water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

Development of Operating Rules for Water Supply and Drought Management for Stand-Alone Dams and Schemes: Eastern Planning Area

# WATER SUPPLY AND DROUGHT OPERATING RULES FOR THE ACORNHOEK SUB-SYSTEM

**June 2022**

Final Report: P RSA 000/00/22921/15

## LIST OF REPORTS

*This report forms part of the series of reports issued as part of the project: Development of Operating Rules for Water Supply and Drought Management for Stand-Alone Dams and Schemes: Eastern Planning Area.*

***Reports as part of this project:***

| REPORT SERIES | REPORT TITLE | DWS REPORT NUMBER |
|---|---|---|
| **1. PROJECT REPORTS/SUPPORTING DOCUMENTS** | | |
| 1.1 | Inception Report | P RSA 000/00/22620/1 |
| 1.2 | Pongolapoort Dam Operating Analysis | P RSA 000/00/22620/1 |
| 1.3 | Nungwane System Operating Analysis | P RSA 000/00/22921/1 |
| 1.4 | Lomati Dam and Suid Kaap River Supply System Drought Operating Analysis | P RSA 000/00/22921/2 |
| 1.5 | Drought Operating Rules for Mhlabatshane Supply System | P RSA 000/00/22921/3 |
| 1.6 | Dam & Run-of-River Site Visit Report: Mhlabatshane Dam; Amanzimyama Dam; Imvutshane Dam & Nungwane Dam | P RSA 000/00/22921/4 |
| 1.7 | WS-DOR Buffalo River System | P RSA 000/00/22921/7 |
| 1.8 | WS-DOR Dullstroom Dorps Dam | P RSA 000/00/22921/8 |
| 1.9 | WS-DOR Hazelmere WSS | P RSA 000/00/22921/9 |
| 1.10 | WS-DOR Middle South Coast WSS | P RSA 000/00/22921/10 |
| 1.11 | WS-DOR White Mfolozi System | P RSA 000/00/22921/11 |
| 1.12 | WS-DOR Hluhluwe Dam System | P RSA 000/00/22921/12 |
| 1.13 | WS-DOR Imvutshane Dam System | P RSA 000/00/22921/13 |
| 1.14 | WS-DOR eDumbe Dam System | P RSA 000/00/22921/14 |
| 1.15 | WS-DOR Acornhoek Dam System | P RSA 000/00/22921/15 |
| 1.16 | Capacity Building and Training Report - March 2022 | P RSA 000/00/22921/16 |
| 1.17 | WS-DOR for the Ixopo Water Supply System | P RSA 000/00/22921/17 |
| 1.18 | WS-DOR for the Bivane Dam | P RSA 000/00/22921/18 |
| 1.19 | Site Visit Report: Acornhoek, Witklip, Longmere & Klipkoppies Dams | P RSA 000/00/22921/19 |
| 1.20 | WS-DOR for the Olifantskop Dam | P RSA 000/00/22921/20 |

List of reports as at issuance of this report.
A complete list of reports will be detailed in the project close-out report.

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|---|---|
| *Project Name:* | ***Development of Operating Rules for Water Supply and Drought Management for Stand-Alone Dams and Schemes: Eastern Planning Area*** |
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| *Author(s):* | ***Stephen Mallory*** |
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***CONSULTANTS: BIGEN AFRICA SERVICES (PTY) LTD in association with Indie Water Resources***

*Approved for PSP by:*

| | |
|---|---|
| …….. | …….. |
| ***Robert Moffat*** | ***Faeeza Ballim*** |
| *Project Director* | *Study Leader/Coordinator* |

***Department of Water and Sanitation (DWS), Directorate: Water Resource Management Planning***
*Approved by **DWS** by:*

| | |
|---|---|
| …….. | …….. |
| ***Mr RB Martin*** | ***Ms CP Ntuli*** |
| *Chief Engineer: Systems Operation* | *Scientific Manager: Systems Operation* |

.....
***Dr B L Mwaka***
*Director: Water Resource Management Planning*

## EXECUTIVE SUMMARY

The development of operating rules for the Acornhoek sub-system in Mpumalanga is undertaken through a support project by the Department of Water and Sanitation (DWS) to 'Develop Operating Rules for Water Supply and Drought Management for Stand-Alone Dams and Schemes: Eastern Planning Area'.

The Acornhoek Dam is a small dam that supplements the water supply to the town of Acornhoek in Mpumalanga. The main source of water to the town is the Inyaka Dam which supplies water to the area via an extensive piped distribution system. The Acornhoek Dam was raised about 15 years ago and a pumpstation was constructed on the banks of the Klein Sand River to transfer water to the dam and hence augment the water supply to the town The combined dam and transfer works are referred to in this report as the Acornhoek Sub-system. It is important to note that the pumpstation delivers water directly to the WTW and not the dam. Hence the operating rules reported on in this report are for the Acornhoek sub-system of which the Acornhoek dam is a component.

The yield of this sub-system has not been determined before and neither have operating rules been proposed.

The historic yield of the dam is estimated at 2.13 million m3/annum assuming no ecological water requirements (EWR). Assuming that the EWR must be met on the Klein Sand before pumping to the dam then the yield decreases to 1.12 million m3/annum with a 1:50 year yield of 1.07 million m3/annum. As an alternative scenario, the sub-system was modelled with the water from the Klein Sand discharged into the dam. This results in slightly higher yields than delivering directly to the WTW because surplus pumped water (in excess of the target draft) can then be stored for later use.

Since the dam is used to supplement the water supply to Acornhoek the suggested operating rule is to maximise the supply from the dam but keep the last 10% in reserve should there be a break in the supply from Inyaka Dam. During droughts, the restriction should be imposed on users based on the water level in the Inyaka Dam and not Acornhoek Dam.

The recently obtained record of water pumped from the Klein Sand indicates that the pumpstation is not operated efficiently and should be able to pump much more than is currently the case. In order to improve the efficiency of the pumpstation and assist with the implementation of the EWR it is recommended that a real-time flow gauging station be installed downstream of the pumpstation.

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The Department of Water and Sanitation
Private Bag X313
PRETORIA, 0001
Republic of South Africa

Tel: (012) 336 7500/ +27 12 336 7500
Fax: (012) 336 6731/ +27 12 336 6731



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In association with:



## TABLE OF CONTENTS

**LIST OF FIGURES**



**LIST OF TABLES**

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| BBR | Bushbuckridge |
| DWS | Department of Water and Sanitation |
| DWA | Department of Water Affairs |
| EWR | Ecological Water Requirement |
| Ha | Hectare |
| IUCMA | Inkomati Catchment Management Agency |
| LM | Local Municipality |
| MAP | Mean Annual Precipitation |
| MAR | Mean Annual Runoff |
| MAE | Mean Annual Evaporation |
| $m^3$/annum | Cubic metres per annum |
| FSC | Full Supply Capacity |
| WTW | Water Treatment Works |
| WWTW | Water Treatment Works |

**Commented [rm1]:** The DWS Annual Performance Plan (APP) seems to use plant and works interchangeable (WTW, WTP), but has separate entries WWTW and WWTP: Waste Water Treatment Works / Plants.
I suggest that WTW and WWTW is used as it should be easier to differentiate

# 1 INTRODUCTION

The development of operating rules for the Acornhoek Dam in Mpumalanga is undertaken through a support project by the Department of Water and Sanitation (DWS) to '*Develop Operating Rules for Water Supply and Drought Management for Stand-Alone Dams and Schemes: Eastern Planning Area*'.

The Acornhoek Dam (also called Mahlebo Dam) is located on a small tributary of the Sand River which is a major tributary of the Sabie River. Refer to **Figure 1.1**. The dam is small with a full supply capacity of only 1.05 million $m^3$. It supplements the water supply to the town of Acornhoek which is also supplied from the Inyaka Dam.

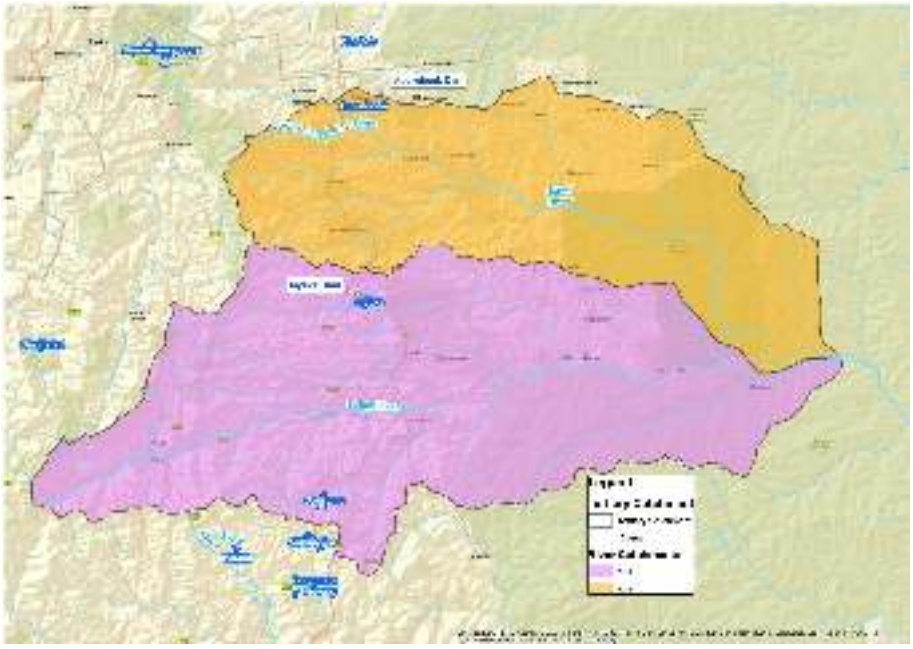

**Figure 1.1: Location of the Acornhoek Dam within the Klein Sand River Catchment**

Commented [FB2]: Bigen team, please consider a more professional graph

While the catchment of the dam is very small, the yield is supplemented by pumping from the Klein Sand River.

# 2 WATER RESOURCES INFRASTRUCTURE

## 2.1 Dams

The details of the Acornhoek Dam are provided in **Table 2.1**. There are no dams upstream of this dam. As far as can be ascertained the dam basin has not been surveyed. The assumed capacity-area-elevation relationship of these dams is attached as **Appendix A**.

**Table 2.1: Physical Characteristics of the Acornhoek Dam**

| Gross Capacity (million $m^3$) | Surface Area ($km^2$) | Dead Storage (million $m^3$) | Owner |
|---|---|---|---|
| 1.05 | 0.19 | 0.0 | DWS |

## 2.2 Groundwater Supply

Based on previous knowledge of the area, it was reported during the groundwater inception meeting (22 January 2021, Anne Beater) that Acornhoek was a conjunctive use scheme in which the water supply from Acornhoek Dam was augmented by groundwater. During the site visit, Frank Khoza of the Bushbuck Ridge local municipality confirmed that some borehole(s) were part of the water supply system, but that these were not operational and generally not used. Further data on the groundwater supply has been requested from the DWS and from the IUCMA, both of whom referred the team to the local municipality. Groundwater data was requested from the LM (Mpho Makhavhu). The LM advised that "the municipality has approximately 120 functional boreholes within its area of jurisdiction" and that these boreholes are "prone to vandalism or theft and other operational challenges such as shortage of operators and diesel shortages". This context relates to rural water supply boreholes, and no information on the boreholes that are connected to the Acornhoek town water supply system was received.

Due to lack of information, it was not possible (at this stage) to review, verify and update the existing groundwater operating rules, nor determine the available yield from groundwater, and incorporate groundwater in conjunctive use operating rules. The remainder of this assessment considers the dam only.

## 2.3 Water Treatment Works

Water supplied from the Acornhoek Dam is treated at a Water Treatment Works (WTW) located downstream of the dam. The capacity of this plant is 6 Mℓ/day.

## 2.4 Pump Station

There is a pumpstation located on the Klein Sand River about 3.5 km to the south of the Acornhoek Dam which pumps water to the WTW. See **Figure 2.1**. The details of this pumpstation are attached as **Appendix B**. The maximum transfer achievable is approximately 2.2 million $m^3$/annum.

**Figure 2.1: Klein Sand Pumpstation and Pipeline**

# 3 CATCHMENT INFORMATION AND HYDROLOGY

## 3.1 Quinary Catchment Information

The Acornhoek Dam lies in the X32C-3 quinary catchment, as defined during the IWAAS Study (DWA, 2009) while the neighboring Klein Sand River from which water is pumped to the Acornhoek Dam which lies in the X32C-4 quinary catchment. Refer to **Figure 3.1**.

The hydrology of the Sabie catchment was studied in detail as part of the IWAAS study (DWA, 2008) and updated by the IUCMA in 2020 (IUCMA, 2021). The catchment is however ungauged so there is uncertainty as to the runoff from the catchment. **Table 3.1** summarises the hydrology of the Acornhoek Sub-System.

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Commented [rm4]: 2008 in References

Commented [SM5R4]: Corrected.

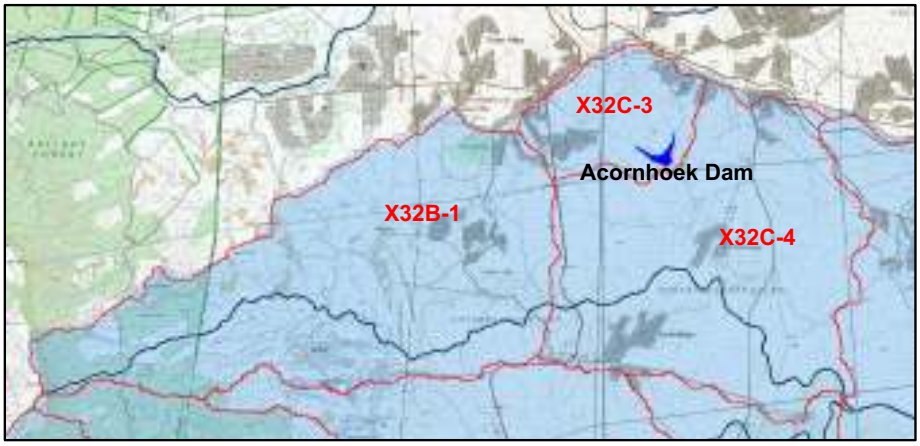


**Figure 3.1: Location of the Acornhoek Dam within the X32C-3 Quinary Catchment**

**Table 3.1: Summary of Climate & Hydrological Information: Klein Sand River Catchment**

| Catchment | Catchment area (km$^2$) | Mean Annual Evaporation (mm) | Mean Annual Precipitation (mm) | Natural Mean Annual Runoff (million m$^3$/annum) | |
|---|---|---|---|---|---|
| | | | | IWAAS study (1920 to 2004) | IUCMA 2021 (1920 to 2016) |
| X32B-1 | 54.1 | 1 506 | 960 | 9.99 | 9.86 |
| X32C-3 | 10.9 | 1 506 | 865 | 1.16 | 1.28 |
| X32C-4 | 46.9 | 1 506 | 826 | 4.21 | 4.30 |

It is important to note that none of these catchments are gauged and hence the natural flows are estimates based on the Pitman Model. There is therefore some uncertainty as to the runoff from these catchments. However, during the Sabie/Sand Operating Rules Study (DWA, 2013) flow measurements were undertaken at the location of the pumpstation. What was clear from these measurements is that the river is perennial at this point with high base flows. This is not surprising since the Klein Sand River rises in the mountains to the West where rainfall in excess of 1 000 mm/annum is experienced.

The Klein Sand abstraction works commands the X32B-1 quinary catchment and 5.1 km$^2$ of the X32C-4 quinary catchment. The natural runoff at this point is therefore 10.33 million m$^3$/annum.

### 3.2 Pumpstation Information

The pumpstation which supplies water to the town of Acornhoek has a maximum pumping rate of 70 ℓ/s (see **Appendix B**). The pumpstation consists of a total of 6 pumps, 4 duty and 2 standby. The four duty pumps are operated continuously when water is available and fewer pumps are used when the river flow is low.

Only recently has a record of the water pumped from the river been kept. See **Figure 3.2** which shows the monthly pumping volumes. This pumping record shows that the maximum volume pumped is in the driest months. The system not operating efficiently since the same or even greater volumes could be pumped in the wetter months. The daily record gives the maximum daily volume pumped at 5 947 m$^3$, which is consistent with the design capacity of the pump station of 70 ℓ/s.

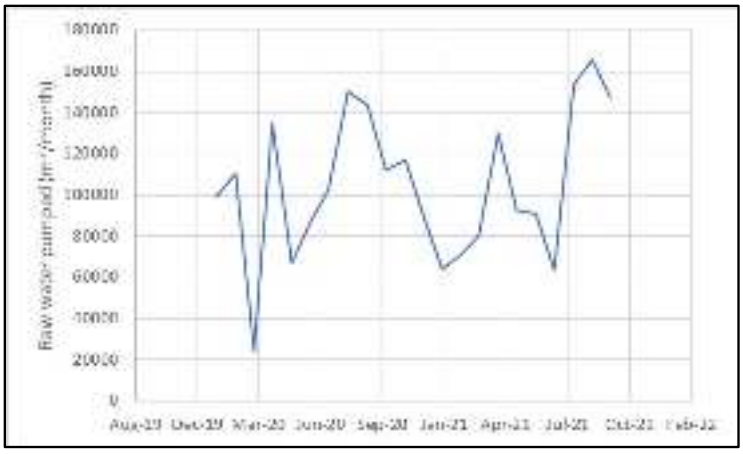


**Figure 3.2: Water Pumped from the Klein Sand River**

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Commented [C8]: Does the pumpstation pump to the Dam or to the town?

Commented [SM9R8]: As it turns out, the Klein Sand pumpstation pumps to the Water Treatment Plant and not into the dam. I have updated the analysis to model the system this way.

While it is accepted practice to take into account the diversion efficiency (Mallory and McKenzie, 1993), there is no daily flow data at the abstraction site with which to estimate this efficiency. As an alternative, and so as not to overestimate the volume of water that can be pumped, the following maximum monthly volume that can be pumped was assumed to be less in the drier months. Refer to **Table 3.2**.

**Table 3.2: Maximum Monthly Flow Volume**

| Month | Maximum volume that can be pumped (million $m^3$) |
|---|---|
| Oct | 0.13 |
| Nov | 0.13 |
| Dec | 0.19 |
| Jan | 0.19 |
| Feb | 0.18 |
| Mar | 0.19 |
| Apr | 0.18 |
| May | 0.16 |
| Jun | 0.14 |
| Jul | 0.13 |
| Aug | 0.13 |
| Sep | 0.13 |

# 4 REVIEW OF PREVIOUS STUDIES

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The IWAAS Study (DWA,2009) quotes a yield of Acornhoek Dam of 0.33 million $m^3$/annum. However, this was before the dam was raised. The IWAAS study also did not model the contribution of the water pumped from the Klein Sand River.

# 5 WATER USE AND WATER ALLOCATIONS

## 5.1 Allocations from the Acornhoek Dam

There does not appear to be a formal allocation from the Acornhoek Dam to the Municipality for domestic use. For the purposes of this report the allocation is assumed to be equivalent to the capacity of the WTW, that is 6 Mℓ/day or 2.2 million $m^3$/annum.

Commented [rm11]: Expand this statement: allocation from whom? For what? etc

Commented [SM12R11]: Done

Commented [C13]: Please include water use projection and/or any plans for future upgrades within the 5year period?

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The current and projected future water requirements for Acornhoek are shown in **Table 5.1**. This information was obtained from the Reconciliation Strategy Water Requirements Report (DWS, 2018).

**Table 5.1: Current and Projected Water Requirements for Acornhoek**

| Year | Requirement (million $m^3$/annum) |
|---|---|
| 2020 | 14.8 |
| 2025 | 15.4 |
| 2030 | 22.9 |
| 2035 | 25.0 |
| 2040 | 26.0 |

The water used by Acornhoek is not measured and hence the current and projected water use are based on a theoretical calculation assuming the RDP standard of 40 ℓ/person/day. The sources of water for Acornhoek are listed in the DWS 2018 Report as the Inyaka Dam (main source) with supplementary sources of Acornhoek Dam, Klein Sand Pumpstation and groundwater.

There are no plans to upgrade the system within the next five years, but a long-term possibility to augment the water resource as a possible dam in the Sand River catchment (DWS, 2021).

## 5.2 Upstream Water Use

It is important when carrying out any yield analysis to take into consideration the water use upstream of the dam or point of abstraction. There is no direct abstraction upstream of the Acornhoek Dam and very limited use within the Klein Sand upstream of the pumpstation which consists of approximately 200 ha of commercial forestry and 17 ha of irrigated Mangos, probably supplied from groundwater. Refer to **Figure 5.1 and Table 5.2**.

Commented [rm15]: Expand on what is in the rest of the catchment: amount of natural forest, built up areas etc

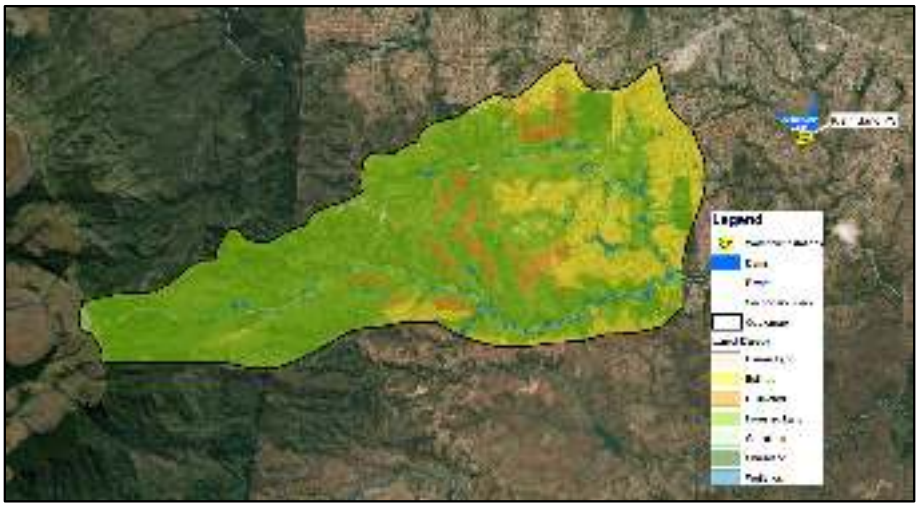


**Figure 5.1: Land and Water Use Upstream of the Klein Sand Pumpstation**

The estimated water use in the Acornhoek system is summarised in **Table 5.3**.

**Table 5.2: Land use**

| Type of land use | Area (ha) |
|---|---|
| Dry land crops | |
| Irrigated crop | 17 |
| Commercial afforestation | 200 |
| Rural settlements | |
| Indigenous forests | |

**Table 5.3: Estimated Water Use**

| Catchment | Forestry | |
|---|---|---|
| | Area ($km^2$) | Streamflow reduction (million $m^3$/annum) |
| Acornhoek Dam (X32C3) | 0.0 | 0.00 |
| Pumpstation (X32B1 plus 20% of X32C4) | 2.0 | 0.17 |
| Total | 2.0 | 0.17 |

## 5.3 Ecological Water Requirements

The small tributary on which the Acornhoek Dam is located is probably not significant from an ecological perspective and as far as can be ascertained there has never been a release from the dam to contribute to the Ecological Water Requirement (EWR). However, the Klein Sand River is a perennial river fed by the Drakensberg escarpment and is the source of base flow for downstream users. It is important therefore that an operating rule be put in place to ensure that the EWR is met as a priority over pumping to the Acornhoek Dam. Based on the limited development upstream of the catchment, a B Category EWR is appropriate.

The Hughes Desktop Model (Hughes and Hannart, 2002) was used to estimate the EWR at the pumpstation. The Rule Curve is attached as **Appendix E** while **Table 5.4** summarises the EWR.

Commented [rm16]: Add to References

Commented [SM17R16]: Done

**Table 5.4: Summary of EWR**

| Natural MAR at the Pumpstation (million $m^3$ /annum) | Mean EWR (million $m^3$ /annum) | % of Natural MAR |
|---|---|---|
| 10.72 | 4.18 | 39% |

# 6 ASSESSMENT OF WATER AVAILABILITY OF THE RESOURCE

## 6.1 Introduction

The Acornhoek Dam cannot be considered in isolation since water to the WTW is supplied from the dam and from the Klein Sand River. This pump station was not taken into account in the IWAAS study (DWA, 2009) or the recently completed Reconciliation Strategy (DWS, 2021). In addition, the larger Acornhoek area is supplied with water primarily from the Inyaka Dam and should therefore not be considered as a 'Stand Alone' system.

A simplified schematic representation of the system is shown in **Appendix C**.

## 6.2 Historical Yield Analysis

The historical firm yield is the maximum quantity of water that can be abstracted from the dam on a sustainable basis assuming a constant abstraction and based on the historical flow record and is estimated to be 2.13 million $m^3$/annum given the current configuration in which the water pumped from the Klein Sand River is delivered directly to the WTW (Scenario 1). An alternative scenario (Scenario 2) was modelled in which the water is pumped into the dam to provide balancing storage.

The trajectory of the dam with a target draft equal to the historical yield is shown in **Table 6.1**.

**Table 6.1: Historical Yield of the Acornhoek Dam**

| Study | Historic firm yield (million $m^3$/annum) | |
|---|---|---|
| | Scenario 1: Current operation | Scenario 2: Pump into the dam |
| DWS, 2021 | | 0.33 |
| This study (no EWR) | 2.13 | 2.20 |
| This study (B category EWR) | 1.12 | 1.35 |

The yield is slightly higher with the option to pump water into the dam. The reason for this is that at times when the water available to pump exceeds the target draft then the surplus water can be stored in the dam for later use.

## 6.3 Long-term Yield Analysis

The long-term yield curve of the Acornhoek Dam was generated for the current operation of the dam (Scenario 1), with and without the EWR. See **Figures 6.1 and 6.2**. These curves are based on 201 stochastically generated time series.

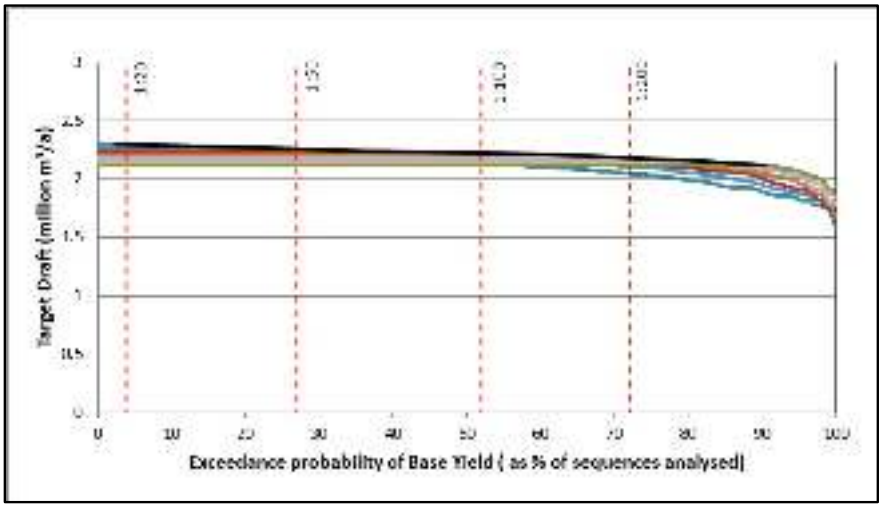


**Figure 6.1: Acornhoek Dam Long-Term Yield Curve: Scenario 1 with EWR**

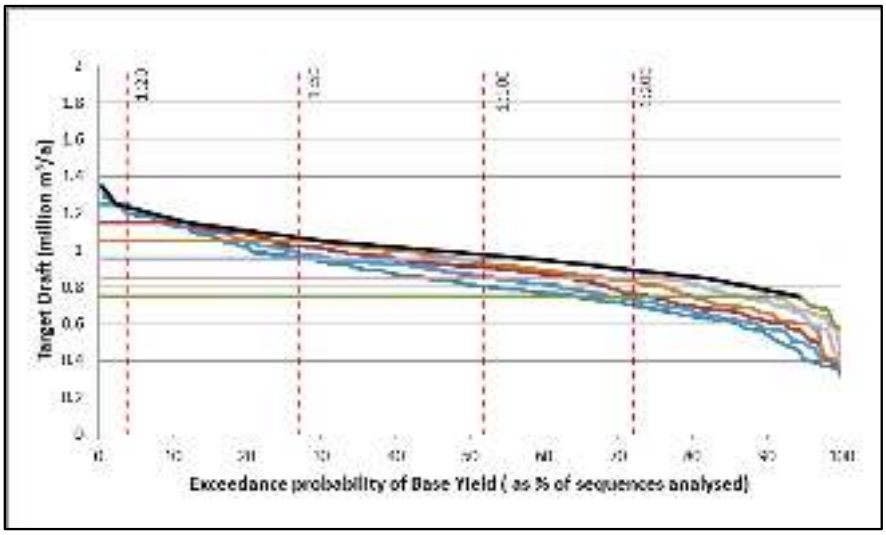


**Figure 6.2 Acornhoek Dam Long-Term Yield Curve: Scenario 1 with EWR Applied at the Klein Sand Abstraction Point**

Based on these curves the historic yield has a high recurrence interval of over 1:200 without the EWR (as currently operated) while the recurrence interval of the historic yield with the EWR applied drops to below the 1:50.

### 6.4 Short-term Yield Analysis

Short-term yield curves were developed for the current operation with the EWR applied on the Klein Sand River and are summarized in **Figure 6.3** with the detailed curves attached as **Appendix D**.

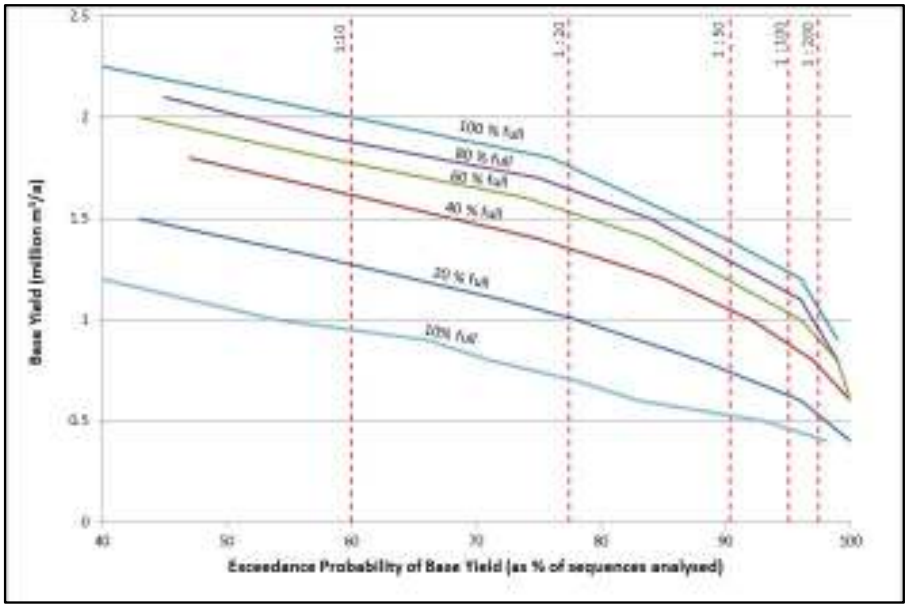


**Figure 6.3: Short Term Yield Curves: Acornhoek Dam**

# 7 OPERATING RULES

## 7.1 Current Operating Strategy

Based on a meeting with dam operators in September 2021, the current operating strategy is to utilise as much water out of the system as possible up to the limit of the water treatment works with water being pumped from the Klein Sand River whenever it is available and supplemented from water supplied from the dam. It is important to note that the water pumped from the Klein Sand is delivered directly to the Water Treatment Works and is not discharged into the dam.

The storage in the dam is not recorded but there are reports that the dam has emptied on occasion.

## 7.2 Assurance of Supply and Degree of Restrictions to be Applied

As a general rule, DWS aims to supply domestic water requirements at assurance of 98%. However, the main source of water for the town of Acornhoek is Inyaka Dam and the Acornhoek Dam is only used as a supplementary supply. The aim is to ensure a high assurance of supply from the combined sources. The WRPM model was set up and run as part of the Mbombela Reconciliation Strategy Study (DWS, 2021) but the report does not indicate the target assurance of supply to users. The Sabie System will be rerun with the May 2022 starting storage as part of this Stand Alone Dams project and at that time the assurance of supplies will the revisited with stakeholders. In the interim, the suggested assurances for domestic supply within the Sabie System are given in **Table 7.1**.

Commented [C18]: How? The operating rule needs to indicate the assurance of supply for this WSS from both Inyaka and Arconhoek Dams

Commented [SM19R18]: This will need to be addressed further when analysing the integrated system. In the interim I have expanded on the discussion regarding assurance of supply.

**Table 7.1: Assurance Reliability of Supply Criterion Adopted for Domestic Water Users**

| User Category | Portion of water supply within indicated priority class and associated RI of failure and annual assurance of supply | |
|---|---|---|
| | High<br>1:100 (99%) | High<br>1:50 (98%) |
| Domestic | 80% | 20% |

## 7.3 Development of Operating Rules

The Acornhoek Dam is not a typical stand-alone dam in that it is operating within a larger system. Provided water can be supplied from the Inyaka Dam, the state of the Acornhoek Dam is not critical. Water can be supplied from Acornhoek Dam at a lower cost than from Inyaka Dam and hence the strategy to supply as much water as possible from this dam is sound. The only suggested addition to this rule is to retain a small percentage of the dam's storage for emergency purposes should there be a break in the supply from the Inyaka Dam. It is recommended that the dam is not drawn below 10% which will allow 2 to 3 weeks for any repairs required on the Inyaka pipeline.

## 7.4 Short Term Stochastic Analysis

A short-term (5-year) stochastic analysis was carried out using 500 stochastic hydrological time series. The storage in the dam is not monitored hence the analysis assumed the dam was full at the start of the simulation (1 May 2021) which is likely. See **Figure 7.1**.

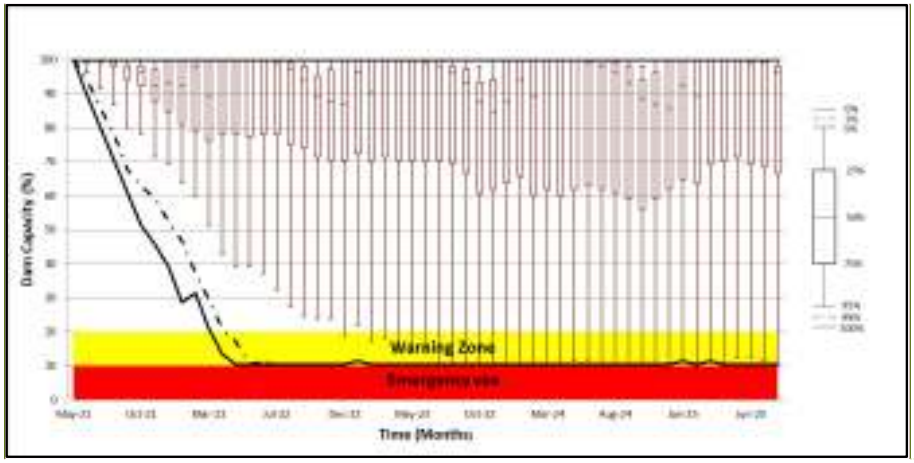


**Table 7.2: Scenario 1: Short Term Stochastic Box Plot: Acornhoek Dam with Pumping from the Klein Sand River**

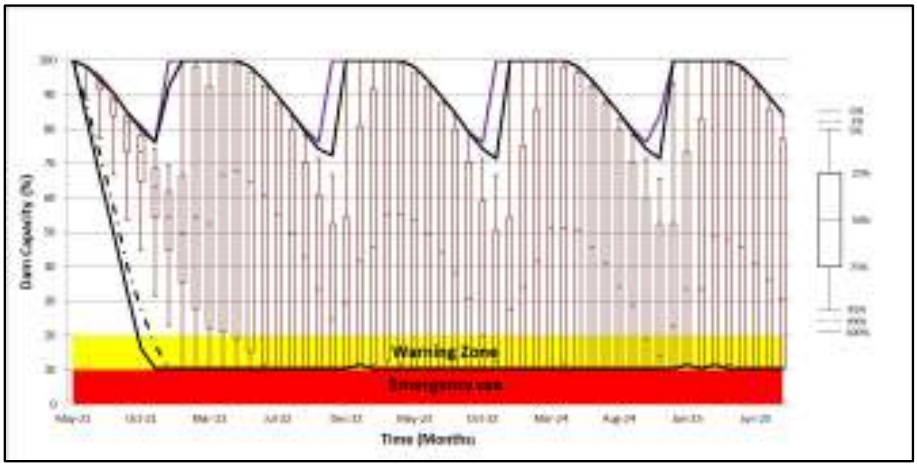


**Table 7.3: Scenario 2: Short Term Stochastic Box Plot: Acornhoek Dam with Pumping from the Klein Sand River**

**Commented [C20]:** From this plot, there is a very high risk of this Dam reaching the Warning zone at the 98-99% probability of exceedance. A more conservative operating rule is recommended to avoid failure to supply from this Dam even though Inyaka Dam is available as backup or main source of supply. An operating rule should protect the Dam from failure to supply

**Commented [SM21R20]:** An operating rule needs to protect the water supply to users and meet acceptable levels of assurance. When there is only one dam in the system then protecting the dam form failure and protecting the supply are synonymous. However, when there are multiple sources of supply the yield can often be maximised by allowing one or more of the dams to empty. Examples of this approach are the Amatole System and the White River system.

However, I have updated to recommended operating rule to be more conservative.

# 8 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The development of operating rules for the Acornhoek Dam in Mpumalanga is undertaken through a support project by the Department of Water and Sanitation (DWS) to '*Develop Operating Rules for Water Supply and Drought Management for Stand-Alone Dams and Schemes: Eastern Planning Area*'.

The Acornhoek Dam was raised about 15 years ago and a pump station was constructed to transfer water from the Klein Sand River to the dam. As far as can be ascertained the yield of the raised dam with transfers has not been determined before. The Reconciliation Strategy (DWS, 2021), estimated the yield of the dam but failed to take into account that the dam has been raised or that water is transferred from the Klein Sand River.

The historic yield of the system with transfers is estimated to be 2.13 million $m^3$/annum given the current operation of the system in which water is delivered directly to the WTW and not discharged into the dam as is currently the case. However, this does not take into account the EWR. Given the importance of the Klein Sand River in providing base flows to the Sand River, it is recommended that the EWR at the Klein Sand River abstraction site is met. Assuming a B Category EWR, the historic yield of the system then reduces to 1.12 million $m^3$/annum.

An alternative option was modelled in which the water pumped from the Klein Sand River is discharged into the dam and not delivered directly to the WTW. This results in slightly higher yields because water pumped in excess of the target draft can be stored in the dam for later use. It is recommended that the pipeline be upgraded to allow excess water to be discharged into the dam.

The Acornhoek Dam is not a typical stand-alone dam in that it is operating within a larger system. Provided water can be supplied from the Inyaka Dam, the state of the Acornhoek Dam is not critical. Water can be supplied from Acornhoek Dam at a lower cost than from Inyaka Dam and hence the current strategy to supply as much water as possible from this dam is sound. The only suggested addition to this rule is to retain a small percentage of the dam's storage for emergency use should there be a break in the supply from the Inyaka Dam. It is recommended that the dam is not drawn below 10% which will allow 2 to 3 weeks for any repairs required on the Inyaka pipeline.

The recently obtained record of water pumped from the Klein Sand indicates that the pumpstation is not operated efficiently and should be able to pump much more than is currently the case. To improve the efficiency and assist with the implementation of the EWR it is recommended that a real-time flow gauging station be installed downstream of the pumpstation.

## REFERENCES

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Department of Water Affairs, 2013. Establishment of a Real-Time Operating Decision Support System for the Sabie River System. Main Report.

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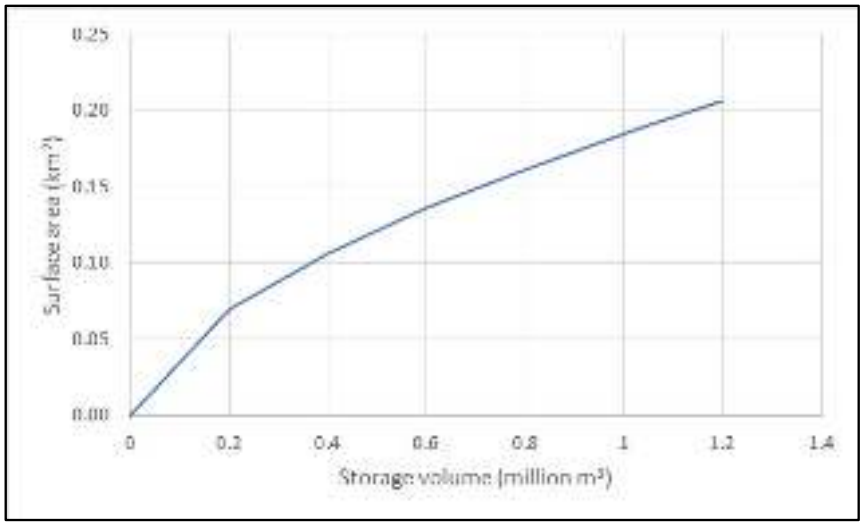
Department of Water and Sanitation, 2021. Continuation of Water Requirements and Availability Reconciliation for the Mbombela Municipal Area. Water Requirements and Return Flows. Report No. P WMA 03/X22/00/6718

Hughes, D.A. and Hannart, P. (2003) A Desktop Model Used to Provide an Initial Estimate of the Ecological Instream Flow Requirement of Rivers in South Africa, *Journal of Hydrology* **270** (3-4), pp 167 - 181.

Mallory SJL and McKenzie RS, 1993. Water Resources Modelling of Flow Diversions. Paper presented at the 6th SANCIAHS Symposium, Pietermaritzburg, South Africa.

# APPENDIX A: AREA-CAPACITY RELATIONSHIP OF THE ACORNHOEK DAM



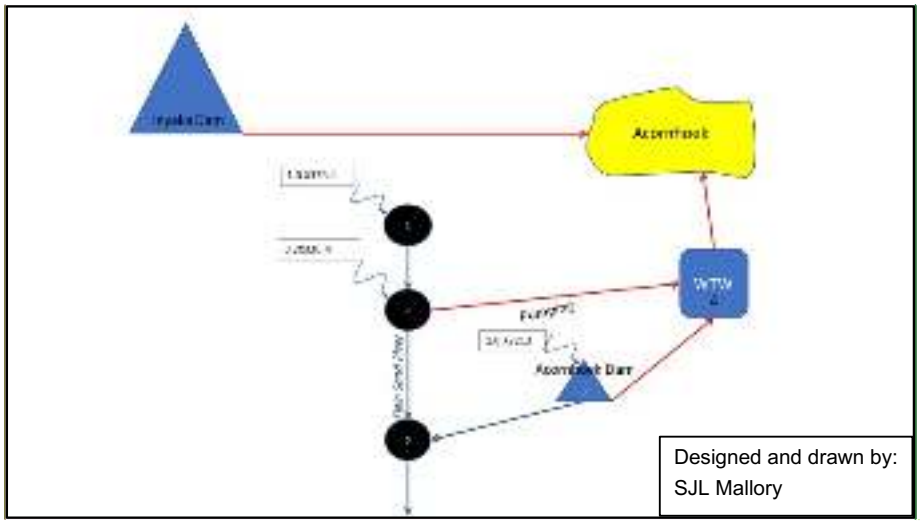
# APPENDIX B: WATER SUPPLY INFRASTRUCTURE

Klein Sand Pumping Station [1]

| | |
|---|---|
| Location: | Klein Sand River |
| Water source: | Klein Sand River<br>Same abstraction weir as old Champagne canal |
| Construction year: | Constructed in 2001, operation started in 2002<br>Constructed by DWAF and BBR Water Board |
| Operator: | BBR Water, plant operated 24/7 |
| Capacity: | no flow meter, report only running hours of the pumps<br>4 pumps (1 standby): 30Kw 20ℓ/s<br>2 pumps (1 standby): 18,5Kw 10ℓ/s<br>Max capacity: 70 l/s: 2.21 million $m^3$/a |
| Service area: | Acornhoek |
| Purification method: | - only pumping |
| Pumping method: | Water needs to overflow into the inlet, from the inlet water gravitates through a 300mm steel pipe to the basement of the pumphouse, 6 pumps pump the water from the basement (h: 15m) into the pipeline to Acornhoek dam, pumps work 24/7, during times of low river flow a smaller number of pumps are operated, as much water as possible is abstracted. |
| Present: | No water is pumped to Acornhoek dam, due to rehabilitation of the dam<br>There is no communication between Acornhoek dam and the pumphouse. The pumphouse operates independently from the dam, as much water as possible is pumped. |

[1] Information from operator and supervisor as supplied by AWARD in 2012

## APPENDIX C: SYSTEM DIAGRAM



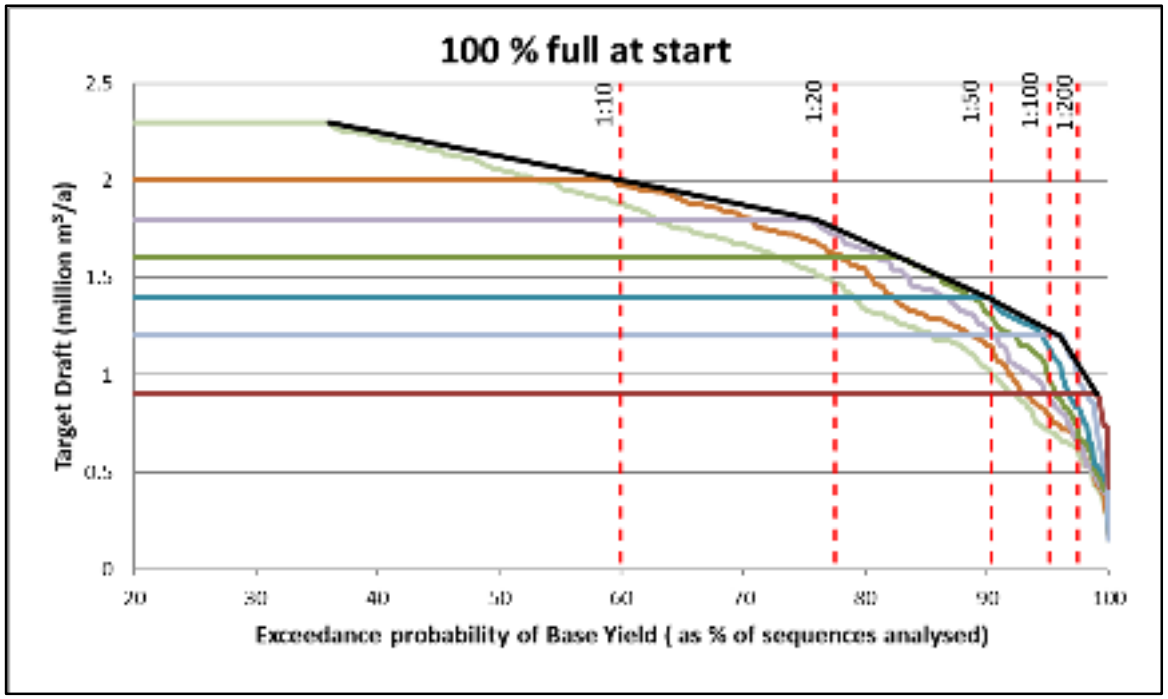

Commented [C22]: Please add the linkage with Inyaka Dam and include the WTP, WWTW and supply nodes also label the circles as well as the river (s)

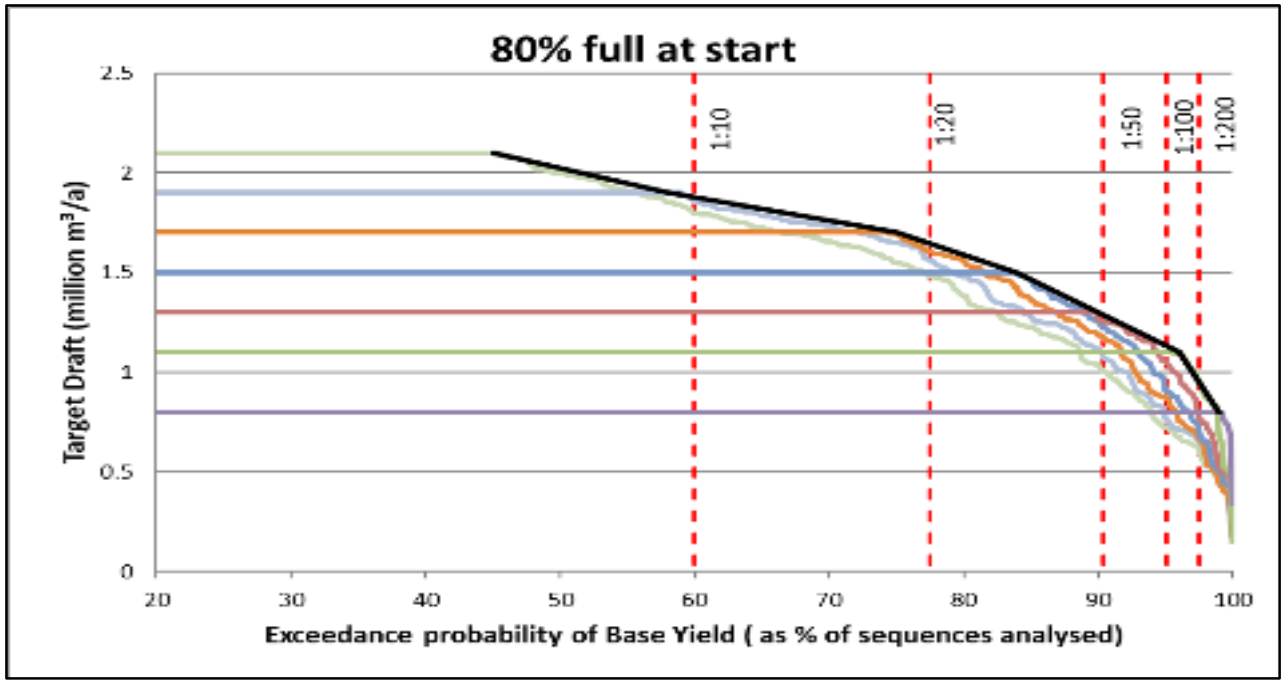
Commented [SM23R22]: Updated.
As far as I know Acornhoek doesn't have water borne sewage so there is no WWTW. I will check up on this. I have heard of complaints that the small package plant at the new Acornhoek Mall discharges into the dam but this should be a very small volume.

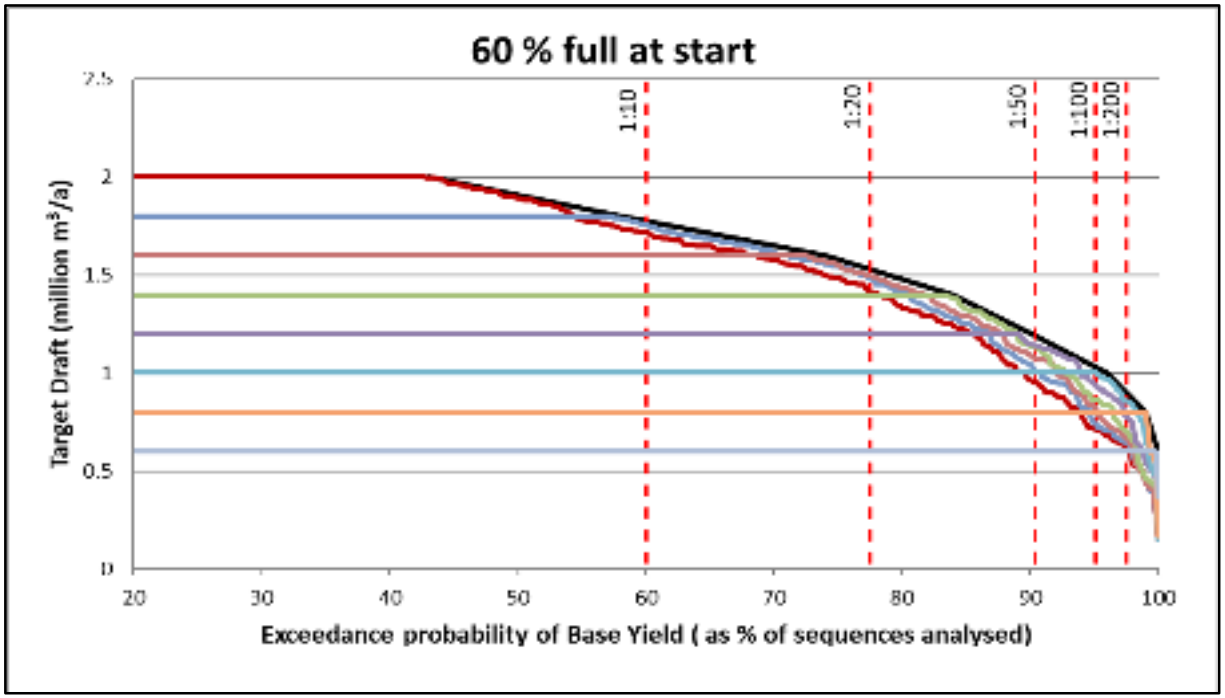
Commented [rm24]: Add note on source of diagramme

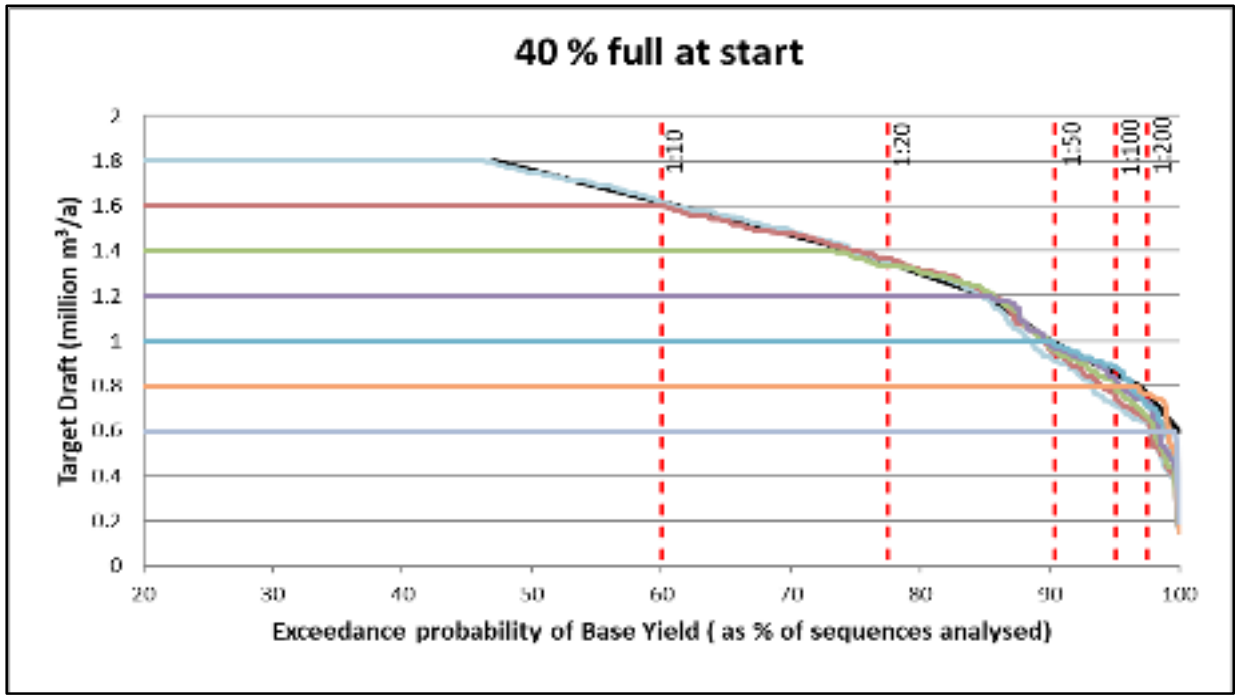
Commented [SM25R24]: Self

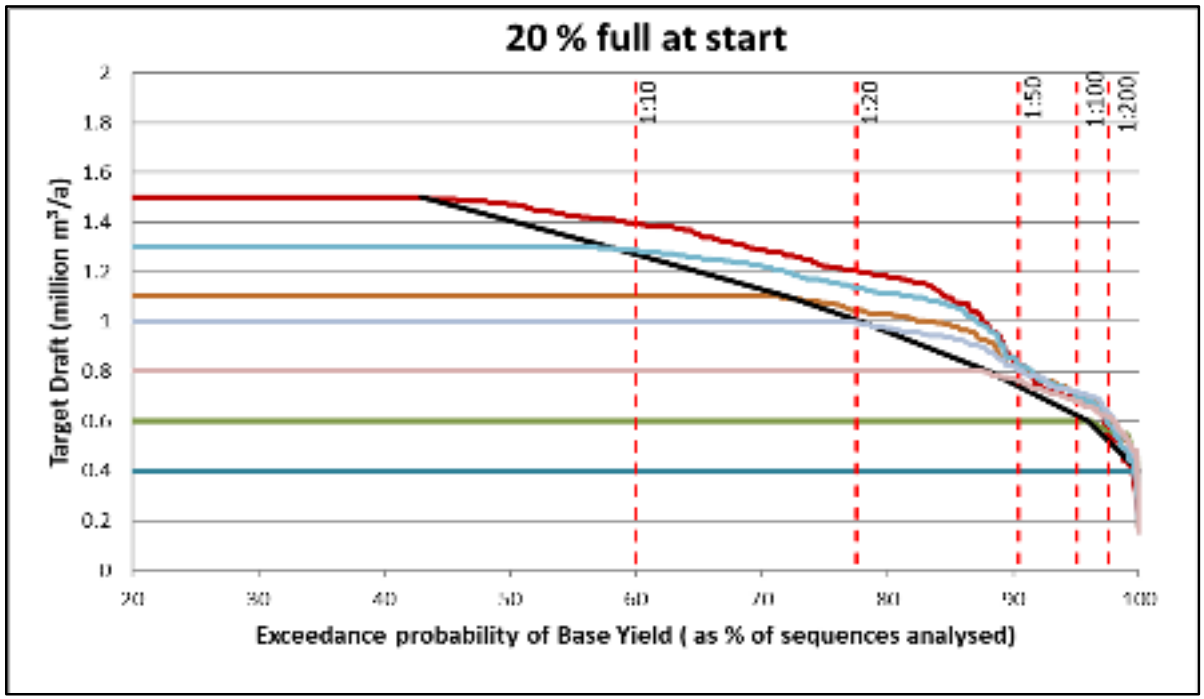
# APPENDIX D: SHORT TERM YIELD CURVES

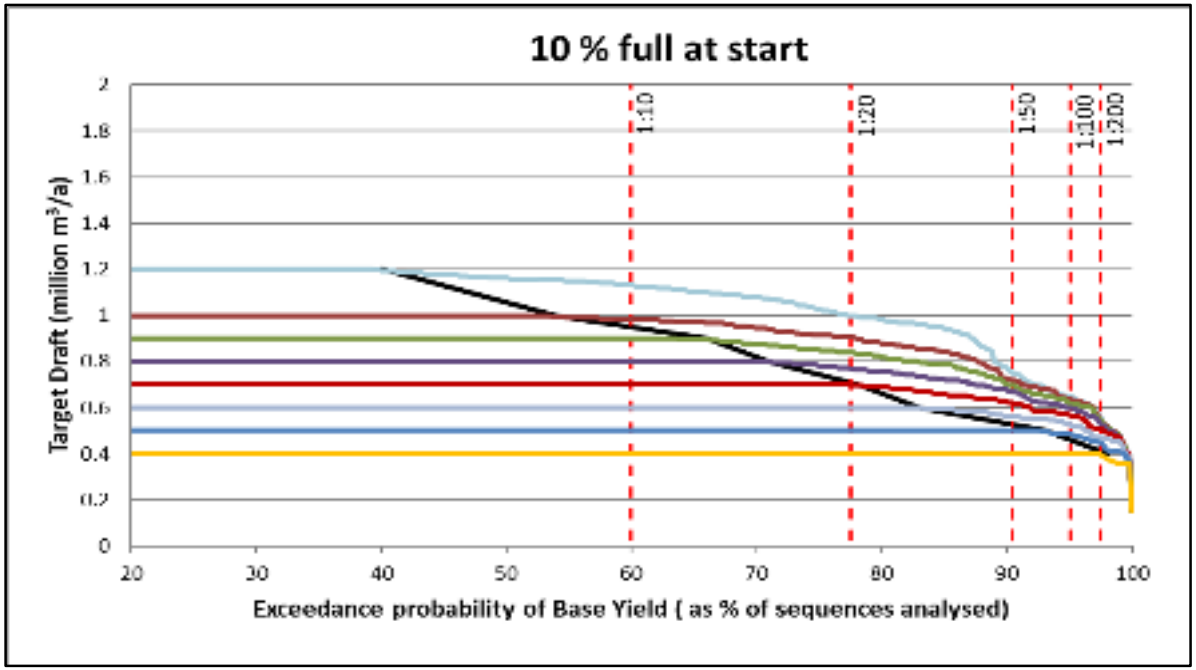

100 % full at start
1:10
1:20
1:50
1:100
1:200
Target Draft (million m³/a)
2.5
2
1.5
1
0.5
0
20
30
40
50
60
70
80
90
100
Exceedance probability of Base Yield ( as % of sequences analysed)


80% full at start
Target Draft (million m³/a)
2.5
2
1.5
1
0.5
0
1:10
1:20
1:50
1:100
1:200
20
30
40
50
60
70
80
90
100
Exceedance probability of Base Yield ( as % of sequences analysed)


60 % full at start
1:10
1:20
1:50
1:100
1:200
Target Draft (million m³/a)
2.5
2
1.5
1
0.5
0
20
30
40
50
60
70
80
90
100
Exceedance probability of Base Yield ( as % of sequences analysed)


40 % full at start
Target Draft (million m³/a)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1:10
1:20
1:50
1:100
1:200
20
30
40
50
60
70
80
90
100
Exceedance probability of Base Yield ( as % of sequences analysed)


20 % full at start
1:10
1:20
1:50
1:100
1:200
Target Draft (million m³/a)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Exceedance probability of Base Yield ( as % of sequences analysed)


10 % full at start
Target Draft (million m³/a)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1:10
1:20
1:50
1:100
1:200
20
30
40
50
60
70
80
90
100
Exceedance probability of Base Yield ( as % of sequences analysed)

# APPENDIX E: ECOLOGICAL FLOW REQUIREMENTS AT THE KLEIN SAND PUMPSTATION

Summary of IFR rule curves for : Klein Sand
Total Runoff : Runoff : RREGIO
Regional Type : E.Escarp
EMC = B

Data are given in m^3/s mean monthly flow

| Month | % Points | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 99% |
| Oct | 0.075 | 0.075 | 0.074 | 0.073 | 0.070 | 0.066 | 0.058 | 0.047 | 0.033 | 0.023 |
| Nov | 0.095 | 0.095 | 0.094 | 0.092 | 0.088 | 0.082 | 0.072 | 0.056 | 0.039 | 0.026 |
| Dec | 0.142 | 0.141 | 0.139 | 0.136 | 0.131 | 0.121 | 0.104 | 0.080 | 0.053 | 0.033 |
| Jan | 0.243 | 0.226 | 0.212 | 0.197 | 0.182 | 0.156 | 0.134 | 0.103 | 0.068 | 0.042 |
| Feb | 0.659 | 0.596 | 0.542 | 0.479 | 0.380 | 0.331 | 0.273 | 0.235 | 0.145 | 0.081 |
| Mar | 0.316 | 0.299 | 0.284 | 0.269 | 0.251 | 0.221 | 0.191 | 0.147 | 0.096 | 0.058 |
| Apr | 0.204 | 0.204 | 0.202 | 0.198 | 0.190 | 0.177 | 0.154 | 0.120 | 0.079 | 0.049 |
| May | 0.123 | 0.123 | 0.122 | 0.120 | 0.116 | 0.108 | 0.095 | 0.076 | 0.052 | 0.034 |
| Jun | 0.107 | 0.107 | 0.106 | 0.104 | 0.101 | 0.095 | 0.084 | 0.067 | 0.046 | 0.031 |
| Jul | 0.091 | 0.091 | 0.090 | 0.089 | 0.086 | 0.081 | 0.072 | 0.058 | 0.040 | 0.027 |
| Aug | 0.082 | 0.082 | 0.081 | 0.080 | 0.077 | 0.073 | 0.064 | 0.052 | 0.036 | 0.025 |
| Sep | 0.073 | 0.073 | 0.072 | 0.071 | 0.069 | 0.065 | 0.057 | 0.047 | 0.033 | 0.023 |

Reserve Flows without High Flows

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 0.065 | 0.065 | 0.064 | 0.063 | 0.061 | 0.057 | 0.051 | 0.041 | 0.030 | 0.021 |
| Nov | 0.069 | 0.069 | 0.068 | 0.067 | 0.064 | 0.060 | 0.053 | 0.043 | 0.031 | 0.022 |
| Dec | 0.087 | 0.086 | 0.085 | 0.084 | 0.081 | 0.075 | 0.066 | 0.053 | 0.037 | 0.026 |
| Jan | 0.125 | 0.124 | 0.123 | 0.120 | 0.115 | 0.106 | 0.092 | 0.073 | 0.051 | 0.034 |
| Feb | 0.192 | 0.191 | 0.189 | 0.185 | 0.178 | 0.164 | 0.143 | 0.112 | 0.076 | 0.050 |
| Mar | 0.197 | 0.197 | 0.195 | 0.191 | 0.183 | 0.170 | 0.148 | 0.116 | 0.078 | 0.051 |
| Apr | 0.168 | 0.168 | 0.166 | 0.163 | 0.157 | 0.146 | 0.128 | 0.101 | 0.068 | 0.045 |
| May | 0.123 | 0.123 | 0.122 | 0.120 | 0.116 | 0.108 | 0.095 | 0.076 | 0.052 | 0.034 |
| Jun | 0.107 | 0.107 | 0.106 | 0.104 | 0.101 | 0.095 | 0.084 | 0.067 | 0.046 | 0.031 |
| Jul | 0.091 | 0.091 | 0.090 | 0.089 | 0.086 | 0.081 | 0.072 | 0.058 | 0.040 | 0.027 |
| Aug | 0.082 | 0.082 | 0.081 | 0.080 | 0.077 | 0.073 | 0.064 | 0.052 | 0.036 | 0.025 |
| Sep | 0.073 | 0.073 | 0.072 | 0.071 | 0.069 | 0.065 | 0.057 | 0.047 | 0.033 | 0.023 |

Natural Duration curves

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 0.157 | 0.146 | 0.127 | 0.112 | 0.105 | 0.097 | 0.090 | 0.086 | 0.071 | 0.052 |
| Nov | 0.316 | 0.216 | 0.177 | 0.158 | 0.147 | 0.131 | 0.116 | 0.096 | 0.081 | 0.062 |
| Dec | 0.620 | 0.403 | 0.314 | 0.250 | 0.217 | 0.172 | 0.146 | 0.131 | 0.105 | 0.067 |
| Jan | 1.400 | 0.750 | 0.519 | 0.343 | 0.302 | 0.261 | 0.209 | 0.187 | 0.142 | 0.097 |
| Feb | 2.914 | 1.724 | 0.765 | 0.479 | 0.380 | 0.331 | 0.273 | 0.236 | 0.178 | 0.083 |
| Mar | 2.225 | 1.057 | 0.650 | 0.474 | 0.358 | 0.291 | 0.258 | 0.224 | 0.168 | 0.090 |
| Apr | 1.100 | 0.525 | 0.401 | 0.359 | 0.301 | 0.270 | 0.239 | 0.201 | 0.181 | 0.085 |
| May | 0.377 | 0.336 | 0.310 | 0.269 | 0.231 | 0.205 | 0.187 | 0.168 | 0.149 | 0.071 |
| Jun | 0.293 | 0.266 | 0.235 | 0.208 | 0.189 | 0.170 | 0.158 | 0.139 | 0.127 | 0.069 |
| Jul | 0.213 | 0.194 | 0.172 | 0.164 | 0.149 | 0.142 | 0.134 | 0.119 | 0.108 | 0.067 |
| Aug | 0.168 | 0.157 | 0.146 | 0.138 | 0.131 | 0.119 | 0.112 | 0.105 | 0.090 | 0.060 |
| Sep | 0.162 | 0.143 | 0.131 | 0.120 | 0.116 | 0.104 | 0.100 | 0.093 | 0.081 | 0.054 |