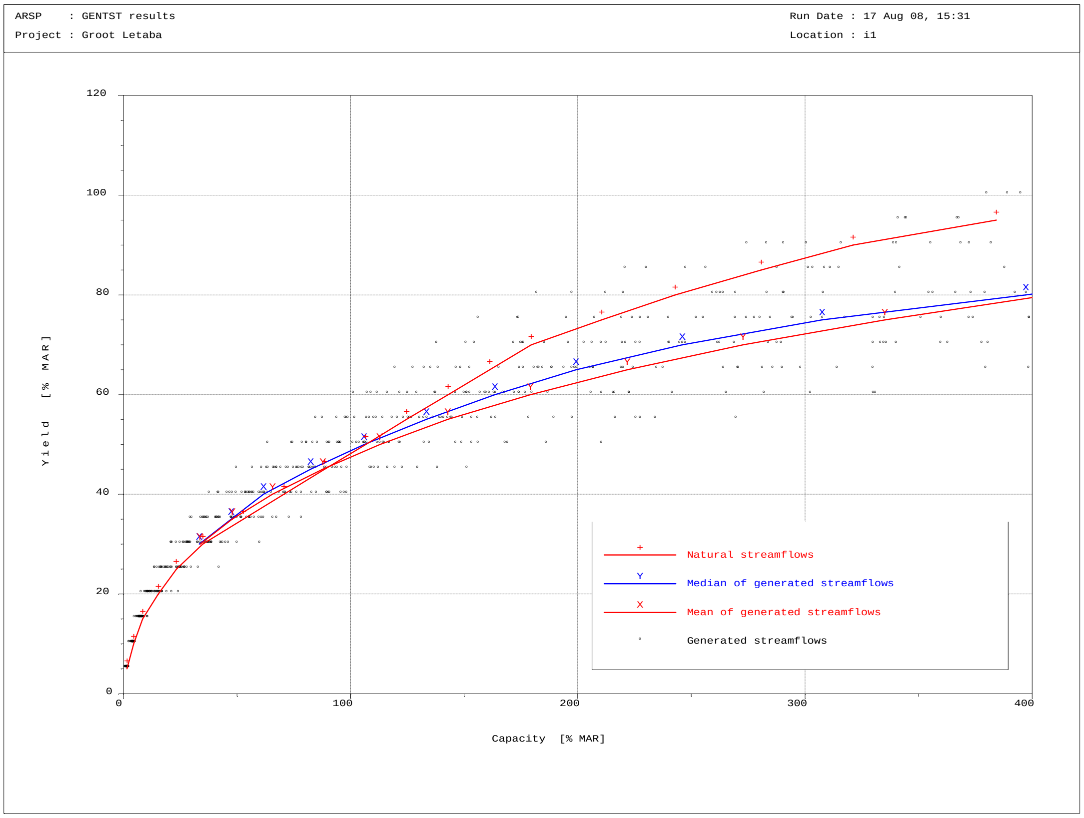
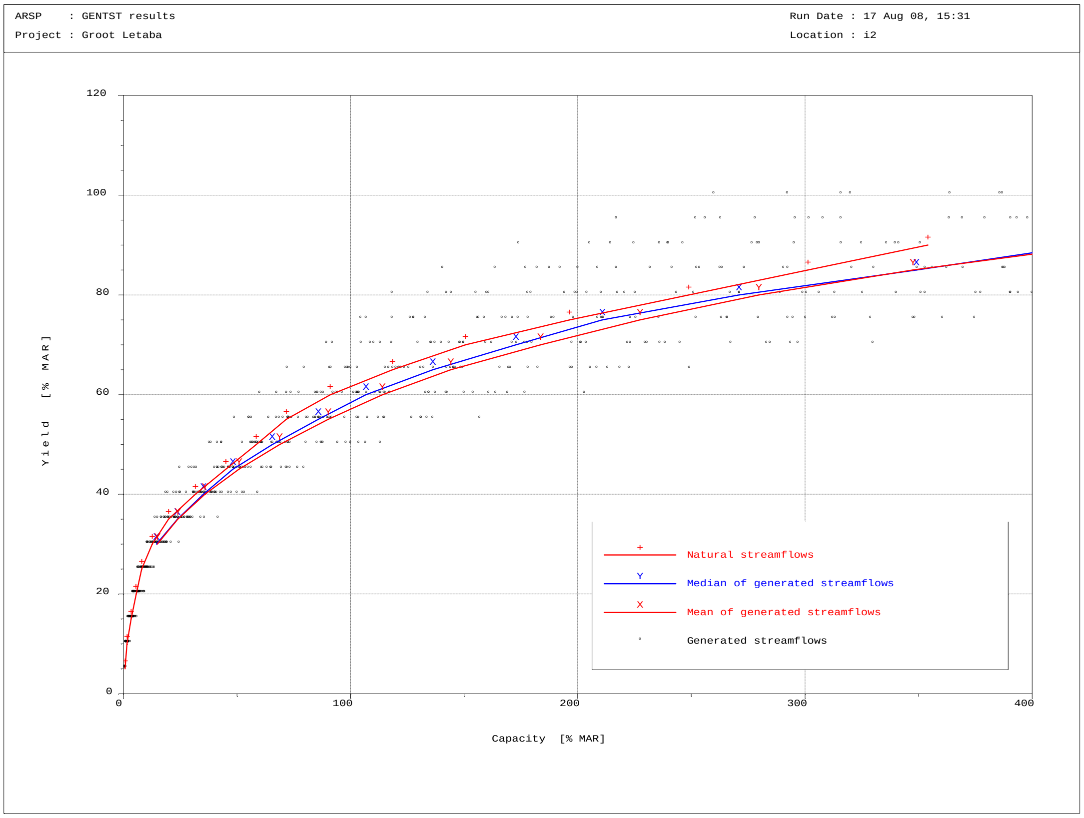
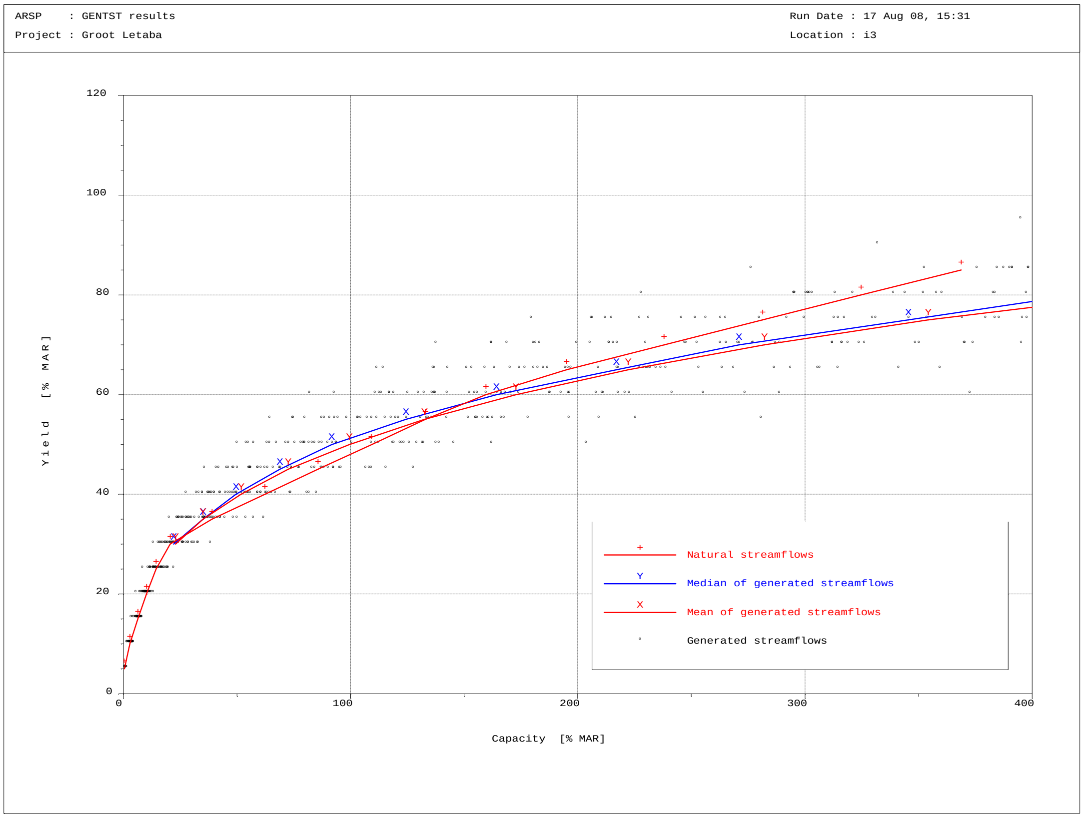
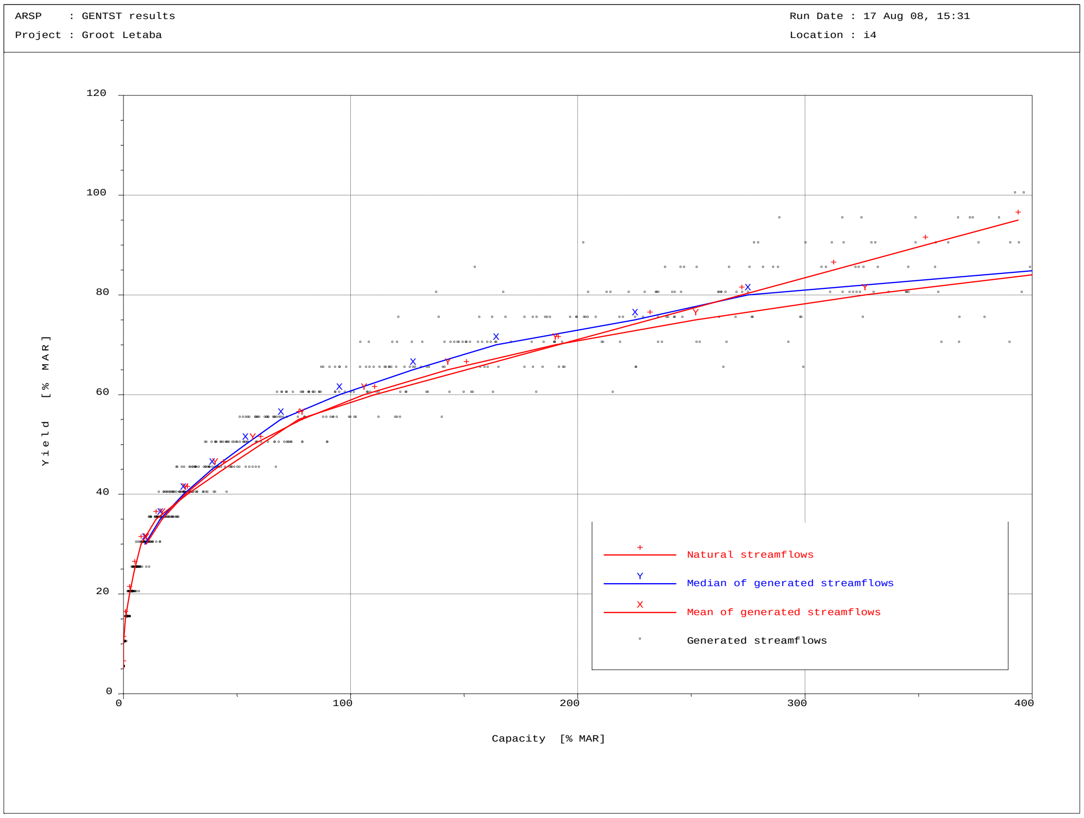
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

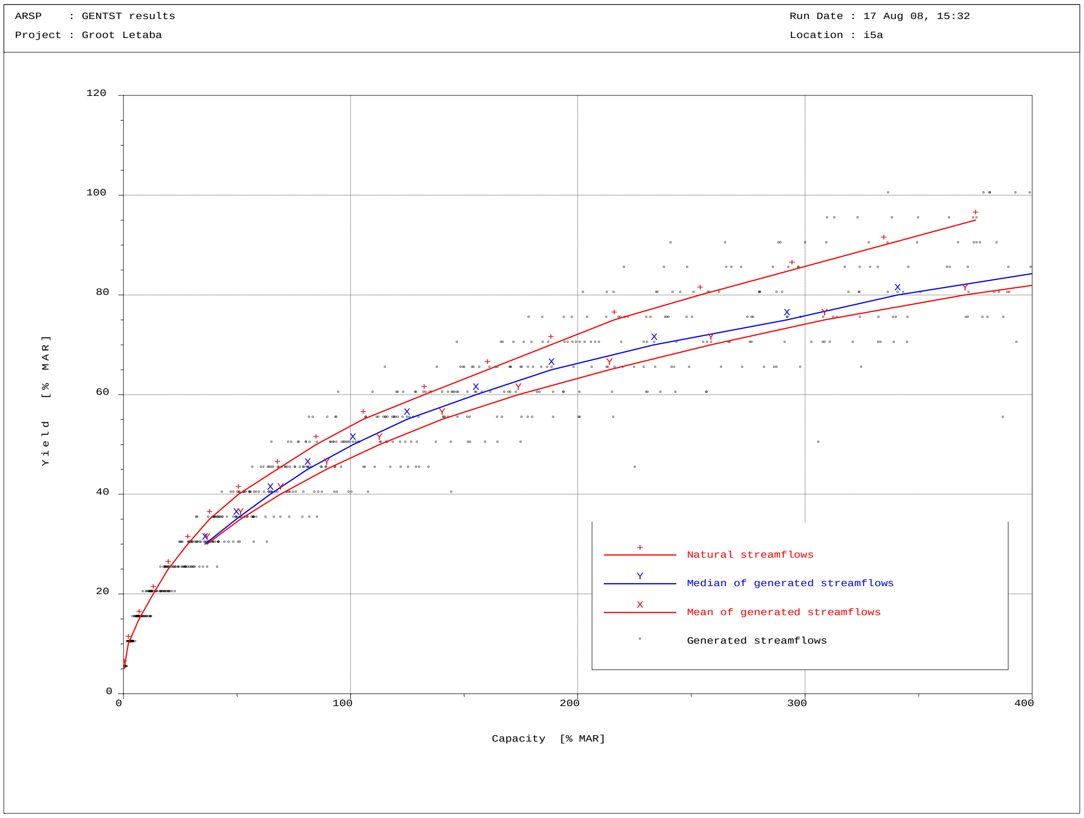


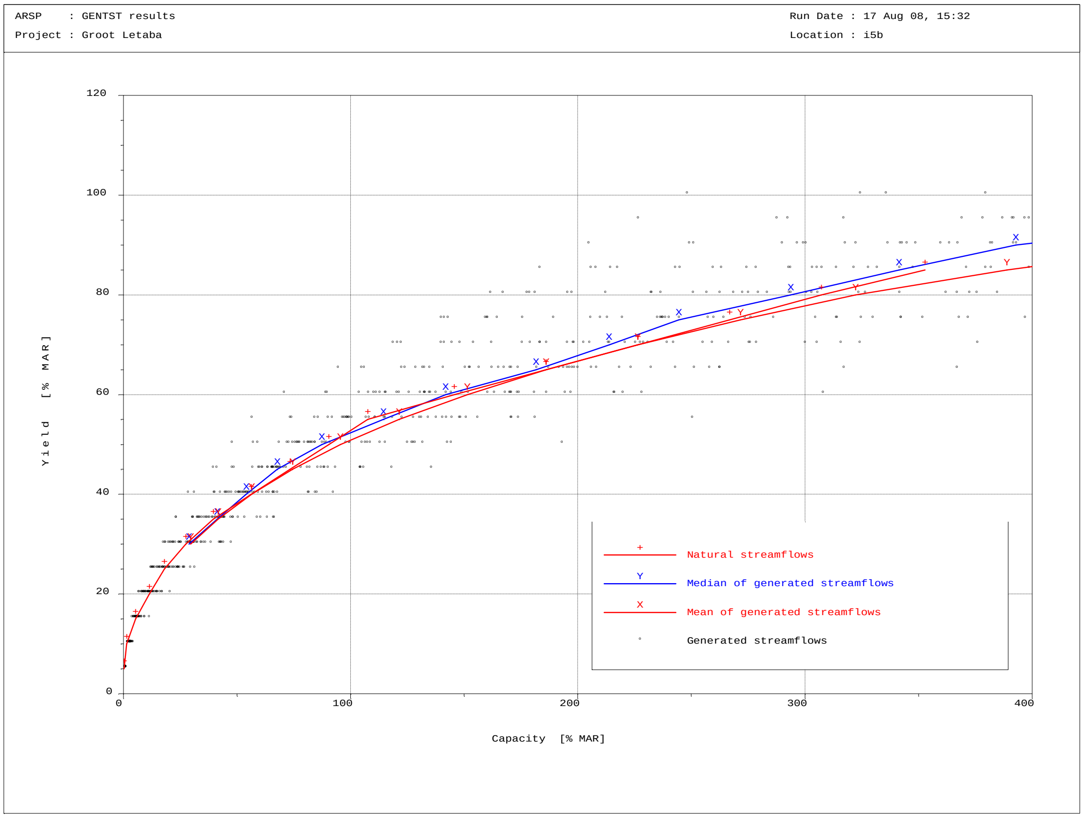
ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i1
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

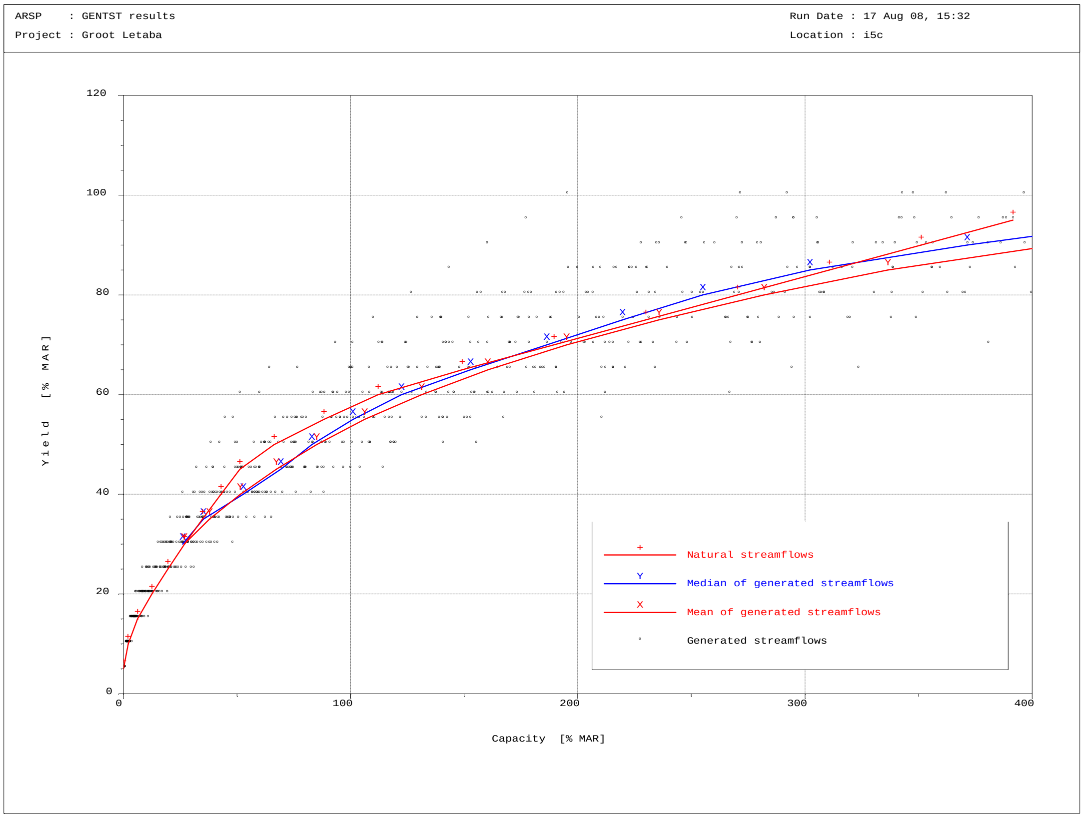

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i2
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows
0
20
40
60
80
100
120
0
100
200
300
400

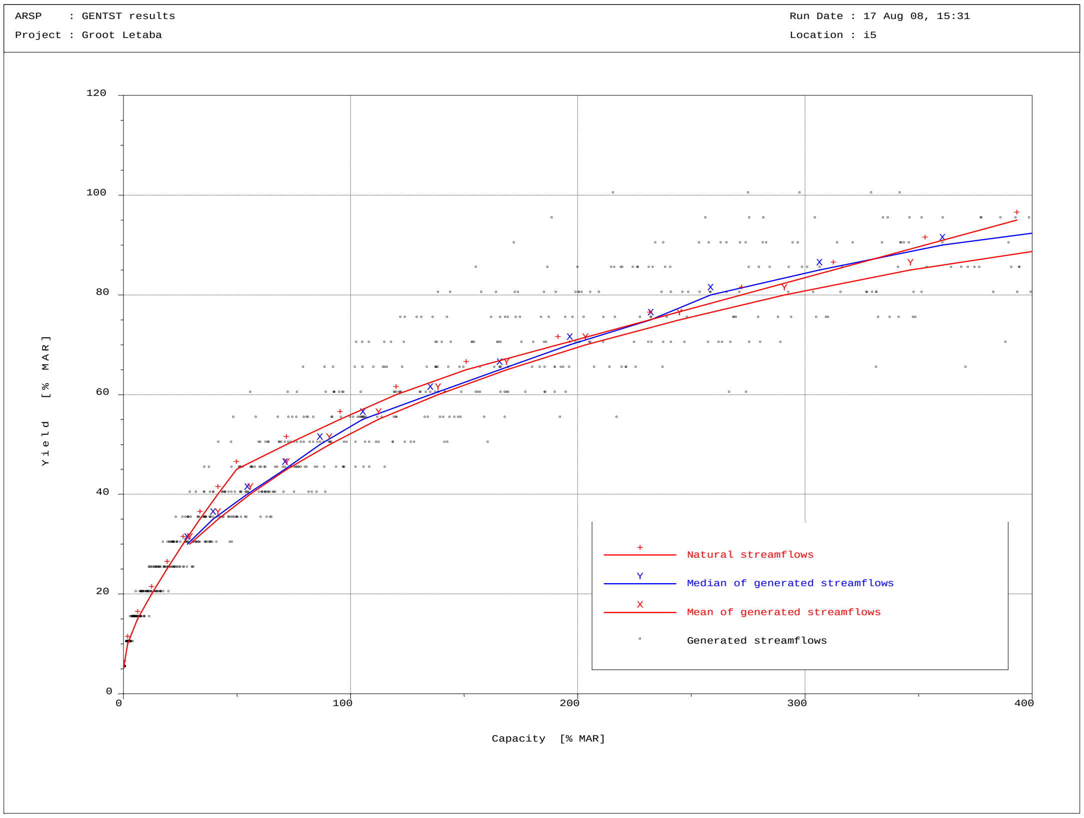

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i3
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

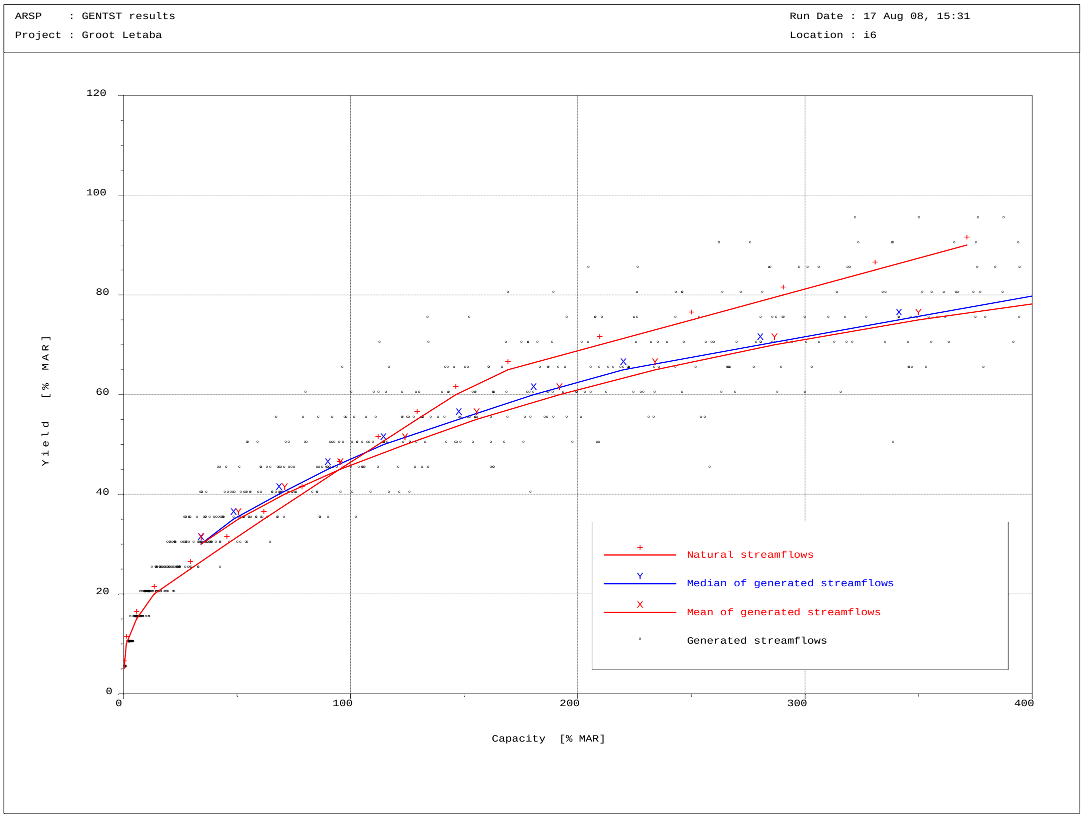

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i4
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

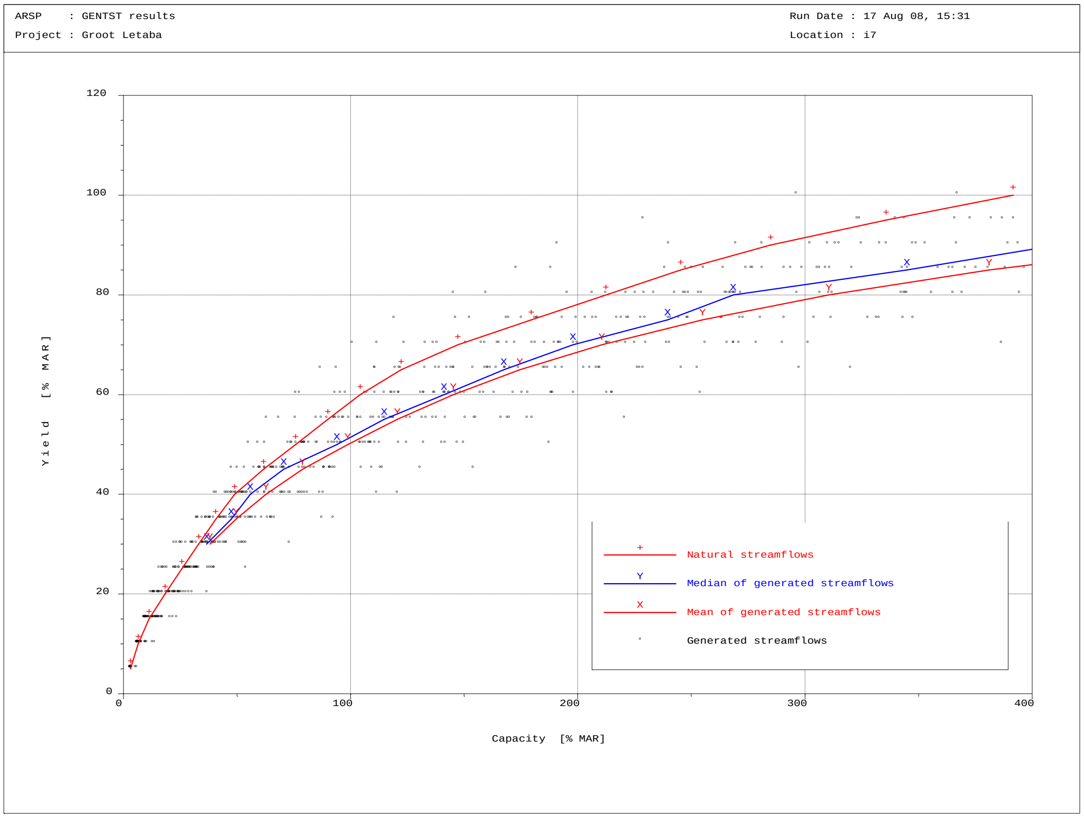

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i5a
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

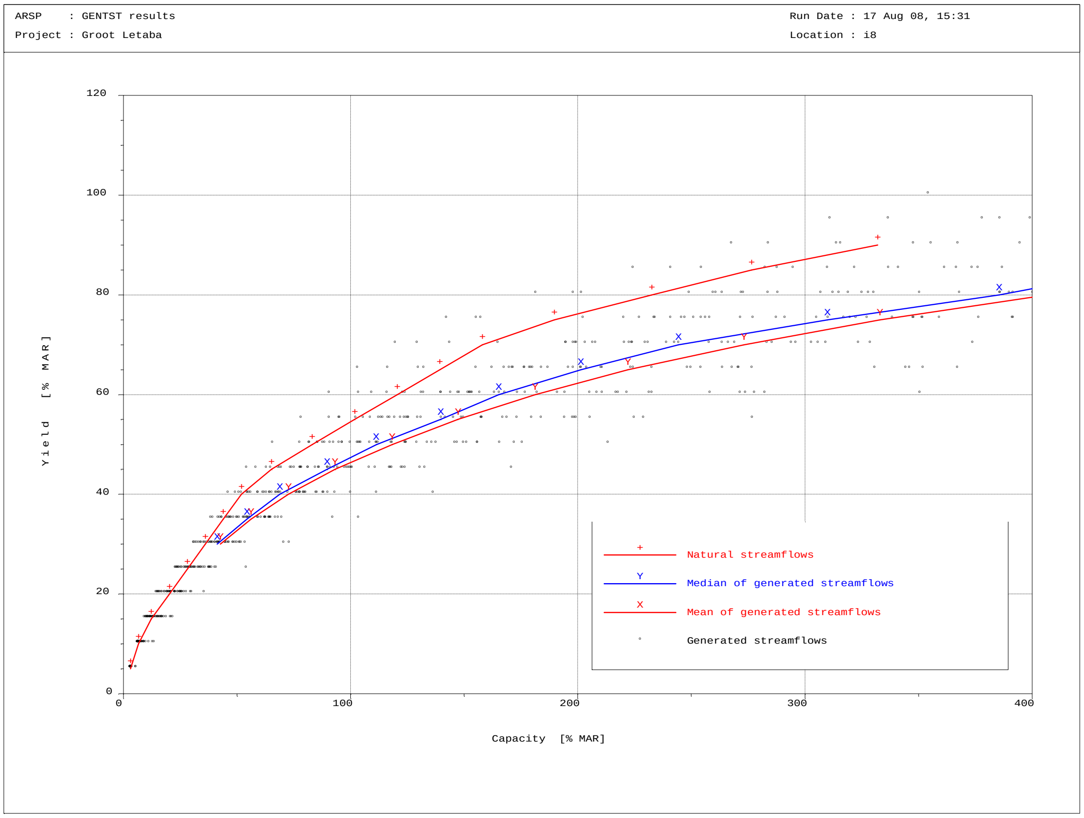

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i5b
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

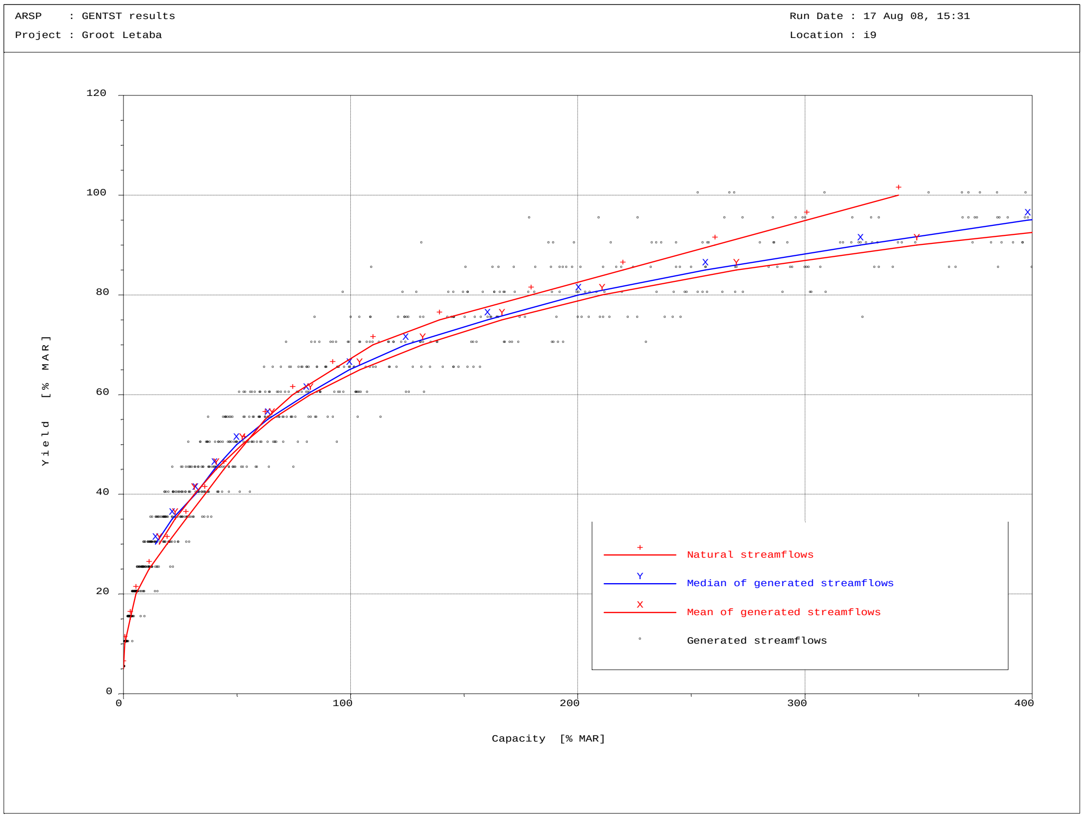

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i5c
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

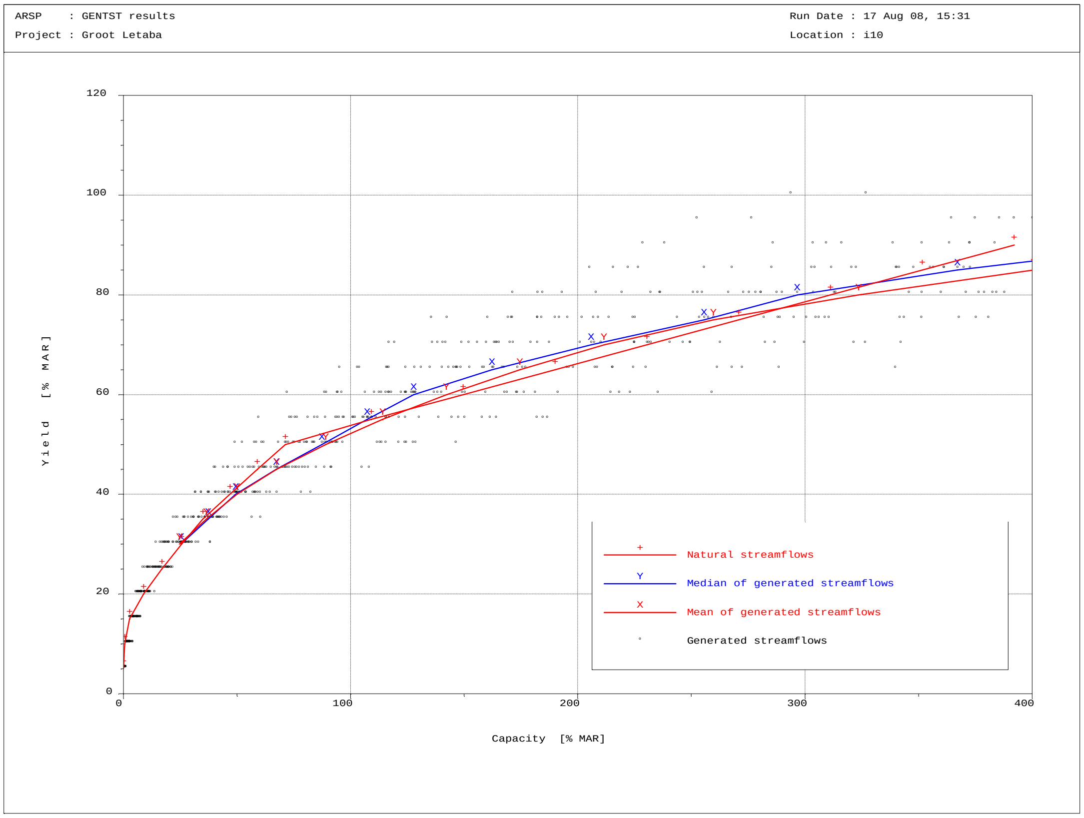

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i5
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

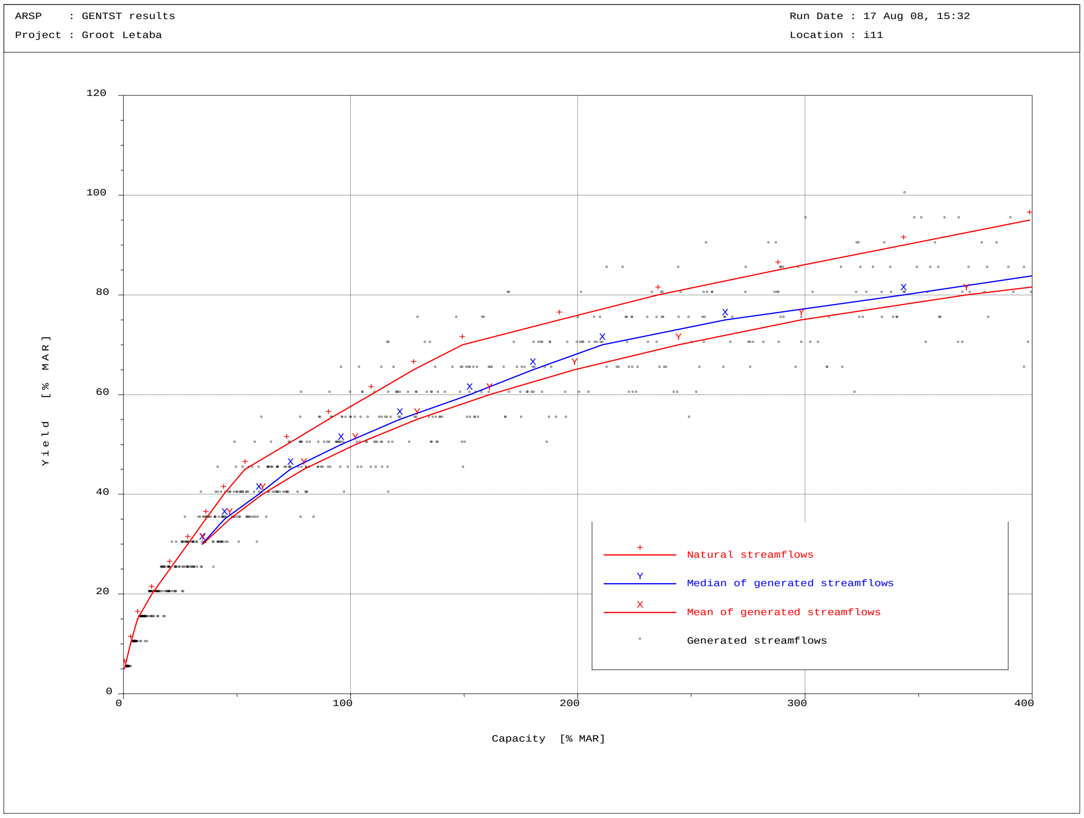

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i6
120
100
80
60
40
20
0
Yield [% MAR]
0
100
200
300
400
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

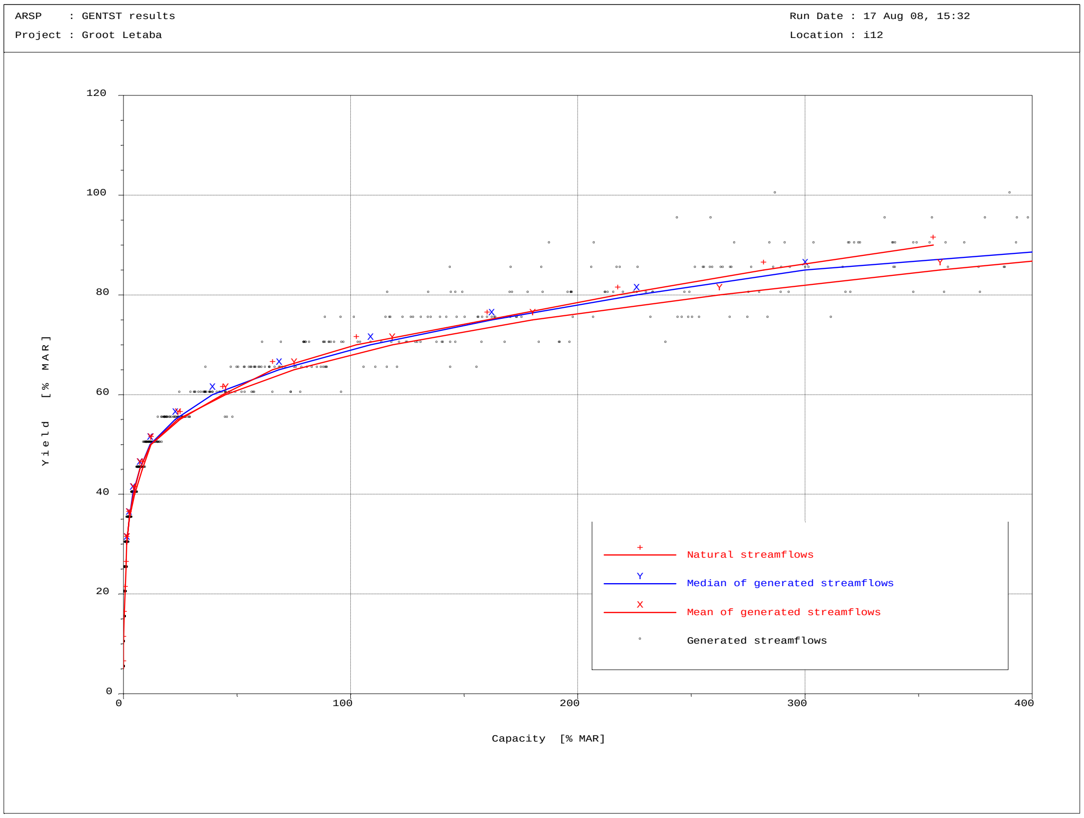

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i7
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

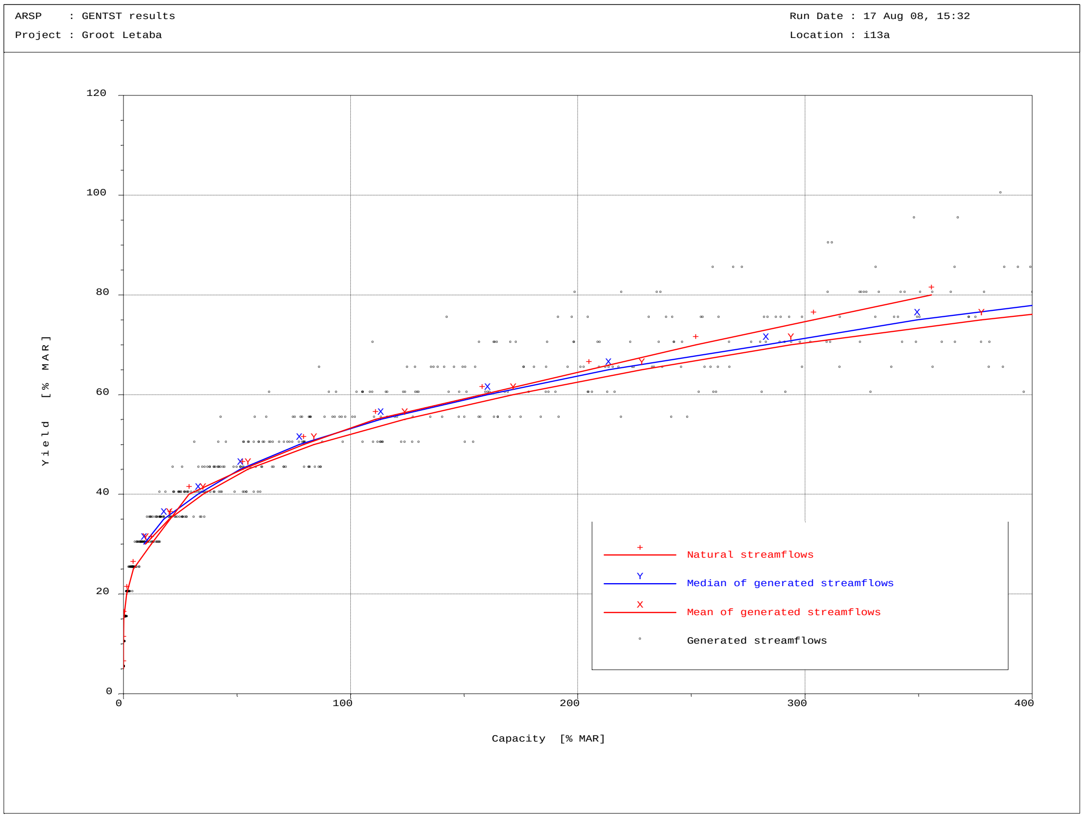

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i8
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i9
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

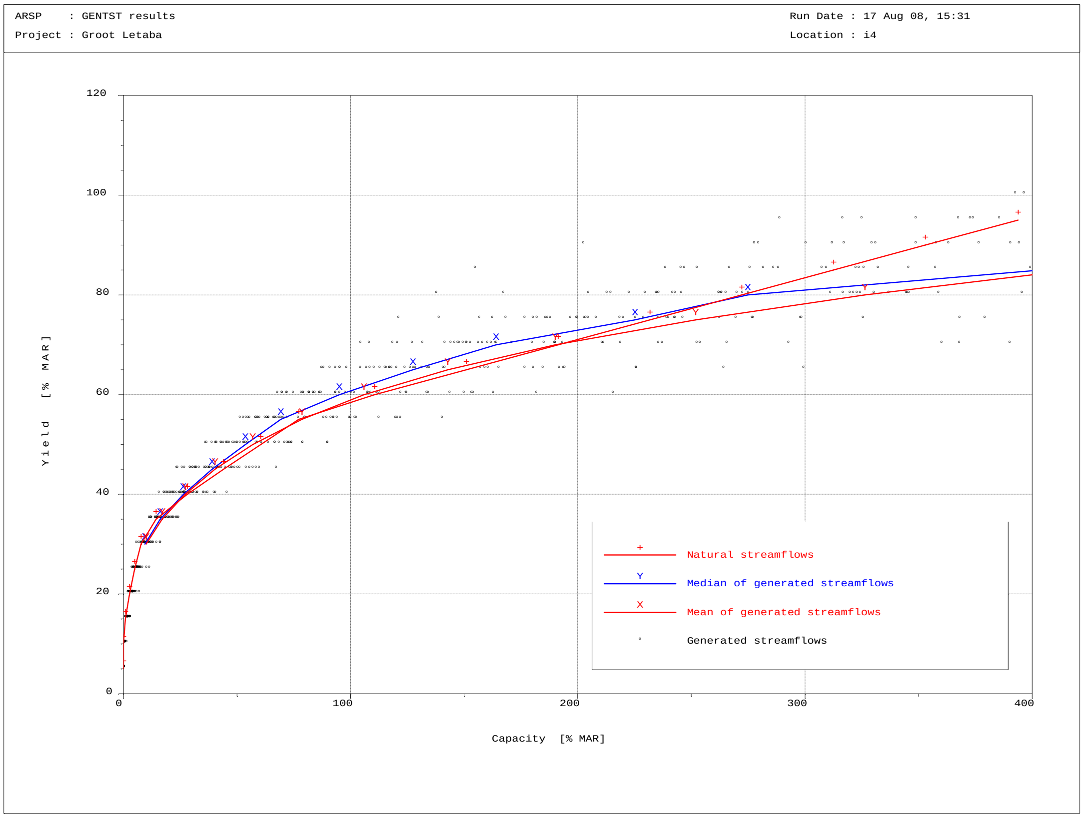

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i10
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i11
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

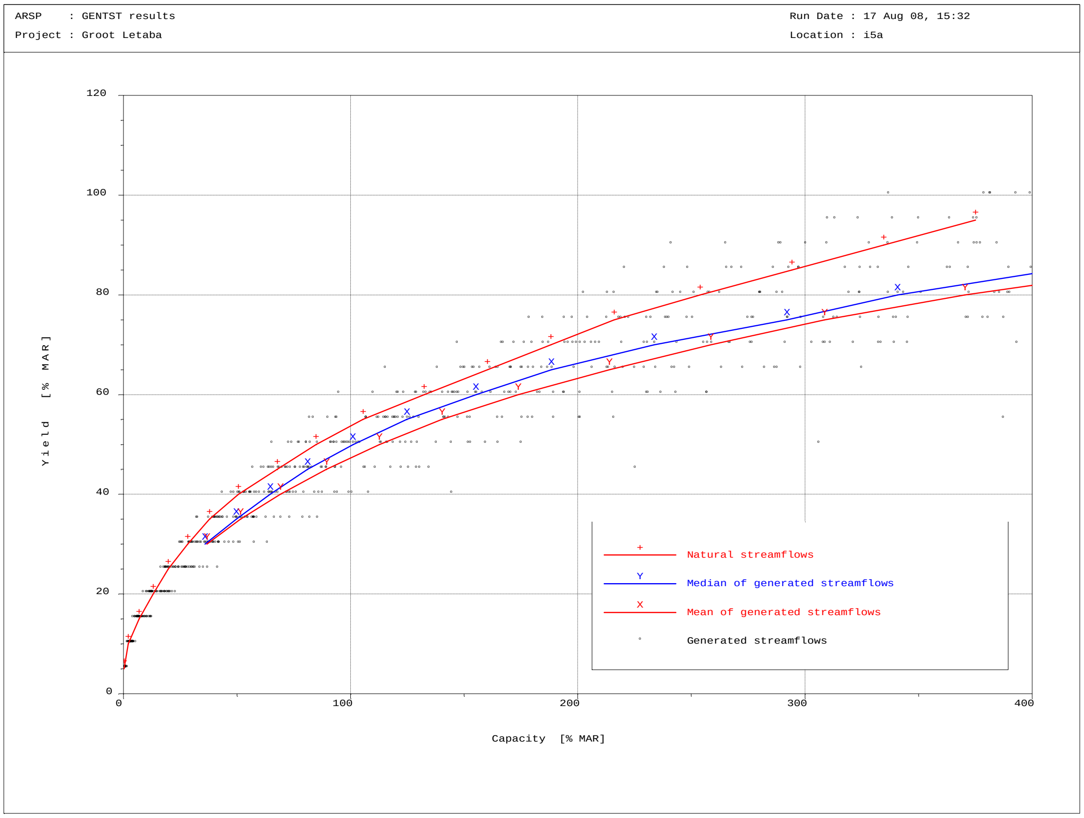

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i12
120
100
80
60
40
20
0
Yield [% MAR]
0
100
200
300
400
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

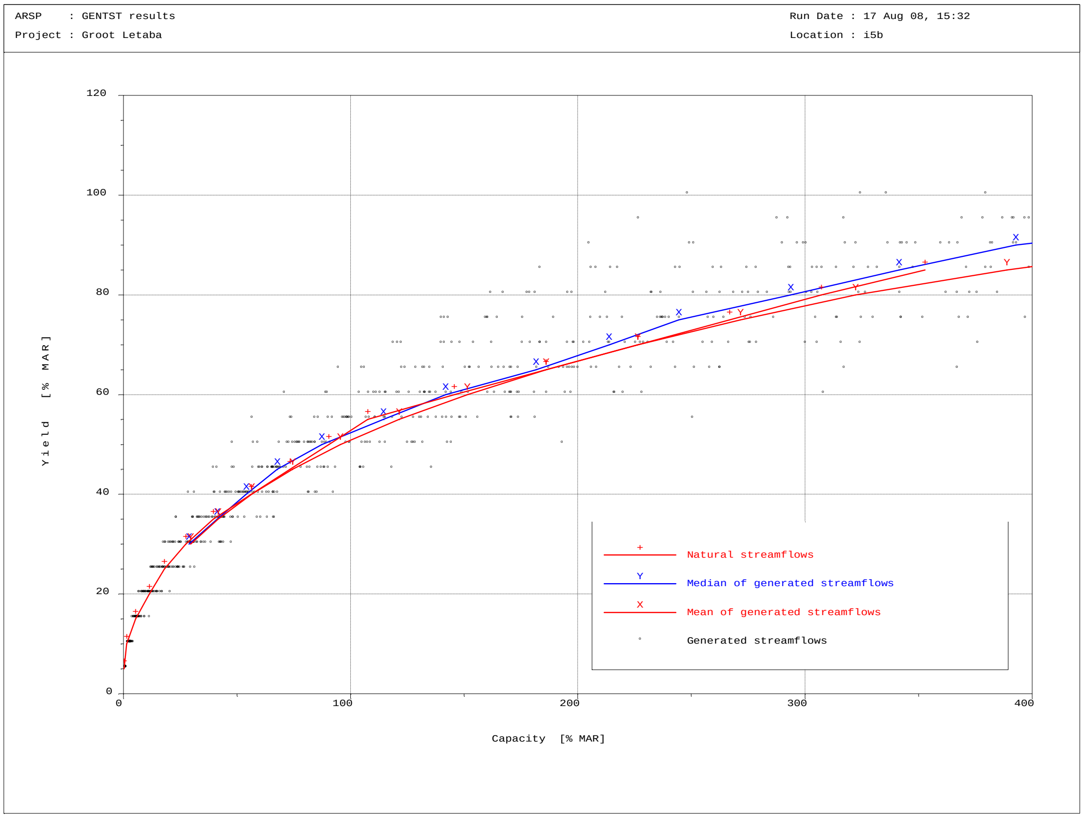


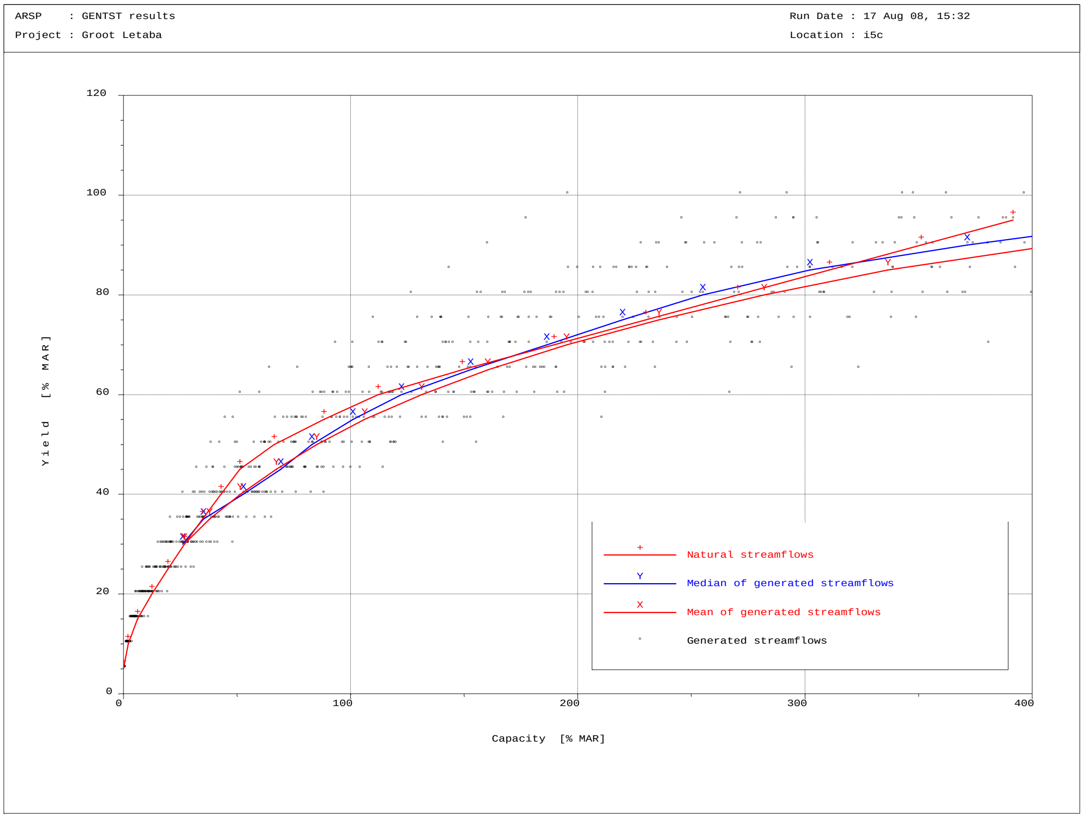
ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i13a
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

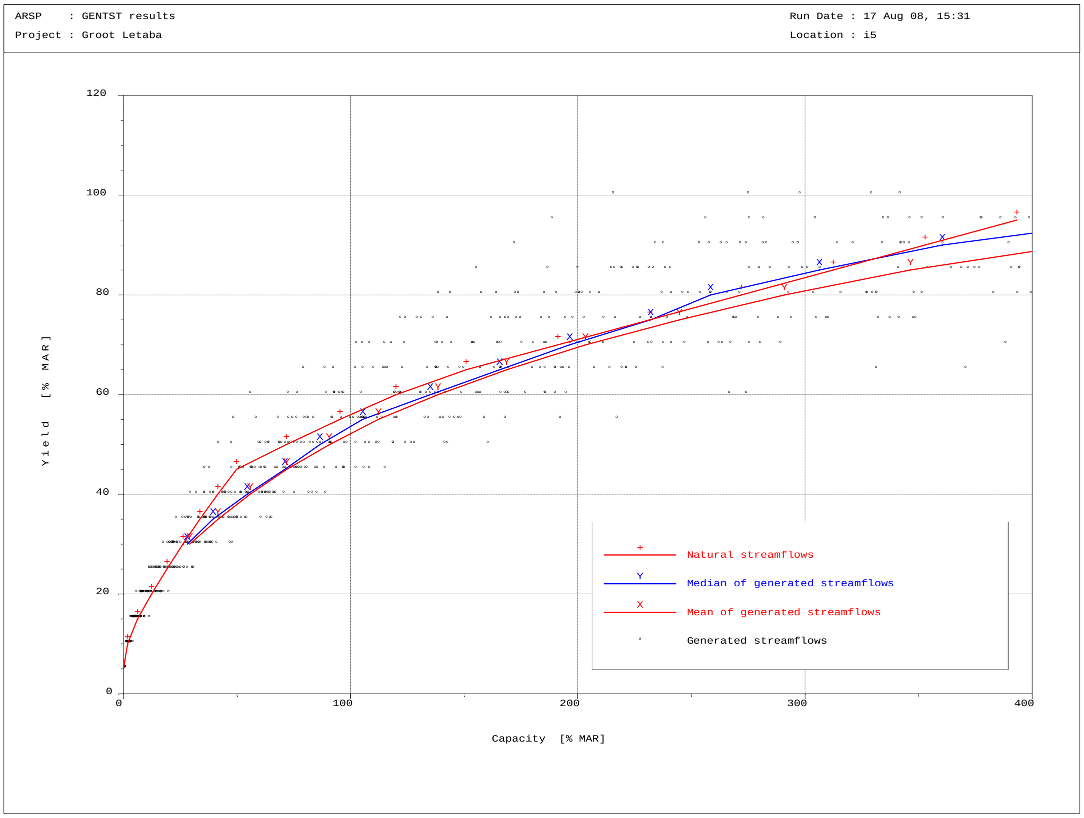


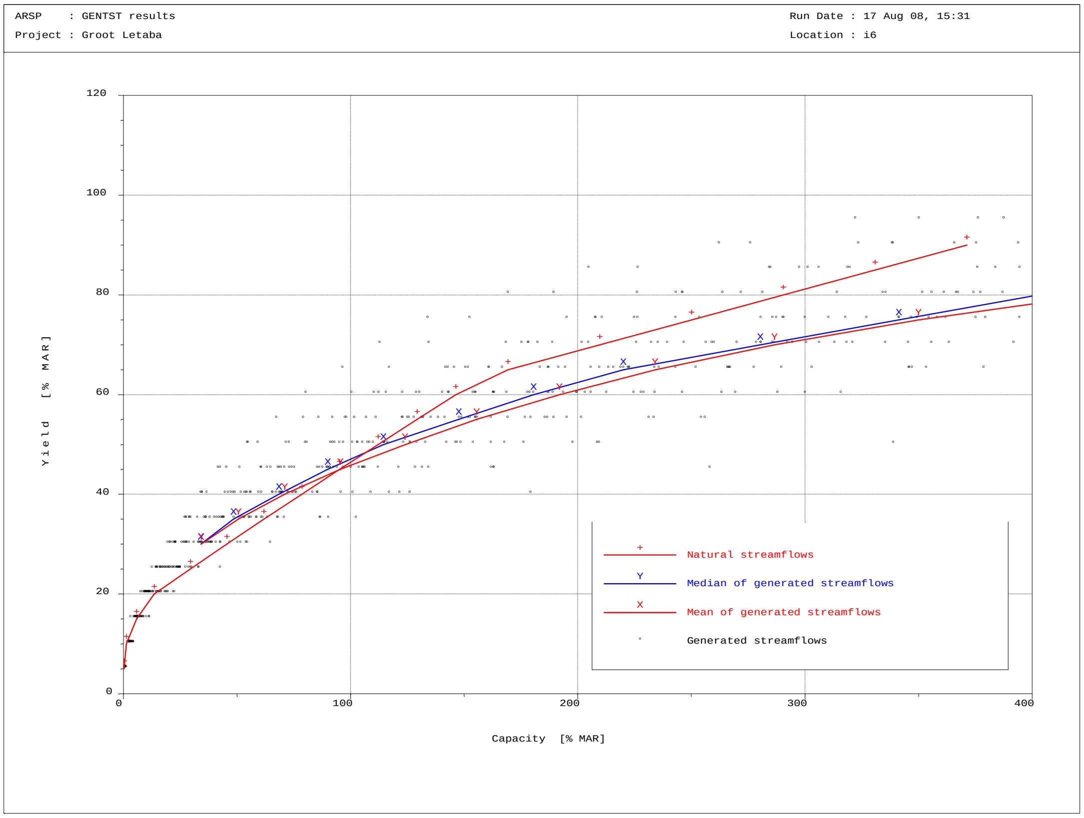
ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i4
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i5a
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i5b
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i5c
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i5
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i6
Yield [% MAR]
Capacity [% MAR]
0
20
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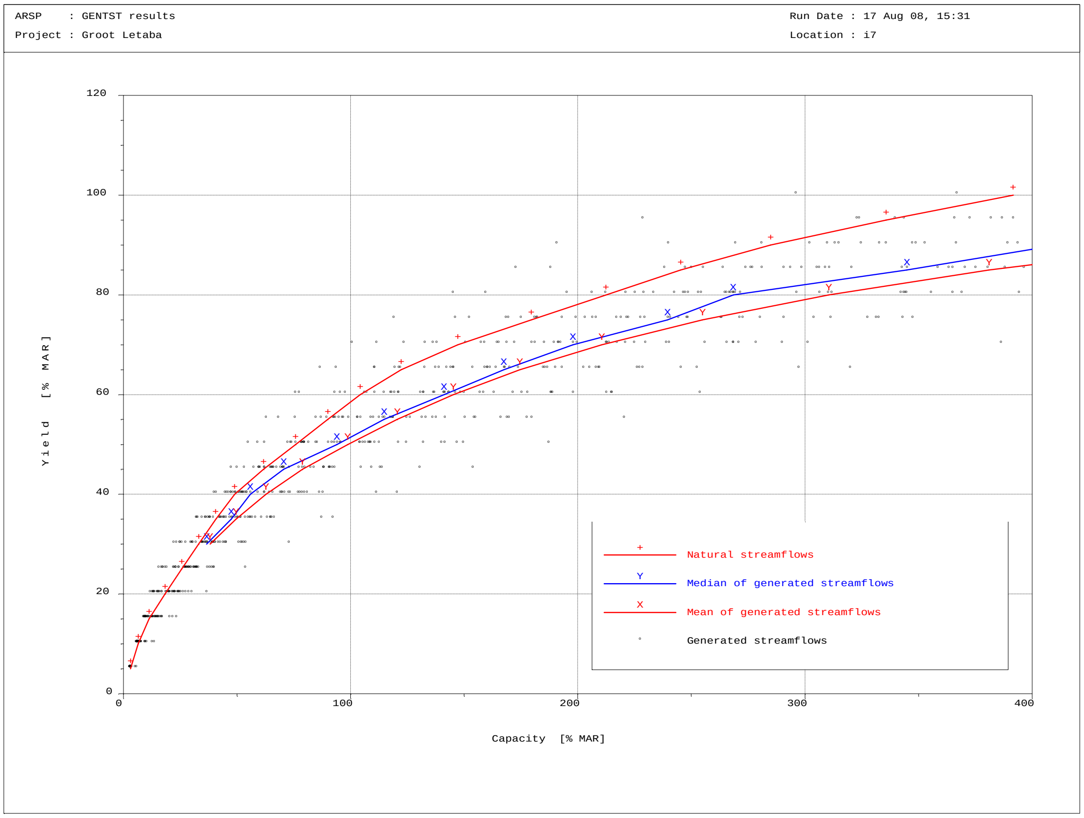
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i7
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
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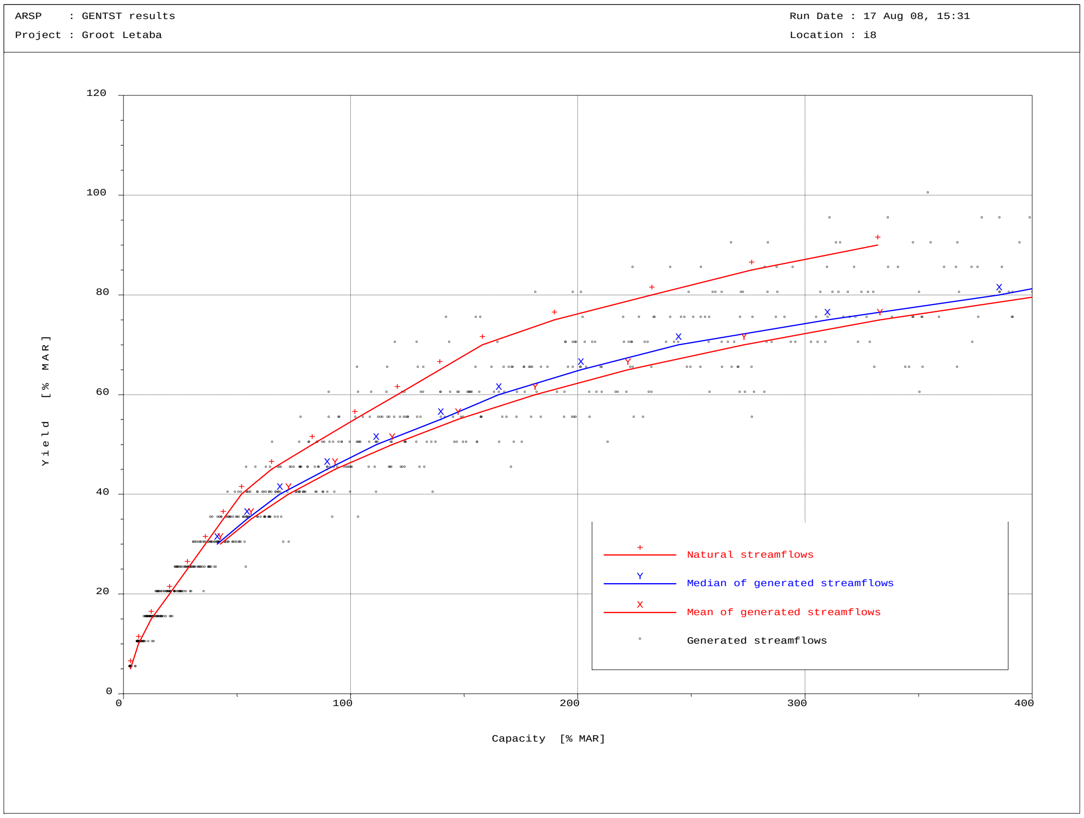
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i8
Yield [% MAR]
Capacity [% MAR]
0
20
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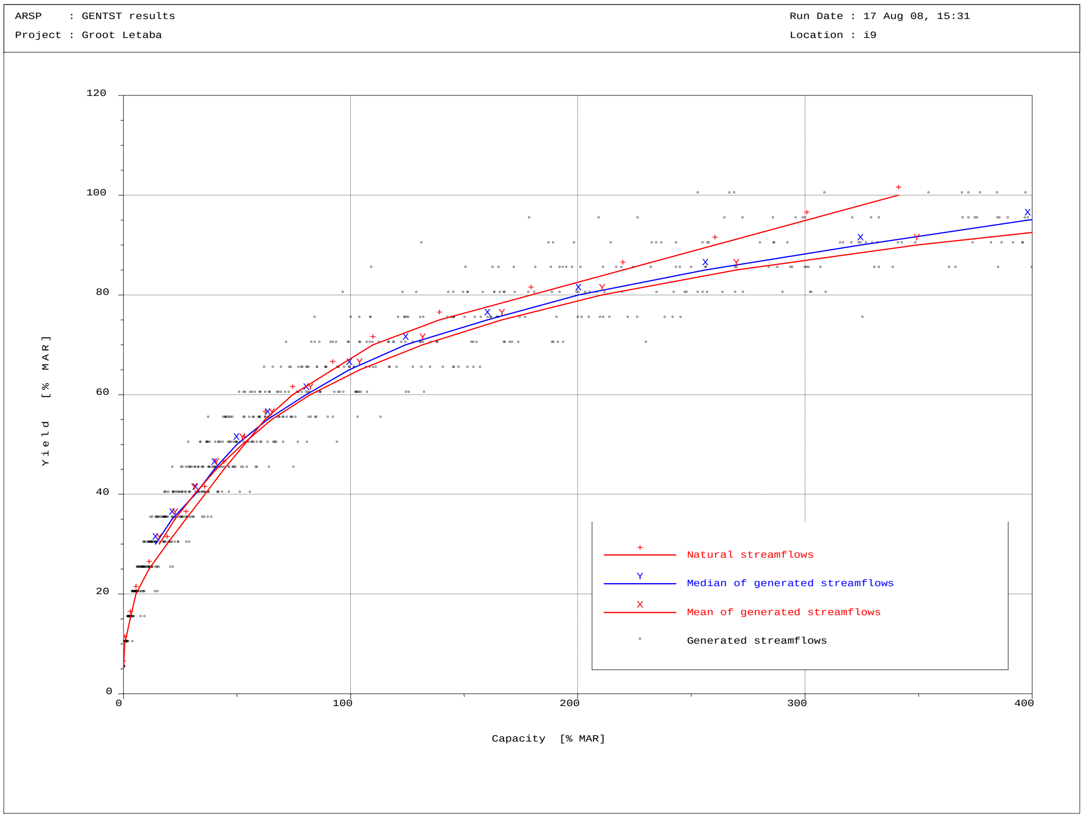
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i9
Yield [% MAR]
Capacity [% MAR]
0
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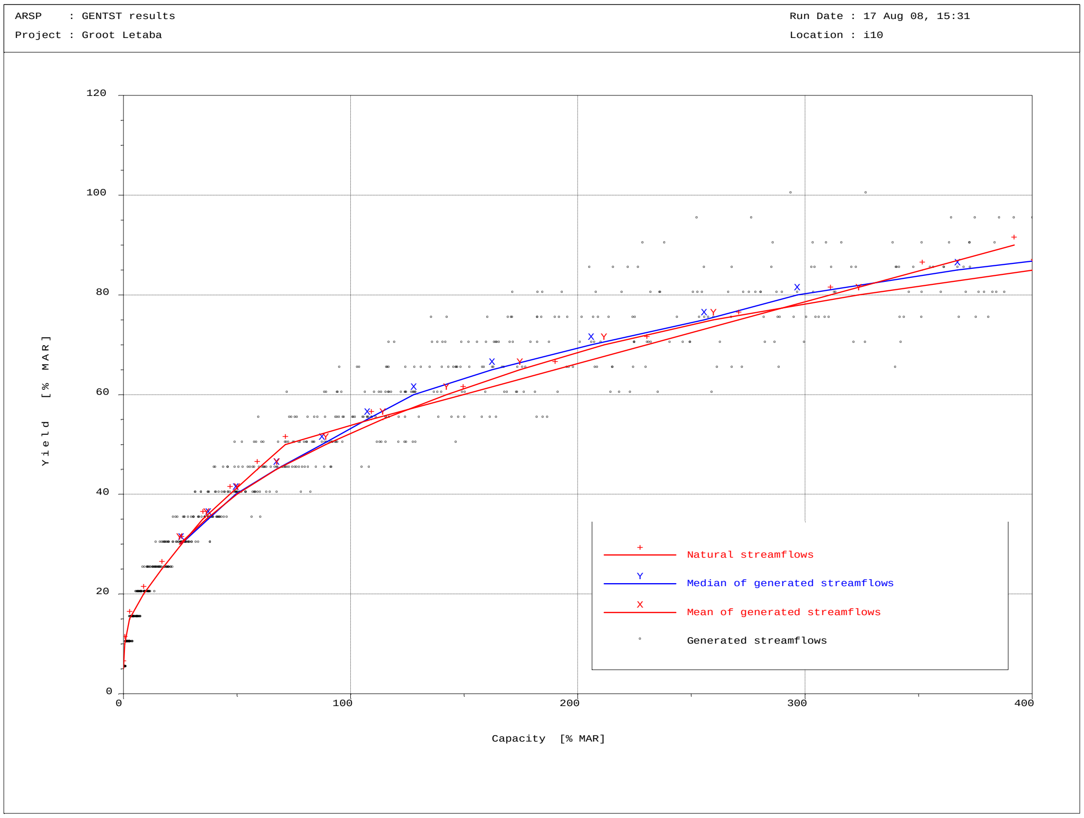
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:31
Location : i10
Yield [% MAR]
Capacity [% MAR]
0
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40
60
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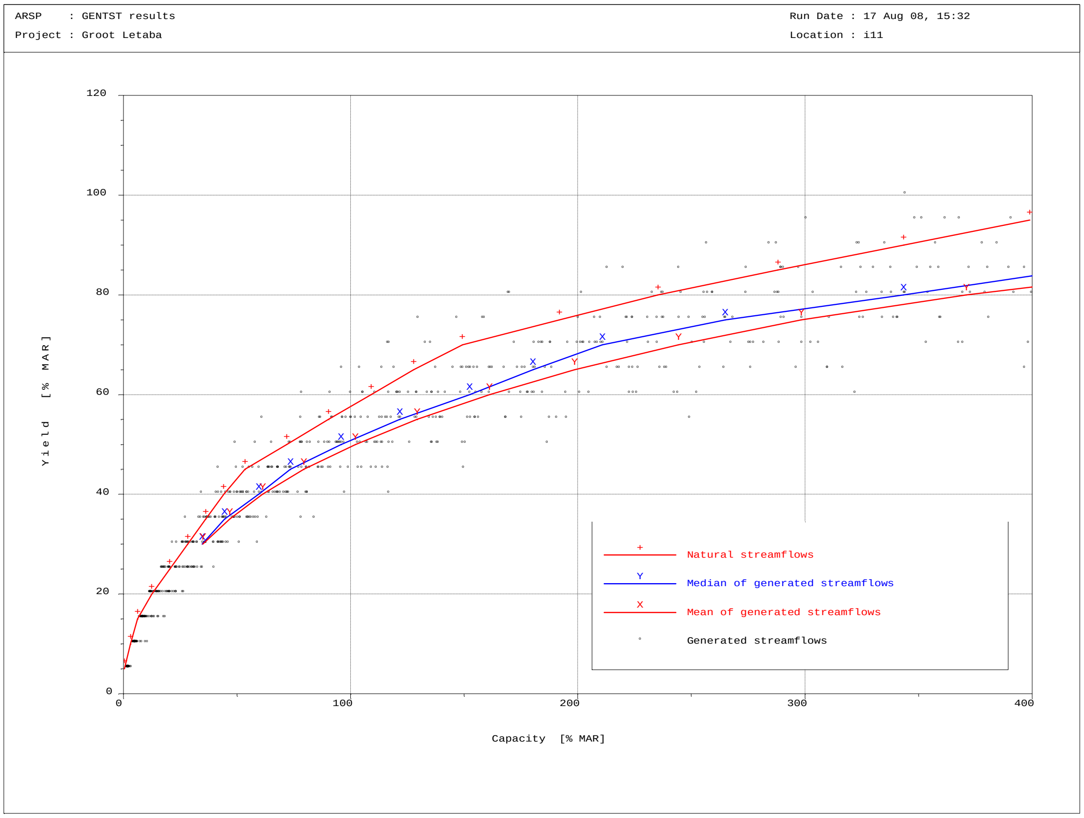
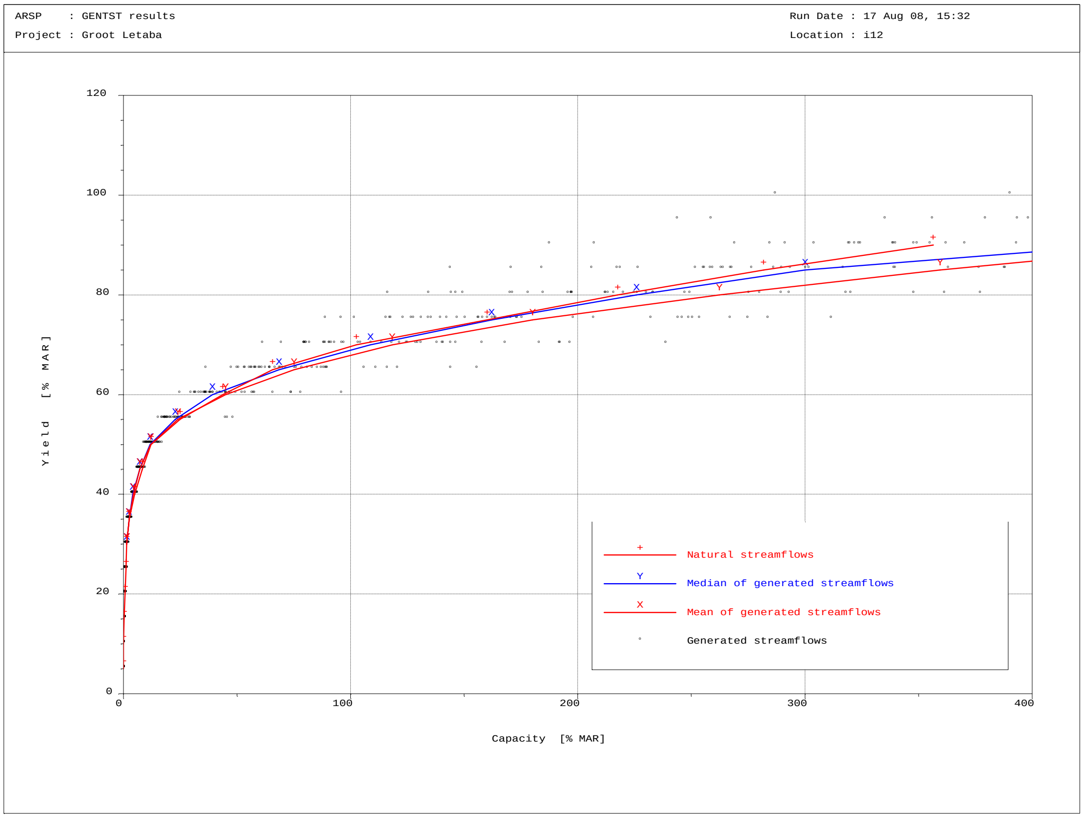
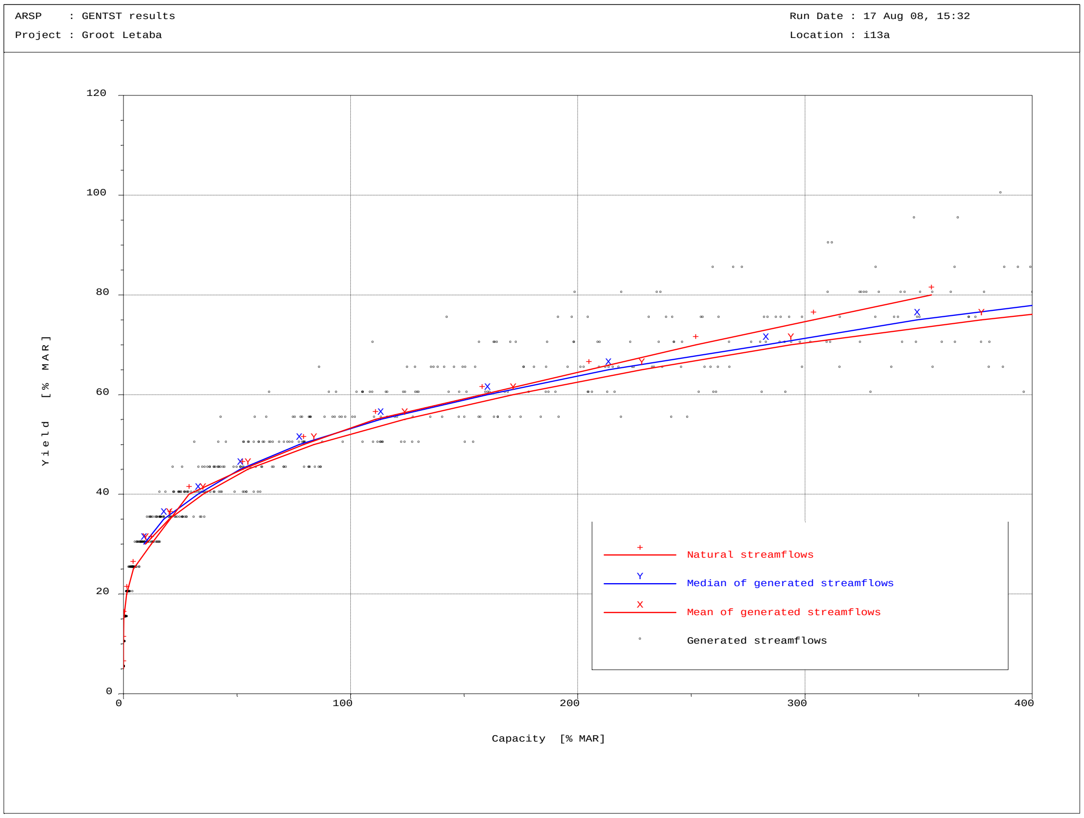
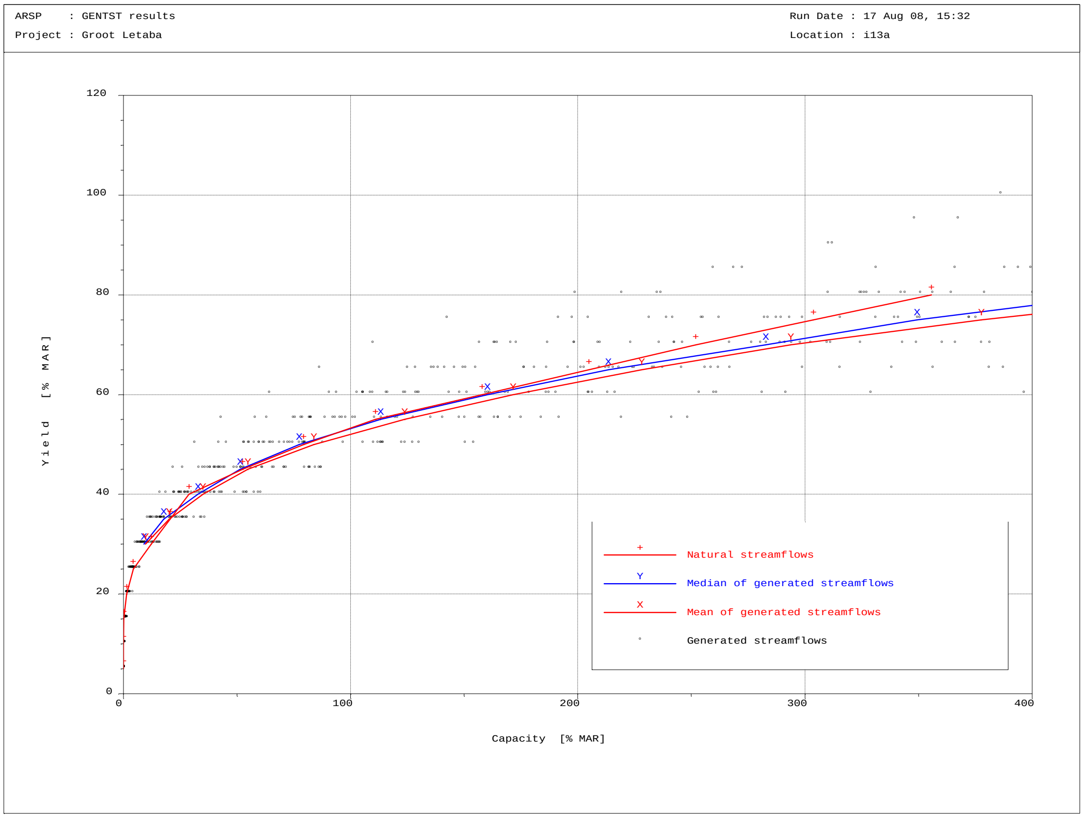
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

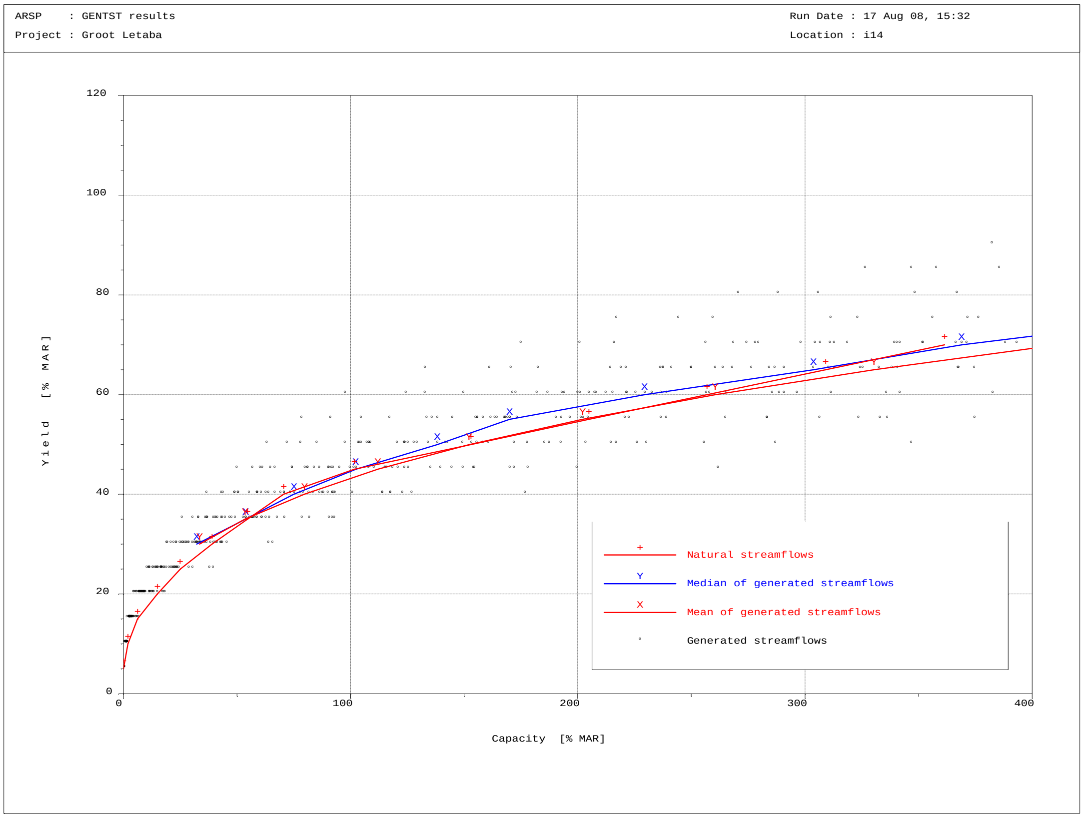

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i11
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

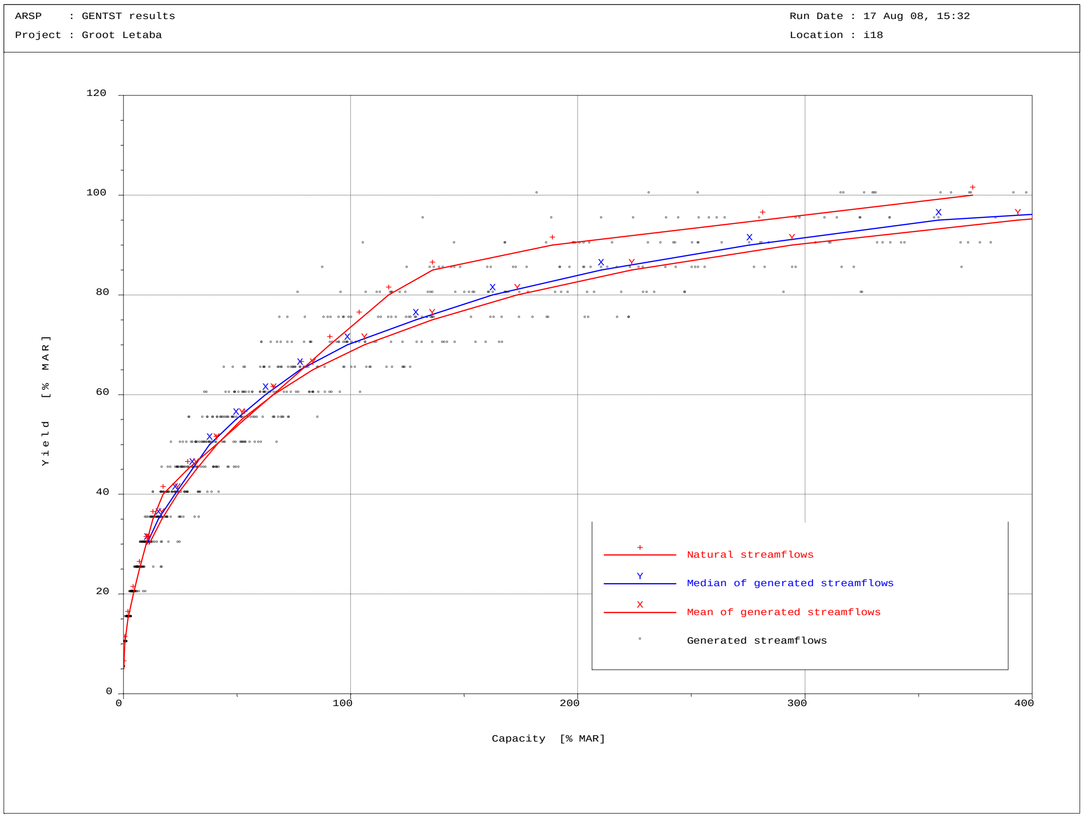

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i12
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows
0
20
40
60
80
100
120
0
100
200
300
400



ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i13a
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

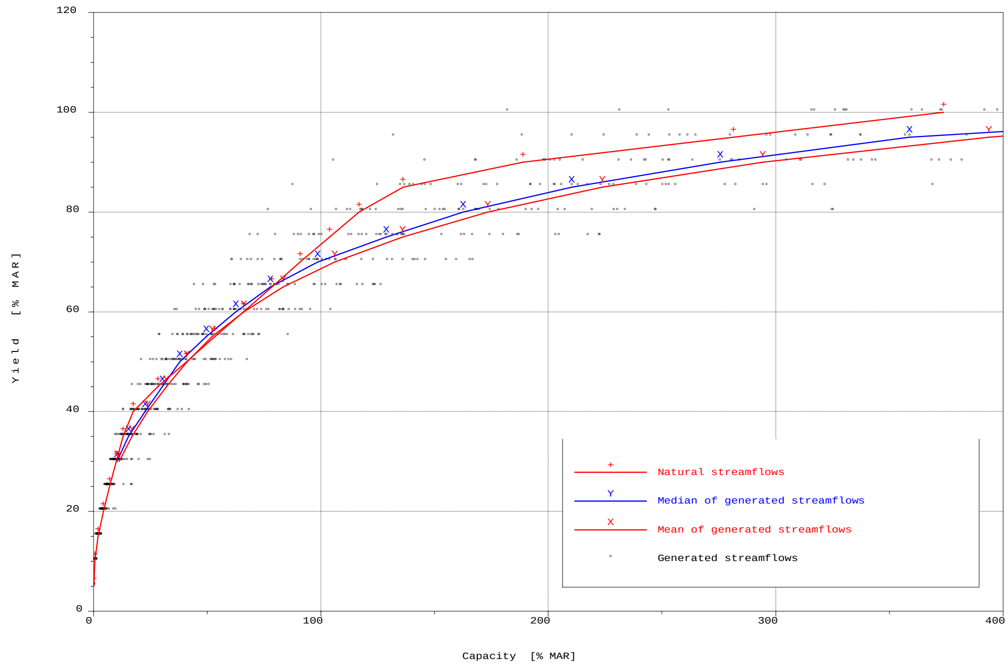

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i13a
Yield [% MAR]
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

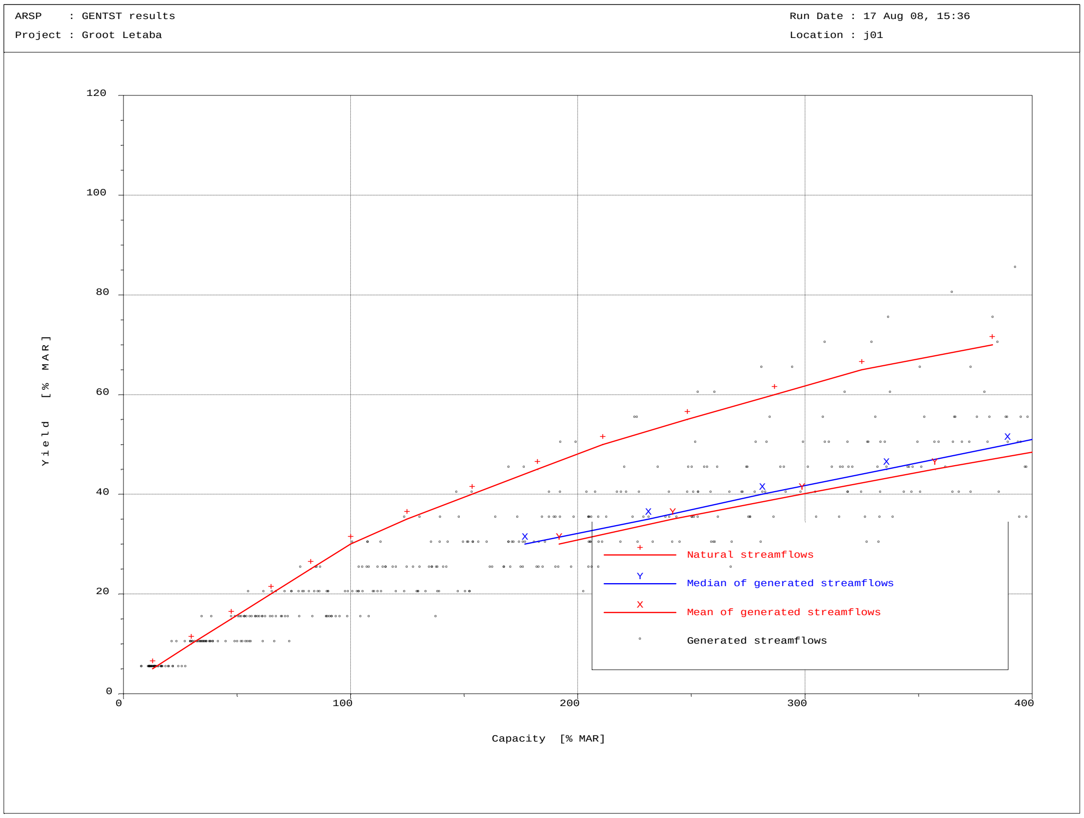

ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i14
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:32
Location : i18
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows

ARSP : GENTST results
Project : Groot Letaba

Run Date : 17 Aug 08, 15:32
Location : i18




ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : j01
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
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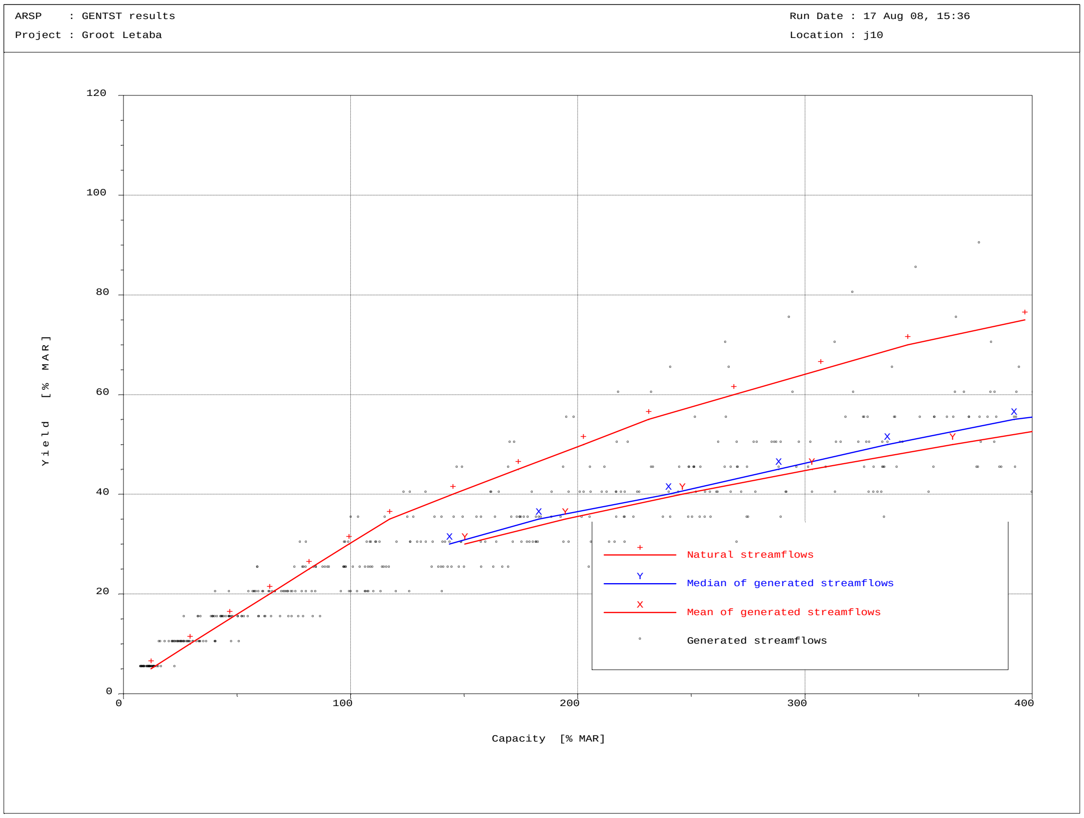
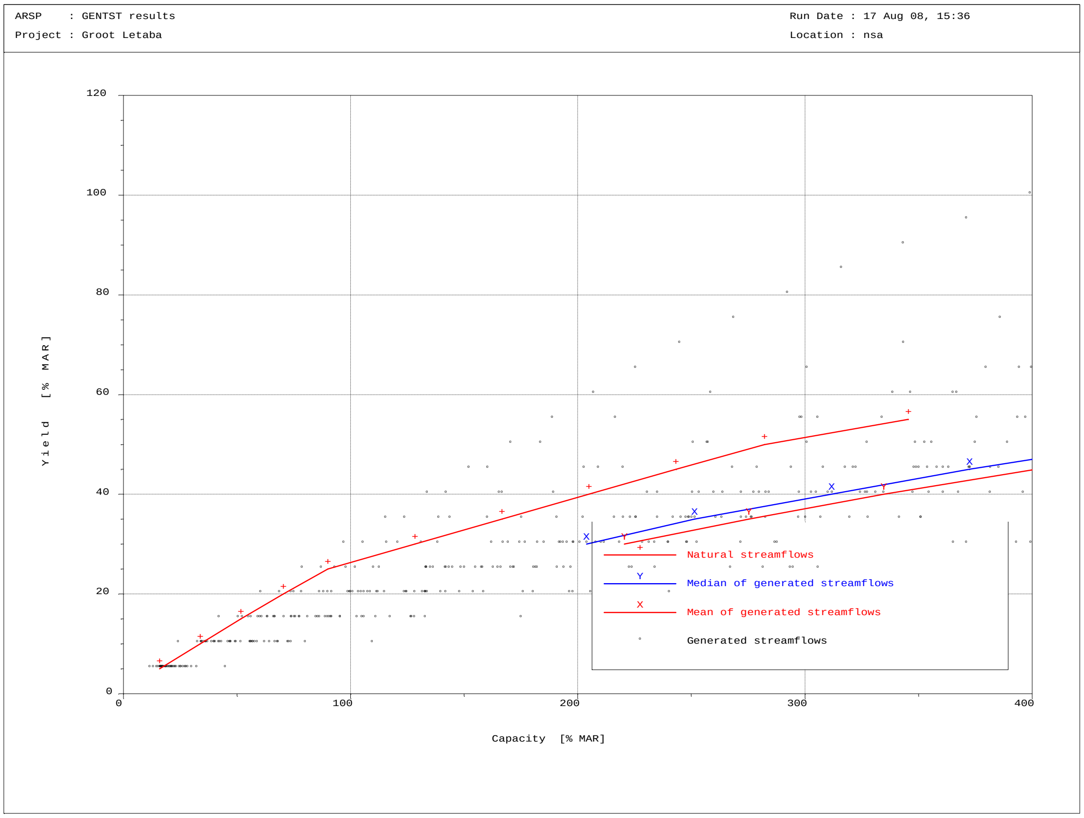
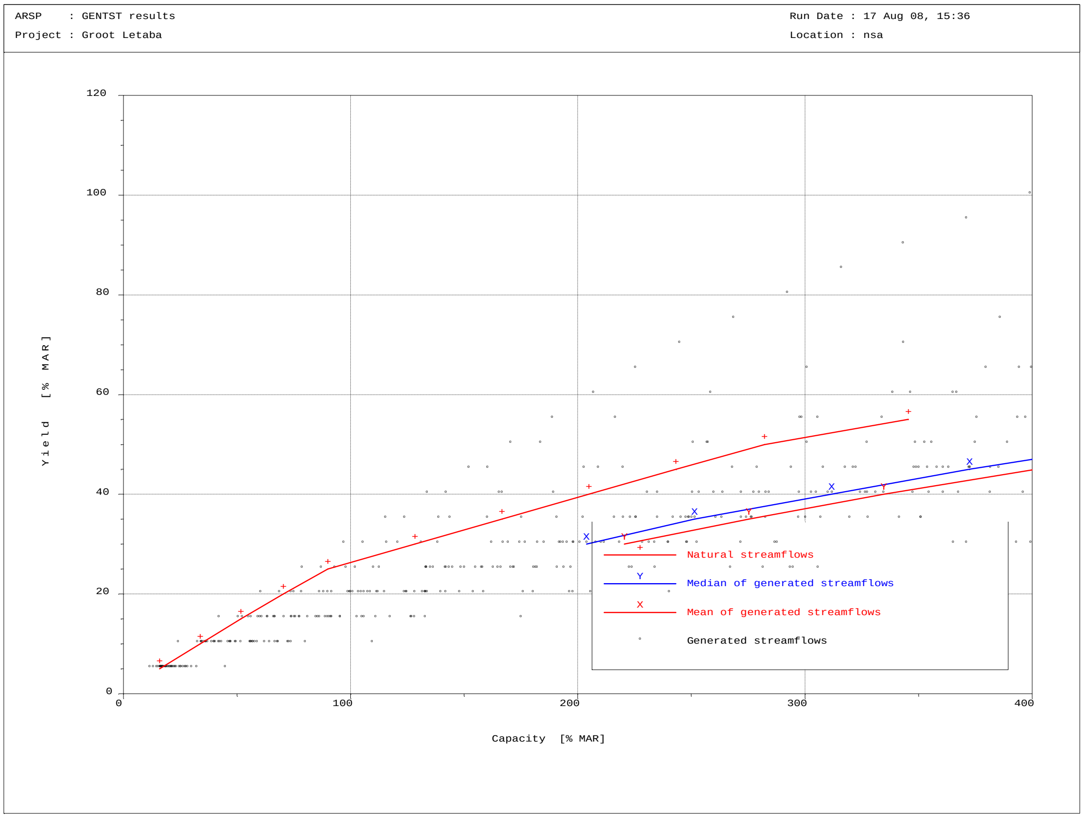
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : j10
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : nsa
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : nsa
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
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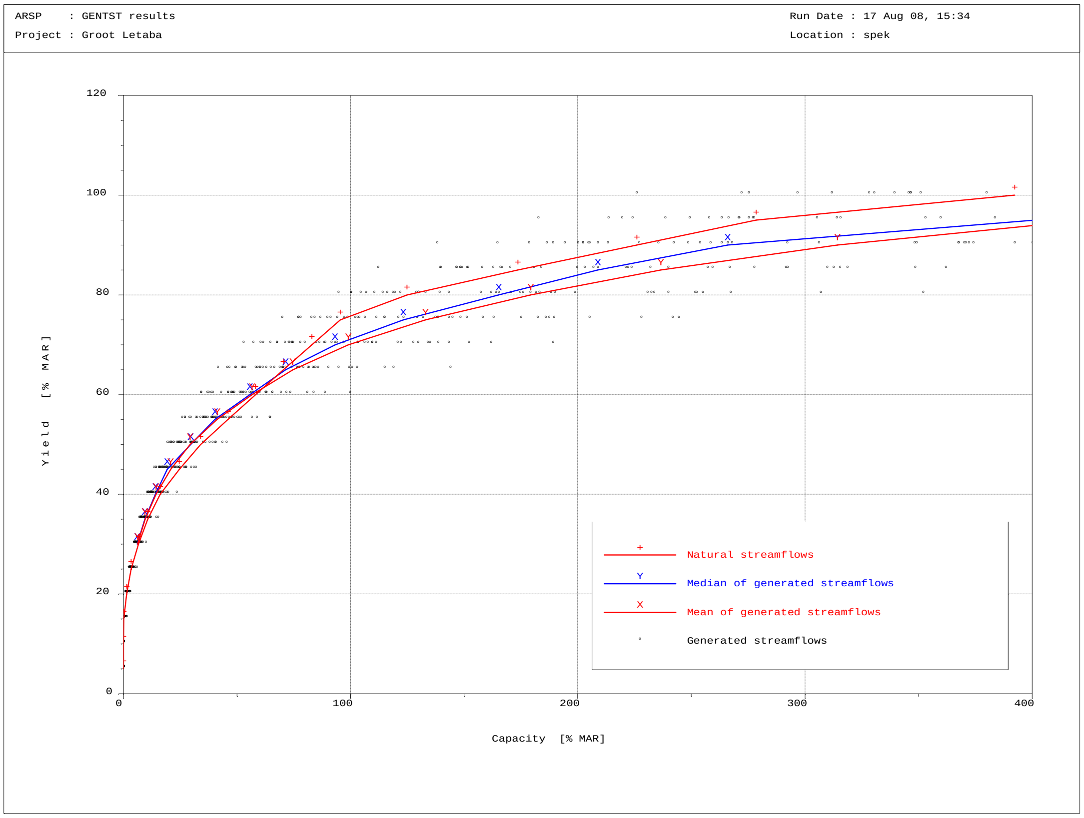
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows



ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:34
Location : spek
Yield [% MAR]
Capacity [% MAR]
0
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40
60
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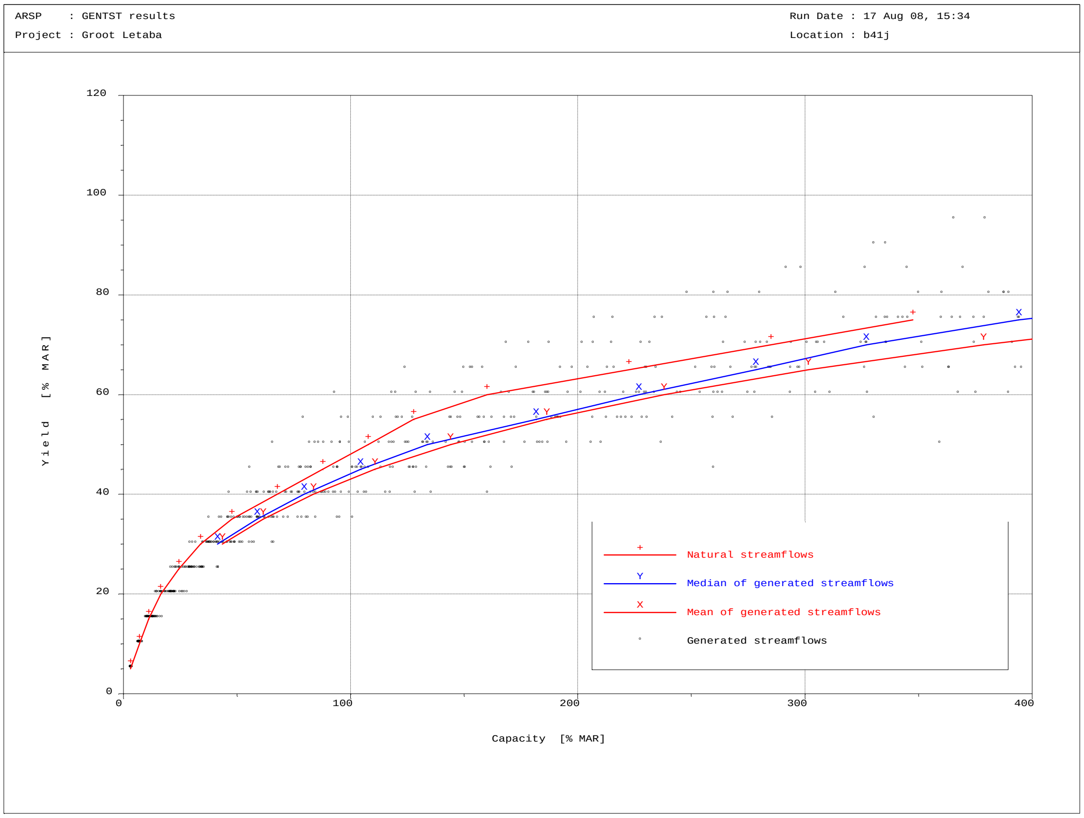
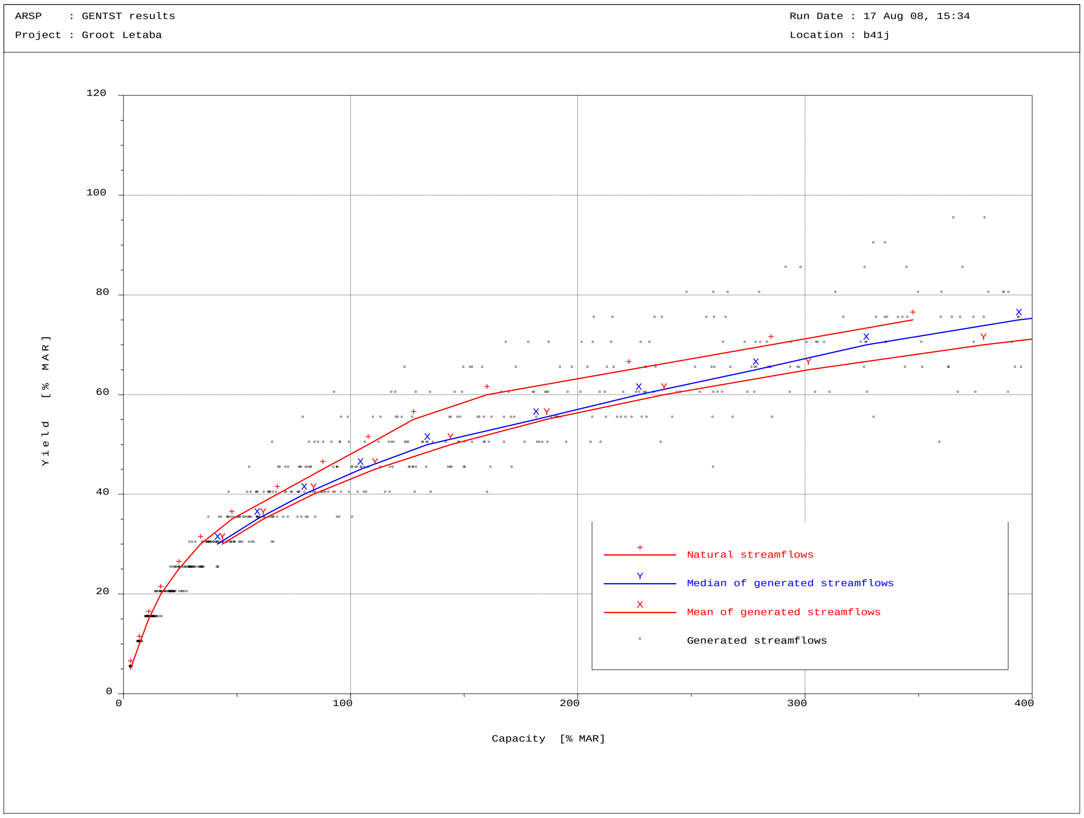
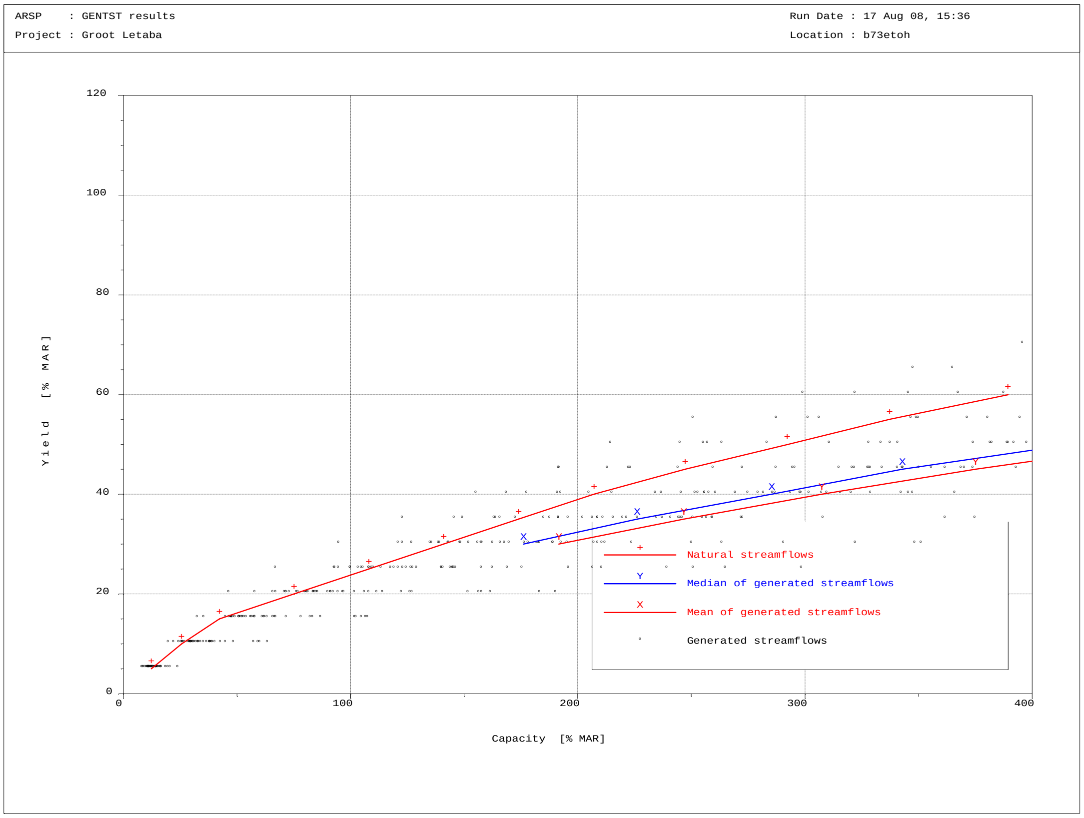
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:34
Location : b41j
120
100
80
60
40
20
0
Yield [% MAR]
0
100
200
300
400
Capacity [% MAR]
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:34
Location : b41j
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
200
300
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b73etoh
Yield [% MAR]
Capacity [% MAR]
0
20
40
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80
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120
0
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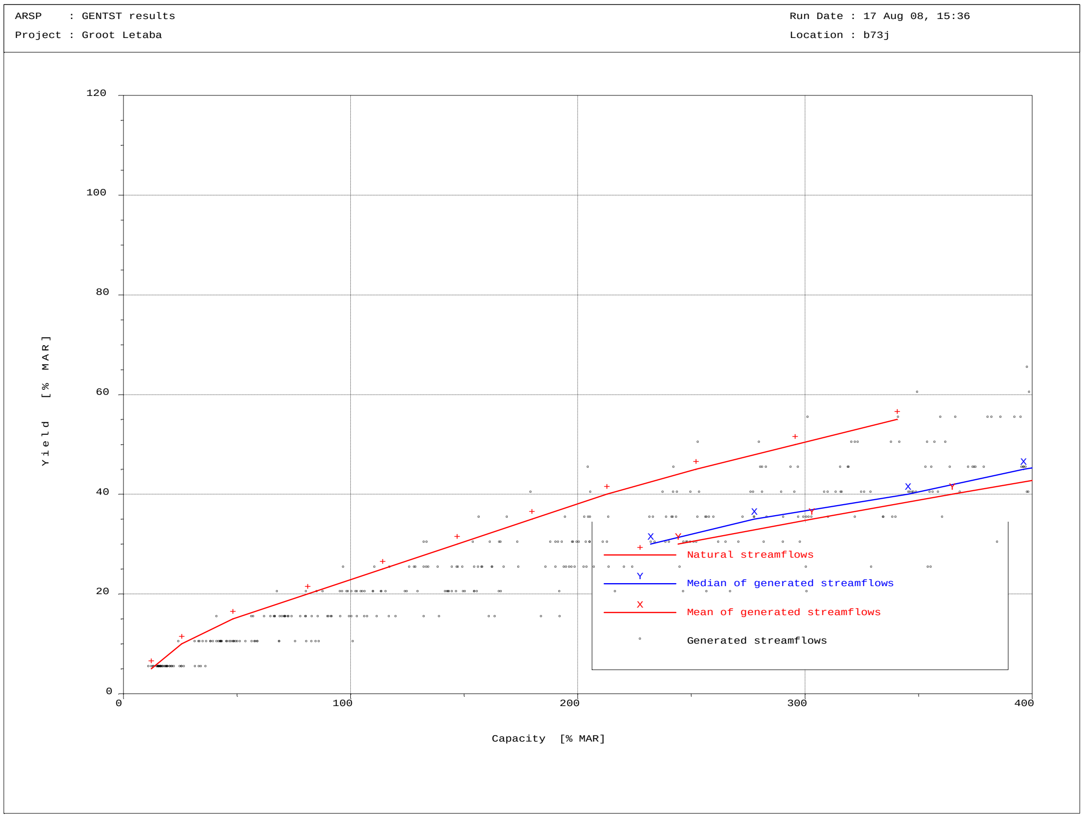
400
Natural streamflows
Median of generated streamflows
Mean of generated streamflows
Generated streamflows


ARSP : GENTST results
Project : Groot Letaba
Run Date : 17 Aug 08, 15:36
Location : b73j
Yield [% MAR]
Capacity [% MAR]
0
20
40
60
80
100
120
0
100
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300
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Natural streamflows
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