# HAIB COPPER PROJECT

## WATER RESOURCE AND WATER DEMAND IMPACT STUDY ON THE ORANGE RIVER FOR THE POSSIBLE ABSTRACTION BY HAIB MINE: SPECIALIST REPORT

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# ABBREVIATIONS

AOA ........ Annual Operating Analysis
CFRD ........ Concrete-Faced Rockfill Dam
DWS ........ Department of Water and Sanitation (RSA)
EPL ........ Exclusive Prospective License
ESIA ........ Environmental and Social Impact Assessment
EWR ........ Environmental Water Requirements
GCM ........ Global Climate Model
HFY ........ Historical Firm Yield
Koryx ........ Koryx Copper Inc.
KP ........ Knight Piésold Consulting (Pty) Ltd.
LHWP ........ Lesotho Highlands Water Project
LORC ........ Lower Orange River Consultants
LORMS ........ Lower Orange Management Study
MOL ........ Minimum Operating Level
NCJV ........ Namibian Copper Joint Venture
NVD ........ Noordoewer-Vioolsdrift Dam
ORASECOM ........ Orange-Senqu River Commission
ORS ........ Orange River System
ORP ........ Orange River Project
PEA ........ Preliminary Economic Assessment
PFS ........ Pre-Feasibility Study
RSA ........ Republic of South Africa
TSF ........ Tailings Storage Facility
WC ........ Water Conservation
WDM ........ Water Demand Management
WRC ........ Water Research Commission
WRP ........ WRP Consulting Engineers (Pty) Ltd
WRPM ........ Water Resources Planning Model
WRYM ........ Water Resources Yield Model

# UNITS OF MEASURE

km ..... Kilometres
$km^2$ ..... Square kilometres
m ..... Meters
$m^3$ ..... Cubic metres
$m^3/s$ ..... Cubic metres per second
$Mm^3$ ..... Million cubic metres
$Mm^3/a$ ..... Million cubic metres per annum
Mtpa/mta ..... Million tonnes per annum

# 1.0 BACKGROUND

The Orange River Project (ORP) includes the two largest storage dams in the RSA, Gariep and Vanderkloof dams. These dams are used to supply water to users along the Orange River from Gariep Dam to the Orange River mouth and include users in the RSA as well as users in Namibia along the RSA-Namibia border in the Lower Orange. Water is also transferred via the Orange-Fish tunnel to the Eastern Cape, mainly for irrigation requirements, but also some urban/industrial requirements, of which the Nelson Mandela Bay Metropolitan area is the largest user.

The total water use from this water supply system has increased over the years and is currently at the 2024 development level, already slightly exceeding the historic firm yield of about 3 300 million $m^3$/a for the ORP system. Further increases in the total water demand imposed on this system will reduce the assurance of water supply to the existing users.

Developments upstream of the Gariep Dam will further significantly impact the available yield from the ORP. This includes the Polihali Dam currently under construction, planned dams in the Lesotho Lowlands, as well as a major dam planned on the Makhaleng River in Lesotho to supply water to Lesotho, with the major volume transferred to Gaborone in Botswana, but also supplying water to RSA towns along the pipeline route, which may include the Greater Bloemfontein. Polihali Dam will be used to transfer an additional 391 million $m^3$/a in support of the Integrated Vaal River System. The proposed dam on the Makhaleng River in Lesotho will supply a total planned water requirement of 308 million $m^3$/a of which 156 million $m^3$/a will be for Botswana and about 64 million $m^3$/a for the RSA when the Greater Bloemfontein is included, and the remainder to be utilised by Lesotho.

A transfer scheme taking water from Gariep Dam to the Greater Bloemfontein area is currently in its feasibility stage and is expected to be in place by 2031/32. The maximum transfer rate is currently set at 101 million $m^3$/a.

DWS RSA carried out a detailed study in 2015, referred to as the "Development of Reconciliation Strategies for Large Bulk Water Supply System: Orange River", in which several intervention options were identified to rebalance the Orange River due to the increased upstream developments and growth in demand imposed on the ORP. Several intervention options were identified, of which the Noordoewer/Vioolsdrift Dam is one of the larger infrastructure options. These intervention options included:

1. Plan and implement WC/WDM in the irrigation and domestic water use sectors.
2. Initial shared utilisation of LHWP Phase II between the Vaal River and Orange River systems to postpone large capital expenditure that would otherwise be required at the same time Polihali Dam becomes operational.
3. Reduce operational losses through real-time monitoring of river flows in the Orange and Vaal rivers, to maximise the beneficial use of the spillages from the Vaal River System.
4. Utilising a greater portion of Vanderkloof Dam's storage capacity by lowering the minimum operating level in the dam. This measure will require pumping infrastructure.
5. Commission Noordoewer-Vioolsdrift Dam at the decided date for alternative EWR implementation.
6. Create additional yield in the system by raising the Gariep Dam by 10m or by building the Verbeeldingskraal Dam.
7. Investigating further management measures, such as lowering the assurances of supply, eliminating unlawful water use and eradicating invasive alien plants in the Kraai River.
8. Hold negotiations with WUA and Irrigation Boards to agree on appropriate assurances of supply for irrigated agriculture.

9. Initiate a process to decide what the desirable EWR should be for the river system.

Items 2 and 9 are currently being addressed by DWS RSA, and item 9 is also through ORASECOM.

Deficits in the water supply within the ORP are expected to start taking place as soon as Polihali Dam starts to inundate water by July 2026 for transfers to the Vaal River System.

The water supply from the ORP to its users and the related ORP water balance are updated every year as part of the Annual Operating Analysis carried out by DWS RSA. The most recent operating analysis was completed in June 2024.

# 2.0 METHODOLOGY – WATER SUPPLY

Due to the small, expected impact of the Hiab Mine water use on the water supply within the ORP it is not deemed necessary to carry out an in-depth water resource analysis in the initial stage of this investigation. Several recent analyses were carried out on this system, and it is proposed to evaluate the impact of the Haib Mine water abstraction first, based on results already available from these analyses.

The most recent analyses were carried out as part of the ORP Annual Operating Analysis by DWS RSA, with the report completed in September 2024. Comprehensive system analyses were also carried out as part of the ORASECOM Study "Preparation of Climate Resilient Water Resources Investment Strategy & Plan and Lesotho -Botswana Water Transfer Multipurpose Transboundary Project," which will be completed by the end of November 2024.

Both these studies included the proposed future developments, or at least most of them. The ORASECOM study also includes some water requirements for the future Haib Mine development.

The methodology followed for this investigation included the following:

1. Evaluate the relevant reports from both studies and select from the scenarios already analysed the most appropriate ones that can be used to provide more insight into the Haib Mine water supply and relate impacts on the overall water supply system.
2. Different Haib Mine water abstraction scenarios will be considered using the WRPM in historic mode. These abstractions are modelled to take place close to the confluence of the Haib River with the Orange River:
    a. Direct abstraction from the Orange River without using an off-channel storage dam.
    b. Direct abstraction from the Orange River using an off-channel storage dam. Water is then not to be supplied from the Gariep and Vanderkloof dams, but only abstracted at times when there is surplus flow available in the river.
3. Based on the latest available information, update the water balance for the ORP with and without the Haib Mine water abstraction.
4. Determine the impact of the Haib Mine abstraction on the overall ORP water supply system.
5. Determine the impact of the Haib Mine abstraction on the downstream users.
6. Describe possible ways to manage or operate the Haib Mine abstraction to minimise the impact on other users.

# 3.0 PREVIOUS STUDIES: SUMMARY

Several Orange River-related studies were identified in which the possible future Haib Mine was included in the future water requirement projections. These include the following five studies:

1. **LORMS 2005:** Prefeasibility Study into Measures to Improve the Management of the Lower Orange River and to Provide for Future Developments along the Border Between Namibia and South Africa. RSA DWAF Report No. PB D000/00/4703, Namibia DWA Report no. 400/1/P-13. Dated September 2005. Produced by the Lower Orange River Consultants for the Permanent Water Commission (RSA & Namibia)
2. **Orange River Recon Study 2014**: Department of Water Affairs, South Africa, 2013: Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River. Final Reconciliation Strategy (November 2014) DWA Report No: P RSA D000/00/18312/11. Prepared by WRP Consulting Engineers, Aurecon, Golder Associates Africa, and Zitholele Consulting.
3. **NVD Study 2020**: Noordoewer / Vioolsdrift Dam Feasibility Study. Main Report. Report no. PWC/JFS/1-2014/17. Prepared by AECOM – WCE Joint Venture for the Permanent Water Commission (RSA & Namibia).
4. **ORASECOM IWRMP Operationalisation 2024**: Preparation of Climate Resilient Water Resources Investment Strategy & Plan and Lesotho-Botswana Water Transfer Multipurpose Transboundary Project. Roadmap for IWRMP Operationalisation Report Component II. Report no. ORASECOM 012/2019. Prepared by WRP in association with Knight Piesold, Ingerop, GWC and WRC Consultants.
5. **Orange AOA 2024**: Department of Water and Sanitation. Development of Operating Rules for Water Supply and Drought Management of Stand-Alone Dams, Schemes and Integrated Systems in the Central Planning Area. Annual Operating Analysis Orange River Project and Greater Bloemfontein Systems 2024/2025. Report no. P RSA 000/00/24523/5. Prepared by WRP Consulting Engineers with support from Gandlati Consulting.

None of the five studies focused on the possible Haib mine development, although they all included the Haib Mine as one of the future possible developments. The estimated water requirements for the Haib Mine differ between the five studies and depend on the information received from Namibia at the time of the specific study. This also applies to the estimated time when the Haib Mine will start to take water from the Orange River.

None of the studies indicated that supplying water to the future Haib Mine will lead to significant deficits in the ORP. It was, however, indicated that additional water resource developments will be required to be able to supply the future expected growth in water requirements imposed on the ORP. From the LORMS study, the focus of a future resource was on the Noordoewer–Vioolsdrift Dam to support specifically the growing future water requirements of Namibia along the Lower Orange, and this included the Haib Mine water requirement estimated at the time to be as high as 30 million $m^3$/a.

For the Orange River Recon Study, the ORASECOM IWRMP Study and the Orange AOA 2024 study, several water resource intervention options were considered to rebalance the ORP system due to significant water resource developments upstream in Lesotho (See Section 1) as well as to supply future water requirements. All these studies included the possible future Noordoewer-Vioolsdrift Dam, which will most probably in all cases be the most appropriate water resource development to supply water to Haib Mine in future.

The NVD 2020 study again focused on the Noordoewer-Vioolsdrift Dam to supply most of the future water requirements along the Lower Orange. Possible dams in the upper Orange were, however, also considered in combination with the Noordoewer-Vioolsdrift Dam. These included the Verbeeldingskraal Dam, the raising of Gariep Dam, as well as the Boskraai Dam and the utilisation of the lower-level storage in Vanderkloof Dam.

The Orange AOA 2024 assumed that the Haib mine will start using water from the Orange River in 2027 at 6 million m$^3$/a. This, however, coincides with the Polihali Dam that starts to inundate water in the same year. This resulted in deficits in the ORP from 2027 onwards. The Polihali Dam's impact on the ORP yield is quite severe, being in the order of 280 million m$^3$/a. This overshadows the impact of the Haib abstraction of only 6 million m$^3$/a. The main reason for the deficits in the ORP from 2027 onwards is therefore the Polihali Dam starting to inundate water.

With yield characteristics available at different assurance levels as obtained from WRYM risk (stochastic) yield analysis carried out as part of the Orange AOA 2024, the WRPM can utilise this information to supply water to users at their required assurance levels, which will differ for different types of user groups. To be able to define the combinations of the different supply assurance levels, a priority classification table is used, as given in Table 3-1 for the ORP System.

From Table 3-1, it is, for example, evident that 50% of irrigation is supplied at a low assurance of 95% (1 in 20-year risk of non-full supply), 40% at a medium assurance (99%) and 10% at a high assurance (99.5%). During severe droughts when restrictions need to be imposed, the water supply allocated to the low assurance class will first be reduced or restricted, followed by the medium, and finally the high assurance class. Restriction level 1 refers to the full restrictions imposed on the low assurance class. The restrictions will, however, be implemented gradually before imposing full level 1 restrictions.

**Table 3-1: Orange River Project Current Priority Classification**

| **Sector** (Recurrence Interval of a restriction; Assurance of supply) | **Priority Categories (Portion of the water requirements %)** | | |
|---|---|---|---|
| | **High** | **Medium** | **Low** |
| | **1: 200 year (99.5%)** | **1: 100 year (99%)** | **1: 20 year (95%)** |
| **Irrigation** | **10** | **40** | **50** |
| **Urban** | **50** | **30** | **20** |
| **Operational requirements** | **100** | **0** | **0** |
| **Environmental** | **68** | **0** | **32** |
| **Restriction levels: 3** | **2** | **1** | **0** |

Losses and river requirements (operational requirements) are not something that can be restricted, as they will always occur even under extreme drought conditions. As these requirements cannot be restricted, they are allocated to the high assurance class.

The assurance classes for the environmental requirements are only applicable to the current Environmental Water Requirements (EWR) releases, which are based on a different methodology than the more recently determined EWRs. The latest EWRs follow the same pattern and probability of occurrence as the natural flows generated in the basin and do not require a specified fixed assurance.

The results from the Orange AOA 2024 were derived by using the WRPM and analysing 1000 possible flow sequences (possible future natural rainfall runoff from each sub-catchment) with record lengths of 10 to 15 years. This means that the model will produce 1000 different answers for each monthly storage volume, water supply, river flow, etc. To be able to put meaning to these vast numbers of results, box plots are used to describe the results in terms of exceedance probability (See Figure 3-1).

The vast number of results is represented by the encircled yellow dots in Figure 3-1. Using the box and whisker plots, meaning is given to these results. For example:

- The lowest solid line of the boxplot indicates that 100% of all the flow sequences analysed are at or above this line.
- The dashed line just above that states that 99.5% of all sequences are at or above this line. This represents a 1 in 200-year recurrence interval.
- The dot, dashed line combination shows the 99% exceedance probability, representing the 1 in 100-year recurrence interval.
- The lower whisker of the boxplot represents the 95% exceedance probability or a 1 in 20 years recurrence interval.
- The middle of the box shows the 50% exceedance probability or median value.

The same approach applies to all the other percentage exceedance probabilities as given in Figure 3-1

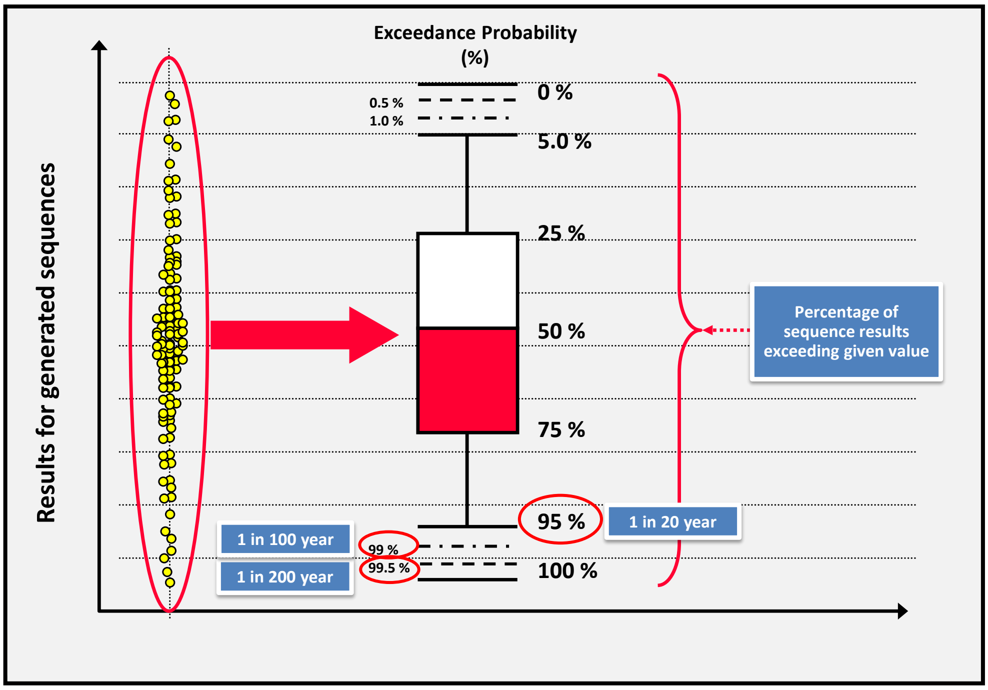


**Figure 3-1: Probability distribution of results**

Base Scenario 2a and 2b from the Orange AOA 2024 study show the impact on the water supply from the ORP due to an increase in the Namibia irrigation of 27.5 million m$^3$/a. This will be more or less in line with the impact of a Haib Mine abstraction of about 20 million m$^3$/a as currently estimated.

Figure 3-2 shows the curtailment plot for Base Scenario 2a, which includes a Namibia irrigation requirement of 75 million m$^3$/a. There is no exceedance of the curtailment criteria in the first 3 years of the analysis. Polihali Dam starts to inundate water in July 2026 and will thus not impact the starting storage levels of 1 May 2026, but on the starting storage of May 2027. In May 2026, real-time monitoring and modelling will be introduced and will increase the system yield by approximately 80 million m³/a. This, to some extent, counters the negative impact of Polihali Dam on the ORP for the 2026/27 operating year and allows the users to be supplied at their required assurance levels. By 2027, the impact of the water stored in Polihali Dam is starting to impact severely on the assurance of water supply from the ORP system, and this impact increases once transfers from Polihali to the Integrated Vaal System start in 2028.

For Base Scenario 2b, the Namibian irrigation is increased by 27.5 million m³/a to 102.5 million m³/a. The impact on the ORP for Base Scenario 2b is shown in Figure 3-3. Due to this increase in irrigation, a small increase in curtailments is evident primarily for the low assurance (1 in 20 years) curtailment level and to a lesser extent in the medium-high assurance (1 in 100 years) curtailment level.

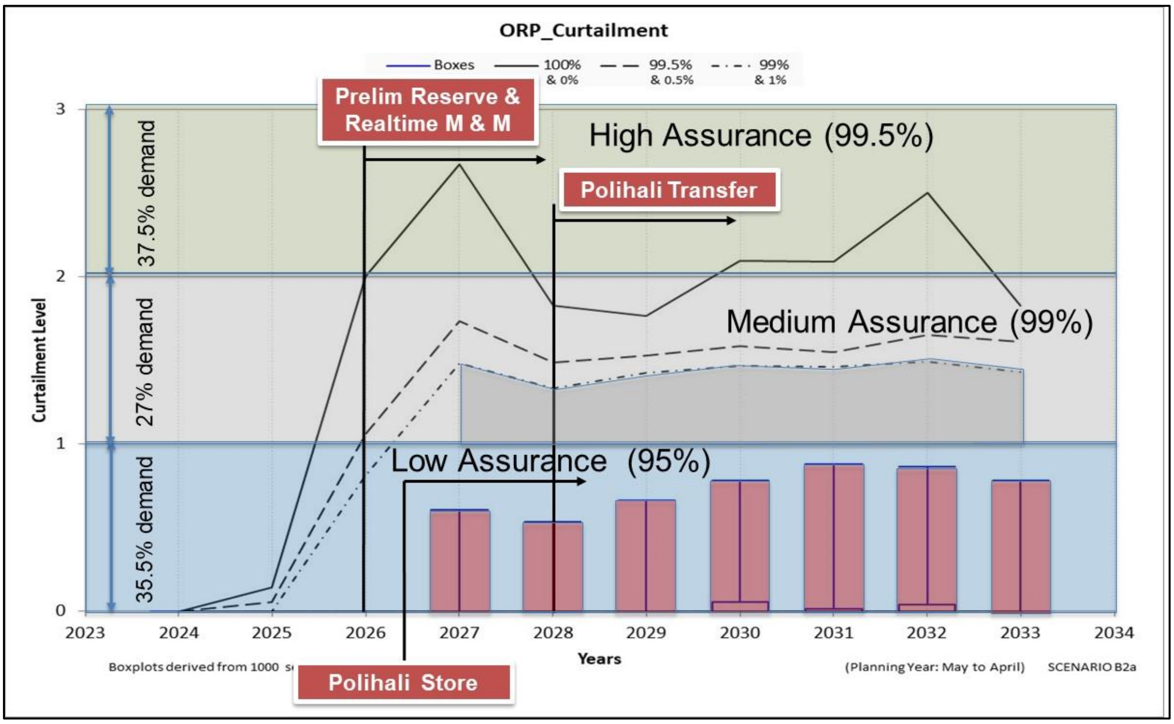


**Figure 3-2: ORP Curtailment plot 2024/25 operating year (Base 2a Scenario)**

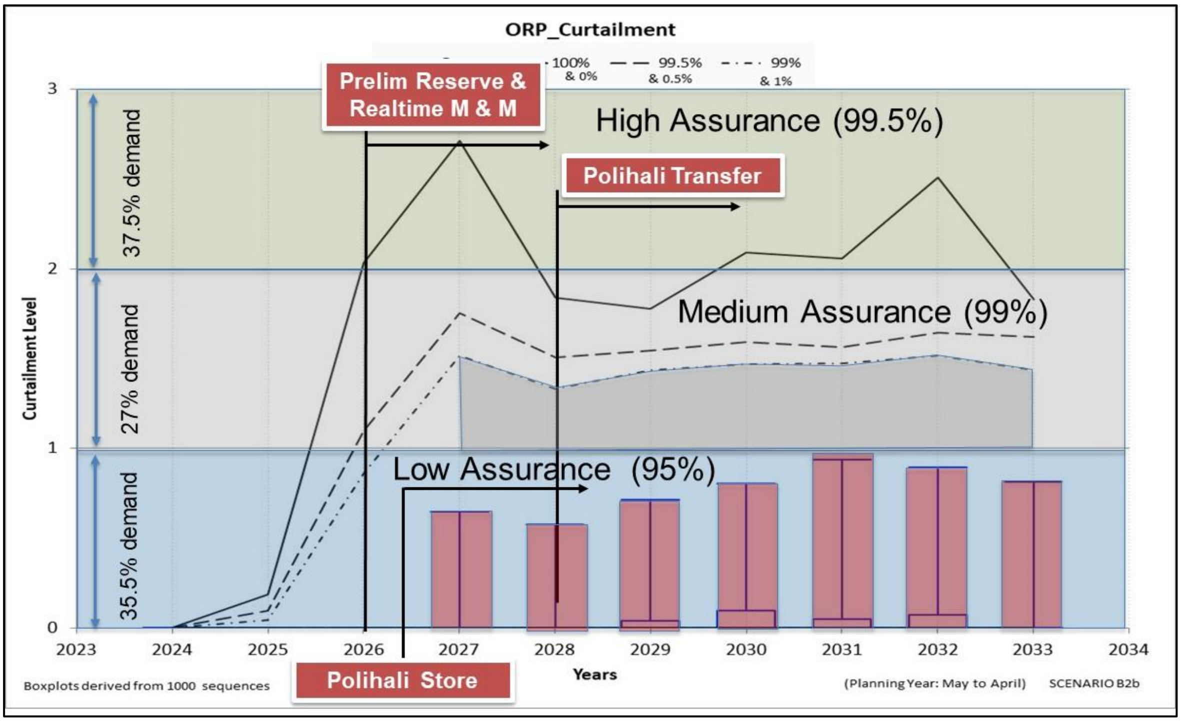


**Figure 3-3:ORP Curtailment plot 2024/25 operating year (Base 2b Scenario)**

A summary of the demand projection for the Namibia water requirements along the Lower Orange River, as obtained from the five studies, is given in Table 3-2. The expected date for the Haib Mine water abstraction to start was given as 2010 in the LORMS study and was moved forward in each study. For the Orange AOA 2024 study, it was given as 2027.

**Table 3-2: Namibia projected water requirements along the Lower Orange from different studies**

| Year | Mine | year and projected demand million m³/a | | | | | | |
|---|---|---|---|---|---|---|---|---|
| LORMS Study | | | | | | | | |
| 2005 | | **2005** | **2010** | **2020** | **2025** | | | |
| | Haib | - | 15.00 | 30.00 | 30.00 | | | |
| | Skorpion | 4.70 | 4.70 | 4.70 | 4.70 | | | |
| | Rosh Pinah | 0.88 | 0.95 | 1.04 | 1.19 | | | |
| | Namdeb Auchas & Daberas | 0.99 | 1.06 | 1.24 | 1.33 | | | |
| | Kudu Gas Power | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| | **Total** | **7.07** | **22.21** | **37.48** | **37.72** | | | |
| | | | | | | | | |
| **Orange Recon Study** | | **2012** | **2015** | **2020** | **2025** | **2030** | **2040** | |
| 2014 | Haib | 0 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | |
| | Rosh Pinah, Auchas & Skorpion | 7.64 | 7.75 | 7.97 | 8.22 | 8.47 | 8.98 | |
| | **Total** | **7.64** | **10.75** | **10.97** | **11.22** | **11.47** | **11.98** | |
| | | | | | | | | |
| **ORASECOM IWRMP Study** | | **2012** | **2018** | **2022** | **2025** | **2030** | **2040** | **2050** |
| 2020 | Haib | 0 | 0 | 6 | 6 | 6 | 6 | 6 |
| | Skorpion | 4.7 | 1.88 | 0 | 0 | 0 | 0 | 0 |
| | Rosh Pinah | 0.98 | 1.07 | 1.14 | 1.19 | 0 | 0 | 0 |
| | Namdeb Auchas & Daberas | 1.1 | 1.2 | 1.24 | 0 | 0 | 0 | 0 |
| | Kudu Gas Power | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | **Total** | **7.28** | **4.65** | **8.88** | **7.69** | **6.5** | **6.5** | **6.5** |
| **NVD Study** | | | | | | | | |
| 2020 | | **2015** | **2020** | **2030** | **2040** | **2050** | | |
| | All Namibia mines u.s of NVD dam | 1.2 | 4.0 | 9.8 | 15.0 | 20.8 | | |
| | All Namibia mines d.s of NVD dam | 21.2 | 21.7 | 22.7 | 23.7 | 24.7 | | |
| | **Total** | **22.4** | **25.7** | **32.5** | **38.7** | **45.5** | | |
| | | | | | | | | |
| **Orange AOA 2024 Study** | | **2024** | **2027** | **2030** | **2040** | **2050** | | |
| 2024 | Haib | 0 | 6 | 6 | 6 | 6 | | |
| | Rosh Pinah, Auchas & Skorpion | 1.89 | 5.28 | 5.36 | 5.52 | 5.66 | | |
| | Mine domestic Rosh Pinah Skorpion Oranjemund | 7.25 | 7.46 | 8.78 | 9.76 | 10.14 | | |
| | **Total** | **9.14** | **18.74** | **20.14** | **21.28** | **21.8** | | |

# 4.0 HAIB WATER DEMAND: IMPACT ON THE ORP

For the first phase of the analysis, only historic flow sequences were considered using the WRPM. This covers historic flows for the period 1920 to 2004. The water requirements and water infrastructure development will, for the entire period, be at a constant development level of 2024 for the initial scenarios.

The WRPM system setup used for this analysis includes the entire Orange, Senqu and Vaal River catchments. This system thus includes the total Lesotho, Molopo and Nossob catchments in Botswana, the Lower Orange, the Fish River and Nossob River in Namibia and a large portion of the RSA, which includes the Orange, Molopo, Vaal River and all related tributaries. This WRPM data set was originally prepared as part of the ORASECOM Phase III study and again updated as part of the 2024 and 2025 ORASECOM EWR study.

The scenarios that were proposed to be analysed for the purpose of this study are discussed in Section 4-1.

## 4.1 WRPM Scenario Descriptions

### 4.1.1 Initial Scenarios

The following scenarios were agreed on to analyse for this study.

**Base Scenario 1:**

This scenario serves as the base reference for scenarios 1 and 2 to be able to measure the difference in water supply to users, dam levels, river flow, etc., of this Base Scenario against the other proposed scenarios. This enabled the modeller to identify the impacts the additional water abstraction for Haib mine has on the system and existing users. The latest Preliminary Reserve, as determined by the RSA DWS in 2017, was included in the WRMP set up to represent the environmental requirements (EWR) at Sendelingsdrift that also support the EWR for the estuary.

The current system setup was configured for the 2024 development level. This refers to the existing water resource-related infrastructure in place in 2024 and the water requirements imposed on the entire system in 2024. Abstraction for Haib Mine is excluded. This scenario was used as a base to compare against results from Scenario 1, 1b and Scenario 2, & 2b.

**Scenario 1:**

Scenario 1 is as Base Scenario 1 with the following changes:

- Direct river abstraction by Haib Mine in combination with a small balancing dam to supply water to Haib Mine, supported by releases from Vanderkloof Dam.
- Water is abstracted continuously as required by the mine, considering an annual abstraction of 20 million $m^3$/a.

The purpose of this scenario is to determine the impact on upstream and downstream users when water is abstracted for Haib Mine constantly, directly from the Orange River. The level of water supply to the Haib Mine is also determined.

**Scenario 1b:**

Scenario 1b is as Scenario 1, with the only difference that the annual abstraction is decreased to only 6 million $m^3$/a. This represents the typical water requirement during the construction period of the mine.

The purpose of this scenario is to determine the impact on upstream and downstream users when water is abstracted for Haib Mine during the construction period, directly from the Orange River and supported by releases from Vanderkloof Dam. The level of water supply to the Haib Mine is also determined.

**Scenario 2:**

Scenario 2 is as the Base Scenario 1 with the following changes:

- Direct river abstraction in combination with an off-channel storage dam to supply water to Haib Mine without support from Vanderkloof Dam.
- The Haib Mine water requirement of 20 million $m^3/a$ will be imposed on the off-channel storage dam.
- These river abstractions are limited to taking place only in months when the flow in the river is higher than the required flow for supply to downstream users.

The purpose of this scenario is to determine the reduced impact on upstream and downstream users when water is abstracted for Haib Mine only when there is surplus flow available in the Orange River. The scenario answers the following questions.

- How does this impact compare with that of Scenario 1?
- Can the existing users still be supplied at the same level as determined for Base Scenario 1?
- What are the ballpark numbers for the storage required and the river abstraction capacity?
- How well is Haib Mine supplied with water, based on this option?

**Scenario 2b:**

Scenario 2b is as Scenario 2 with the following changes.

- A requirement of 14 million $m^3/a$ will be imposed on the off-channel storage dam.
- An additional annual abstraction of 6 million $m^3/a$ will be taken directly from the Orange River and will be supported through releases from Vanderkloof Dam.

It should be noted that the abstractions to fill the off-channel storage are limited taking place only in months when the flow in the river is higher than the required flow for supply to downstream users. Thus, no support from Vanderkloof for these abstractions.

This Scenario represents a combination of Scenario 2 and Scenario 1b.

The purpose of this scenario is to determine the impact on upstream and downstream users when water is abstracted for Haib Mine only when there is surplus flow available in the Orange River to support a demand of 14 million $m^3/a$ in combination with a 6 million $m^3/a$ directly from the Orange River that is supported from Vanderkloof Dam.

**Base Scenario 2**

This scenario includes the near-future developments that will significantly impact the water supply downstream of the Gariep and Vanderkloof dams. This scenario results in a deficit in the Orange River Project (ORP) water supply. Intervention options, as identified in the RSA Reconciliation strategy, that can be put in place in a relatively short time, are included to decrease the expected deficit. This includes real-time monitoring and modelling of the river downstream of the Vanderkloof and Bloemhof dams. The near future developments include the following:

- Polihali Dam and the tunnel to Katse Dam. The related increased volume to be transferred to the Vaal River System will form part of the analysis.
- Transfer water from the Gariep Dam to the Greater Bloemfontein area, including the improvements in the Greater Bloemfontein water supply system.

- Neckartal Dam irrigation and hydro-power generation are in place.
- Haib mine abstraction is not active.
- Water requirements at the 2035 development level.

The purpose of this scenario was to look at the water balance in the near future when some of the planned water resource developments are in place, as given above. This option will be used as a basis to compare against the Scenario 3 results.

**Scenario 3**

Scenario 3 will be as the Base Scenario 2 with the following changes:

- Direct abstraction from the Orange River in combination with an off-channel storage dam to supply water to Haib Mine without support from Vanderkloof Dam.
- These abstractions are limited to taking place only in months when the flow in the river is higher than the required flow for supply to downstream users.

The purpose of this scenario is to determine the impact at the 2035 development level, with Polihali Dam included, on upstream and downstream users when water is abstracted for Haib Mine only when there is surplus flow available in the Orange River. The scenario answers the following questions:

- How does this impact compare with that of Scenario 2?
- Can the existing users still be supplied at the same level as determined for Base Scenario 2?
- What are the ballpark numbers for the storage required and the river abstraction capacity?
- How well is Haib Mine supplied with water based on this option?

**Scenario 3e**

Scenario 3e is as Scenario 3 with the following changes:

- A requirement of 14 million $m^3/a$ will be imposed on the off-channel storage dam.
- An additional annual abstraction of 6 million $m^3/a$ will be taken directly from the Orange River and will be supported through releases from Vanderkloof Dam.

It should be noted that the abstractions to fill the off-channel storage are limited taking place only in months when the flow in the river is higher than the required flow for supply to downstream users. Thus, no support from Vanderkloof for these abstractions.

Scenario 3e is similar to Scenario 2b, with the only difference that Scenario 3e is at the 2035 development level while Scenario 2b is at the 2024 development level.

The purpose of this scenario is to determine the impact on upstream and downstream users when water is abstracted for Haib Mine only when there is surplus flow available in the Orange River to support a demand of 14 million $m^3/a$ in combination with a 6 million $m^3/a$ directly from the Orange River that is supported from Vanderkloof Dam.

**Scenario 3f**

Scenario 3f is as Scenario 3e with the following change:

- The characteristics of the off-channel storage dam. As no information was initially available on the actual off-channel dam characteristics, a typical dummy dam, normally used to simulate a combination of farm dams, was used for this purpose. The actual surveyed dam storage characteristics for an off-channel storage dam at Haib were received almost at the end of the analyses and were therefore only included in Scenario 3f as one of the sensitivity analyses that was carried out.

### 4.1.2 Follow up Scenarios in Support of Design Work

The following scenarios were agreed on to analyse in support of the design work.

**The improvement of existing scenarios.**

- Scenario 2 as described in Section 4.1.1:
  - Direct river abstraction in combination with an off-channel storage dam to supply water to Haib Mine without support from Vanderkloof Dam.
  - The Haib Mine water requirement of 20 million m$^3$/a will be imposed on the off-channel storage dam.
  - These river abstractions are limited to taking place only in months when the flow in the river is higher than the required flow for supply to downstream users.
  - The only difference with the initial Scenario 2 analysis is that the actual surveyed characteristics of the off-channel storage dam will be used.
  - A sensitivity analysis will be carried out using different possible abstraction rates.
  - The purpose of this scenario is to determine the difference in results between the initial analysis and the analysis using the actual surveyed characteristics of the selected off-channel storage dam derived from the 2021 LiDAR survey data as well as the sensitivity of the off-channel storage dam size versus different abstraction rates.

- Scenario 3 as described in Section 4.1.1:
  - Direct abstraction from the Orange River in combination with an off-channel storage dam to supply water to Haib Mine without support from Vanderkloof Dam.
  - These abstractions are limited to taking place only in months when the flow in the river is higher than the required flow for supply to downstream users.
  - The only difference with the initial Scenario 3 analysis is that the actual surveyed characteristics of the off-channel storage dam will be used.
  - Sensitivity analysis will be carried out using different possible abstraction rates.
  - The purpose of this scenario is to determine the difference in results between the initial analysis and the analysis using the actual surveyed characteristics of the off-channel storage dam derived from the 2021 LiDAR survey data as well as the sensitivity of the off-channel storage dam size versus different abstraction rates.

**New Scenarios to analyse.**

- **Scenario 3g2:**
  - Direct abstraction from the Orange River in combination with an off-channel storage dam to supply water to Haib Mine without support from Vanderkloof Dam.
  - These abstractions are limited to taking place only in months when the flow in the river is higher than the required flow for supply to downstream users.
  - Using the actual surveyed characteristics of the off-channel storage dam will be used.
  - A 6 million m$^3$/a abstraction from peak flows in combination with an off-channel storage at Haib Mine.
  - This scenario is similar to Base Scenario 2 and thus includes:
    - Polihali Dam and the tunnel to Katse Dam. The related increased volume to be transferred to the Vaal River System will form part of the analysis.
    - Transfer water from the Gariep Dam to the Greater Bloemfontein area, including the improvements in the Greater Bloemfontein water supply system.
    - Neckartal Dam irrigation and hydro-power generation are in place.
    - Haib mine abstraction is not active.

    - Water requirements at the 2035 development level.
  - The purpose of this scenario is to determine the impact on upstream and downstream users when water is abstracted for Haib Mine only when there is surplus flow available in the Orange River to support a demand of 6 million m$^3$/a. Secondly to determine the abstraction rate from the Orange and the related size of the off-channel storage dam.

- **Base Scenario 3:**
  - This scenario is as Base Scenario 2 (see Section 4.1.1) with water requirements at 2035 development level, but with Noordoewer-Vioolsdrift and Verbeeldingskraal dams in place, with no abstraction for Haib Mine. The purpose of Noordoewer-Vioolsdrift and Verbeeldingskraal dams is to re-balance the Orange River Project (ORP).
  - The purpose of this scenario is to prepare a Base Scenario in which the ORP is in balance again and the Noordoewer-Vioolsdrift Dam is in place so that it can be used to support the Haib Mine water requirements.

- **Scenario 4:**
  - Scenario 4 is as Base Scenario 3 but with a 6 million m$^3$/a continuous abstraction by Haib Mine supported from the Noordoewer-Vioolsdrift Dam.
  - The storage capacity of the Noordoewer-Vioolsdrift Dam used for this option is 2 800 million m$^3$.
  - The total demand imposed on the Noordoewer-Vioolsdrift Dam includes:
    - 185 million m$^3$/a for Namibia users
    - 112 million m$^3$/a for RSA users
    - Supporting the downstream EWR (± 290 million m$^3$/a)
    - Supplying River Requirements (121 million m$^3$/a)
  - The purpose of this scenario is to determine the impact on Noordoewer-Vioolsdrift Dam, the ORP and the other users when 6 million m$^3$/a continuous abstraction by Haib Mine is taken from the Noordoewer-Vioolsdrift Dam. The Haib demand of 6 Mm$^3$/a corresponds with the demand values assessed in the 2020 Feasibility Study of the NVD as well as two 2024 assessments into the Orange River System

- **Scenario 5:**
  - Scenario 5 is as Scenario 4 with the only difference that a 20 million m$^3$/a continuous abstraction by Haib Mine will be supported from the Noordoewer-Vioolsdrift Dam.
  - The purpose of this scenario is to determine the impact on Noordoewer-Vioolsdrift Dam, the ORP and the other users when 20 million m$^3$/a continuous abstraction by Haib Mine is taken from the Noordoewer-Vioolsdrift Dam.

**Stochastic analysis of selected scenarios:**

A stochastic system analysis is undertaken based on stochastically generated natural streamflow sequences. The main advantage of a stochastic system analysis is that it includes the assurances of supply to users from the system as well as the reliability of the resource. The following scenarios will be analysed using a 251 stochastic flow sequences.

- Base Scenario 2
- Scenario 3
- Scenario 3g2
- Base Scenario 3
- Scenario 4
- Scenario 5

## 4.2 WRPM Scenario Results from Initial Analyses

### 4.2.1 Base Scenario 1

Over the 85-year analysis period at the 2024 development level, 7 years required restrictions to protect the resource from total failure (dams running empty). Only in 1933 was it required to restrict all the water use at the lower assurance level and some at the medium assurance level. For the remaining 6 years, only the low-assurance water use required restrictions from as high as 32% to as little as 1%. More frequent restrictions than 4 to 5 years over an 85-year period on the low assurance use would not be expected, while these were found to occur in 7 years. This shows that the system is at the 2024 development level, already slightly over-utilised.

### 4.2.2 Scenario 1 and Scenario 2 – 2024 Development Level

For Scenario 1, a 20 million $m^3$/a abstraction directly from the Orange River was included for Haib Mine. This demand was considered to be part of the total demand to be supplied from the Gariep and Vanderkloof dams, also known as the Orange River Project (ORP). An equal monthly distribution was assumed for the abstraction.

Scenario 1b is as Scenario 1 but with the abstraction for Haib Mine reduced to only 6 million $m^3$/a. Due to the significantly reduced Haib Mine abstraction for Scenario 1b, the average water supply to Haib improved to 100% overall, as well as 100 % for the worst year, as compared to Scenario 1 (See Table 4-1). Abstracting only 6 million $m^3$/a for Haib Mine had a very small impact on the other users from the ORP.

In the case of Scenario 2, the 20 million $m^3$/a requirement for Haib Mine was not considered to be part of the demand imposed on the ORP. No water will thus be released from Vanderkloof Dam in support of Haib Mine. Haib Mine can, for this scenario only, abstract water from the Orange River when there is surplus water available in the river due to spills from the Vaal River, local runoff that was generated and additional releases or spills from Vanderkloof Dam. As surplus flows are not always available, the Scenario 2 option requires an off-channel storage dam to store the surplus water. From the analysis results, it was shown that an off-channel storage capacity of about 35 million $m^3$/a in combination with a 1.8 $m^3$/s diversion pump capacity from the Orange River should be sufficient to supply Haib Mine with a 20 million $m^3$/a requirement. Approximately 35.5 million $m^3$/a was pumped on average into the off-channel storage dam, of which about 18% was from Orange River surplus flows and 82% from the Vaal inflows and incremental runoff. Further optimisations of the diversion pump capacity versus the storage capacity may still be possible. A larger pump capacity will require less storage; for example, a 2 $m^3$/s diversion pump capacity will require an off-channel storage capacity of about 25 million $m^3$. For this scenario, the Haib abstraction should not negatively impact the water supply to existing users, as the abstraction for Haib does not form part of the total demand imposed on the ORP for Scenario 2. The restrictions imposed on the ORP system users, therefore, do not directly impact the Haib Mine abstraction.

Scenario 2b is a combination of Scenario 1b and Scenario 2, where 6 million $m^3$/a is supplied from Vanderkloof Dam to Haib mine, with 14 million $m^3$/a supplied from the off-channel storage dam at Haib mine, which is filled from surplus water when available in the river. An off-channel storage capacity of 35 million $m^3$/a in combination with a 1.07 $m^3$/s diversion pump capacity from the Orange was able to supply the 14.14 million $m^3$/a to Haib Mine. Approximately 28.3 million $m^3$/a was pumped on average into the off-channel storage dam, of which about 19% was from Orange River surplus flows and 81% from the Vaal inflows and incremental runoff.

A comparison of the average system supply over the 85 years for the Base 1 Scenario, Scenario 1, Scenario 1b, Scenario 2 and Scenario 2b is given in Table 4-1.

**Table 4-1: Average annual system supply comparison (2024)**

| Description | Base 1 million $m^3/a$ | Scenario 1 million $m^3/a$ | Scenario 1b million $m^3/a$ | Scenario 2 million $m^3/a$ | Scenario 2b million $m^3/a$ |
|---|---|---|---|---|---|
| Total ORP system demand | 3,455.93 | 3,475.93 | 3,461.93 | 3,455.93 | 3,461.93 |
| Total average ORP system supply | 3,394.11 | 3,408.19 | 3,396.86 | 3,394.11 | 3,398.34 |
| Percentage average ORP system supply | 98.21% | 98.05% | 98.12% | 98.21% | 98.16% |
| Worst year ORP system sypply | 64.00% | 63.00% | 64.00% | 64.00% | 64.00% |
| Haib Demand | 0 | 20 | 6 | 20 | 20 |
| Haib supply | 0 | 19.84 | 6 | 20 | 19.96 |
| Percentage Haib average supply | - | 99.21% | 100% | 100% | 99.82% |
| Worst year system sypply | - | 79.96% | 100% | 100% | 94.31% |

**Table 4-2: Total ORP system 2024 demand (million m$^3$/a) allocated at selected assurance levels**

| Scenario | Total demand as allocated to different assurance levels | | | |
|---|---|---|---|---|
| **Base 1** | Low assurance | 1 in 20 year | | 1,231.57 |
| | Medium assurance | 1 in 100 year | | 934.20 |
| | High assurace | 1 in 200 year | | 1,290.16 |
| | **Total demand** | | | **3,455.93** |
| **Scenario 1** | Low assurance | 1 in 20 year | | 1,238.70 |
| | Medium assurance | 1 in 100 year | | 939.61 |
| | High assurace | 1 in 200 year | | 1,297.62 |
| | **Total demand** | | | **3,475.93** |
| **Scenario 1b** | Low assurance | 1 in 20 year | | 1,230.69 |
| | Medium assurance | 1 in 100 year | | 936.49 |
| | High assurace | 1 in 200 year | | 1,294.75 |
| | **Total demand** | | | **3,461.93** |
| **Scenario 2** | Low assurance | 1 in 20 year | | 1,231.57 |
| | Medium assurance | 1 in 100 year | | 934.20 |
| | High assurace | 1 in 200 year | | 1,290.16 |
| | **Sub-total demand** | | | **3,455.93** |
| | Haib Mine * | ± 1 in 100 year | | 20.00 |
| | **Total demand** | | | **3,475.93** |
| **Scenario 2b** | Low assurance | 1 in 20 year | | 1,230.69 |
| | Medium assurance | 1 in 100 year | | 936.49 |
| | High assurace | 1 in 200 year | | 1,294.75 |
| | **Sub-total demand** | | | **3,461.93** |
| | Haib Mine ** | ± 1 in 100 year | | 14.00 |
| | **Total demand** | | | **3,475.93** |

*Note * - For Scenario 2, the Haib Mine water requirement is not part of the ORP total demand.*
*** - For Scenario 2b, 14 million m$^3$/a of the total 20 million m$^3$/a Haib water requirement is not part of the ORP total demand.*

As indicated in Section 3 in Table 3-1the water users within the ORP system are supplied at different assurance levels. Table 4-2provides a summary of the total water requirement imposed on the ORP as allocated to the different assurance levels. The Base 1 Scenario still excludes the Hiab Mine water requirement, and the total demand is thus 20 million m$^3$/a, less than the total demand shown for Scenario 1 and Scenario 2 and 6 million m$^3$/a less than the total demand shown for Scenario 1b and 2b.

It is important to note that the Haib Mine water requirement for Scenario 2 does not form part of the ORP system as it is supplied separately through surplus flows in the system, when available. The total demand imposed on the ORP system for Scenario 2 is thus the same as for the Base 1 Scenario. For Scenario 2b, 14 million m$^3$/a of the total 20 million m$^3$/a Haib water requirement is not part of the ORP demand.

As the ORP System is already slightly overloaded, restrictions within the ORP System are already taking place more often than they should. For the Base 1 Scenario, restrictions for the low assurance users took place in 7 out of the 85 years, while it should occur on average less than 4 to 5 times over 100 years (See Table 4-3) based on the required assurance of supply.

**Table 4-3: Years when restrictions were required for the ORP System and the related severity of the restrictions (2024 development level)**

| Years | % Supplied | | | | | % Restriction | | | | | Supply volume reduction (million $m^3/a$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base 1 | Scenario 1 | Scenario 1b | Scenario 2* | Scenario 2b+ | Base 1 | Scenario 1 | Scenario 1b | Scenario 2* | Scenario 2b+ | Base 1 | Scenario 1 | Scenario 1b | Scenario 2* | Scenario 2b+ |
| | 91% | 88% | 89% | 91% | 90% | 9% | 12% | 11% | 9% | 10.3% | 327 | 429 | 381 | 327 | 357 |
| **1933** | 64% | 63% | 64% | 64% | 64% | 36% | 37% | 36% | 36% | 36.3% | 1,244 | 1,301 | 1,262 | 1,244 | 1,258 |
| **1947** | 100% | 98% | 98% | 100% | 99% | 0% | 2% | 2% | 0% | 0.8% | 8 | 70 | 53 | 8 | 26 |
| **1970** | 68% | 64% | 66% | 68% | 66% | 32% | 36% | 34% | 32% | 33.6% | 1,119 | 1,240 | 1,188 | 1,119 | 1,162 |
| **1971** | 95% | 94% | 94% | 95% | 95% | 5% | 6% | 6% | 5% | 5.0% | 170 | 196 | 191 | 170 | 174 |
| **1984** | 100% | 100% | 100% | 100% | 100% | 0% | 0.2% | 0.0% | 0% | 0.0% | 0 | 8 | 0 | 0 | 0 |
| **1985** | 78% | 73% | 76% | 78% | 77% | 22% | 27% | 24% | 22% | 23.2% | 755 | 934 | 832 | 755 | 804 |
| **1986** | 97% | 96% | 96% | 97% | 97% | 3% | 4% | 4% | 3% | 3.1% | 98 | 123 | 123 | 98 | 106 |
| **1987** | 99% | 98% | 98% | 99% | 98% | 1% | 2% | 2% | 1% | 1.5% | 44 | 70 | 64 | 44 | 52 |
| **Average** | **88%** | **86%** | **87%** | **88%** | **87%** | **12%** | **14%** | **13%** | **12%** | **12.6%** | **418** | **486** | **455** | **418** | **438** |

*Note * - For Scenario 2, the Haib Mine water requirement is not part of the ORP total demand and was always over the 85 years 100% supplied. Restrictions imposed on the ORP system had thus no effect on the Haib Mine supply.*
*+ - For Scenario 2b, 14 of the 20 million $m^3/a$ Haib Mine water requirement is not part of the ORP and was always over the 85 years 100% supplied.*

When the Haib Mine demand is added to the total demand imposed on the ORP System (Scenario 1, 1b and 2b), it is evident from Table 4-3 that the number of restrictions now increases to 9 times over the 85-year analysis period. The severity of the restrictions is, however, less for Scenario 1b. The restriction on all users is now also more severe than that for Base Scenario 1 (2024 development conditions).

For Scenario 2, where the Haib Mine is not part of the ORP system, thus no releases are made from the ORP system in support of Haib Mine, the restrictions within the ORP system remain the same as for the Base 1 Scenario. This shows that for Scenario 2, the Haib Mine abstraction will have no or a negligible impact on the existing users when the system is managed well.

The slight reduction in supply to typical downstream users, in this case for Alexander Bay, for Scenario 1 when the Haib Mine requirement is included, is clearly shown in Figure 4-1. The reduction in supply to Alexander Bay is, however, relatively small and even smaller when considering Scenario 1b.

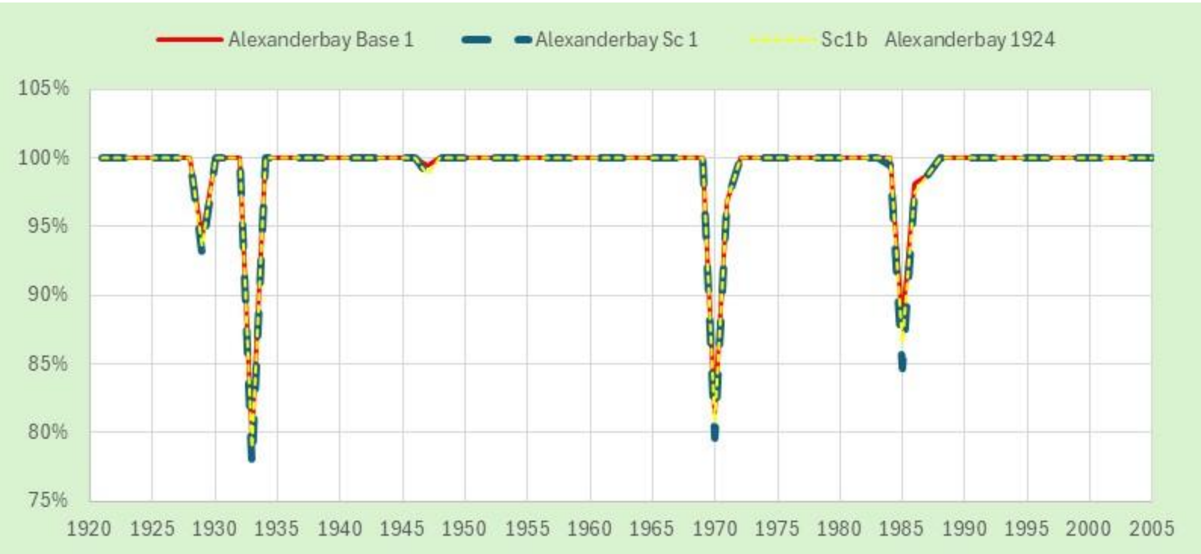


**Figure 4-1:Alexander Bay water supply comparison of the Base 1 Scenario versus Scenario 1.**

The water supply to Haib Mine improves significantly when the off-channel storage dam option is used (Scenario 2) versus no off-channel storage dam (Scenario 1), as shown in Figure 4-2

Considering the small abstraction of only 6 million m$^3$/a with no off-channel storage dam (Scenario 1b) Haib Mine supply also improved significantly from Scenario 1, similar to that of Scenario 2.

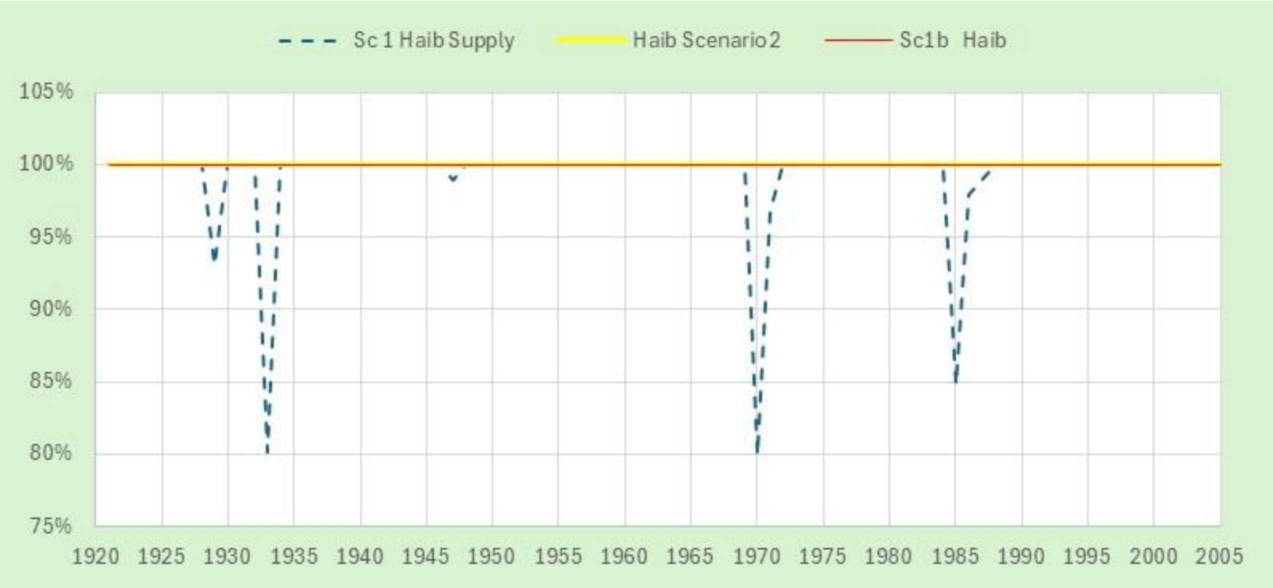


**Figure 4-2:Scenario 1 Haib water supply versus Scenario 2 & 1b Haib water supply**

For Scenario 2, the required pumping of surplus flows into the Haib Mine off-channel storage dam is shown in Figure 4-3 requiring a maximum pumping capacity of 1.8 m$^3$/s with an average pumping rate of 1.10 m$^3$/s over the 85-year analysis period. The detailed monthly pumping sequence is given in Appendix A, Table A-1.

For Scenario 2b, the required maximum pumping capacity is reduced to 1.07 m$^3$/s with an average pumping rate of 0.89 m$^3$/s over the 85-year analysis period. The detailed monthly pumping sequence is given in Appendix A, Table A-2.

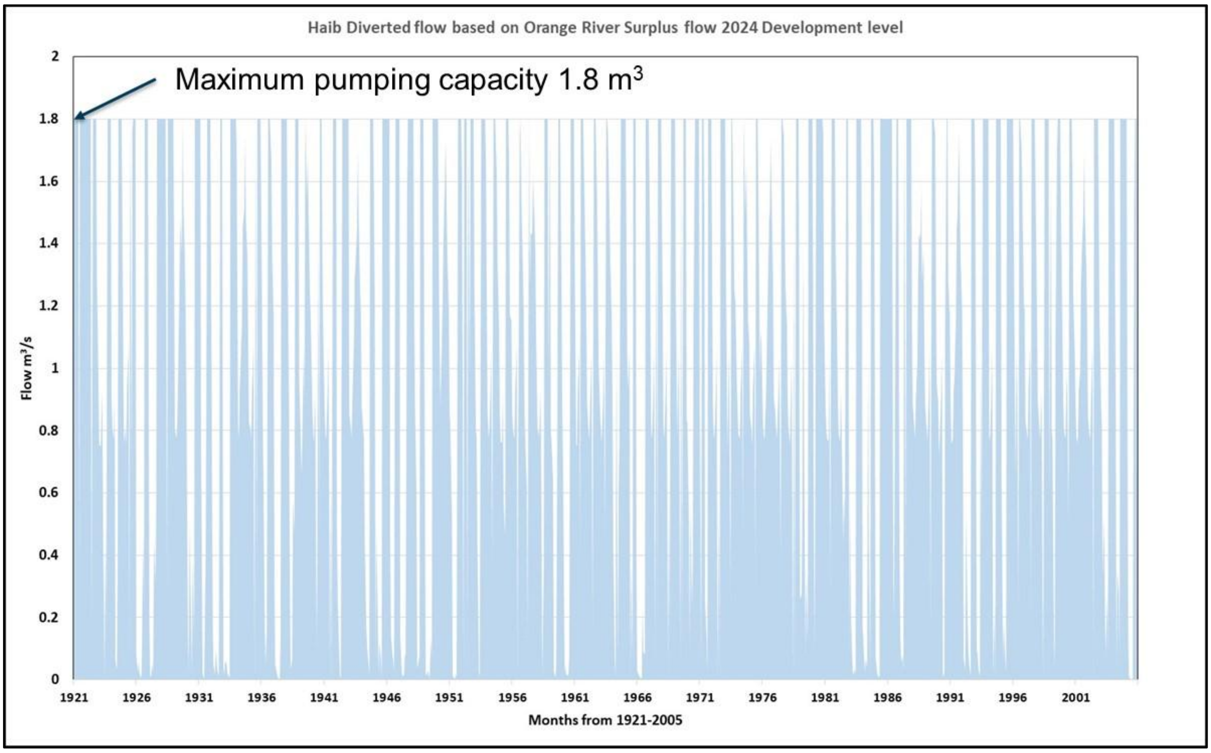


**Figure 4-3: Scenario 2 – Pumped inflow into the off-channel storage**

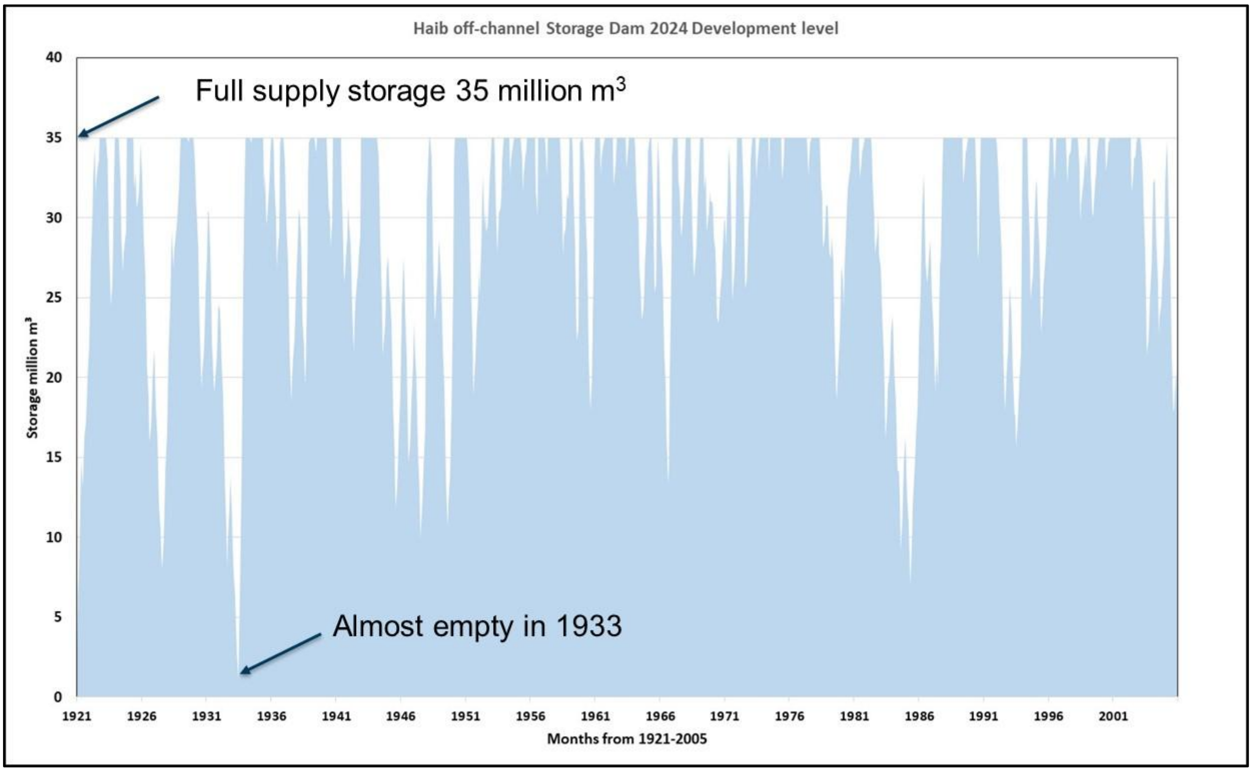


**Figure 4-4: Scenario 2 – Haib Mine off-channel dam storage over the simulation period**

A storage capacity of 35 million m$^3$ was required for Scenario 2 to ensure a 100% supply of 20 million m$^3$/a to Haib Mine over the analysis period of 85 years (See Figure 4-4). If a reduced capacity had been used, the dam would have failed in 1933 and not been able to fully supply the Haib Mine requirement.

### 4.2.3 Base Scenario 2 and Scenario 3 Results

The main differences between Base Scenario 2 and Base Scenario 1 are that:

- Base Scenario 2 is based on 2035 development-level demands imposed on the system.
- Base Scenario 1 is based on 2024 development-level demands imposed on the system.
- Base Scenario 2 includes the Polihali Dam.
- Base Scenario 1 excludes the Polihali Dam.

Polihali Dam is part of the Lesotho Highlands Water Project, delivering water to the Integrated Vaal River System. It is expected that the Polihali Dam will start to inundate water in 2026. When this happens, it means that water which previously entered Gariep and Vanderkloof dams from Lesotho will now be captured in Polihali Dam for transfers to the Integrated Vaal River System. This will impact negatively on the ORP by reducing the ORP yield by approximately 280 million $m^3$/a.

Only limited irrigation demand growth is allowed within the ORP system. This and normal growth in towns and mines resulted in a 3.2% or 111 million $m^3$/a increase in the total system demand from 2024 to 2035 (Table 4-2 and Table 4-4). The combined impact of the increase in demand and the effect of the Polihali Dam on the ORP resulted in restrictions being imposed on the system, much more frequently and to such an extent that the assurance of supply to users will be significantly compromised. The Base Scenario 1 analysis (2024 development level) showed that 7 out of the 85 years analysed required restrictions, while for Base Scenario 2 (2035 development level), a total of 31 years out of the 85 years (Table 4-6) required restrictions to be able to protect the resource from running empty. For the system to adhere to the given assurance of supply, it should not have more than 4 to 5 restrictions over the simulation period. The impact of the Polihali Dam and the increased demand is resulting in the users being supplied at much lower assurances than required.

Table 4-4 provides a summary of the total water requirement imposed on the ORP as allocated to the different assurance levels. The Base 2 Scenario still excludes the Hiab Mine water requirement, and the total demand is thus 20 million $m^3$/a, less than the total demand shown for Scenario 3. For Scenario 3, the Haib Mine abstraction of 20 million $m^3$/a is added, but not supplied by releases from Gariep and Vanderkloof dams. An off-channel storage dam is used to store water pumped from surplus flow in the Lower Orange. The surplus flow is due to Orange and Vaal River spills; irrigation return flows from the Lower Vaal River, and incremental flow generated in the Lower Vaal below Bloemhof Dam and incremental flow generated from the Orange River downstream of Vanderkloof Dam. The same dam size of 35 million $m^3$ and pumping rate of 1.8 $m^3$/s for the Haib off-channel storage dam was used for Scenario 3, as estimated from Scenario 2. This was found to be adequate for Scenario 3 as the Haib Mine demand was fully supplied over the analysis period (Table 4-5).

A similar volume as for Scenario 2 was pumped into the Haib off-channel storage dam of 35.1 million $m^3$/a on average. For Scenario 3, however, only 14.7% came from the surplus in the Orange, with 85.3% from the Vaal spills and local runoff. This is a result of the significant developments upstream of the Gariep and Vanderkloof dams.

Scenario 3, as for Scenario 2, only utilises surplus water in the system for the Haib Mine abstraction, and in both cases has no or negligible impact on the water supply to the other users when the system is operated well.

**Table 4-4: Total ORP system 2035 demand (million m³/a) allocated at selected assurance levels**

| Scenario | Total demand as allocated to different assurance levels | | |
|---|---|---|---|
| **Base 2** | Low assurance | 1 in 20 year | 1,285.32 |
| | Medium assurance | 1 in 100 year | 990.37 |
| | High assurace | 1 in 200 year | 1,291.77 |
| | **Total demand** | | **3,567.46** |
| **Scenario 3** | Low assurance | 1 in 20 year | 1,285.32 |
| | Medium assurance | 1 in 100 year | 990.37 |
| | High assurace | 1 in 200 year | 1,291.77 |
| | **Sub-total demand** | | **3,567.46** |
| | Haib Mine * | ± 1 in 100 year | 20.00 |
| | **Total demand** | | **3,587.46** |
| **Scenario 3e** | Low assurance | 1 in 20 year | 1,287.76 |
| | Medium assurance | 1 in 100 year | 992.00 |
| | High assurace | 1 in 200 year | 1,293.69 |
| | **Sub-total demand** | | **3,573.46** |
| | Haib Mine * | ± 1 in 100 year | 14.00 |
| | **Total demand** | | **3,587.46** |

Scenario 3e is a combination of Scenario 3 and Scenario 1b, as 6 million m³/a of the Haib requirements is supplied directly from Gariep and Vanderkloof dams, with the remaining 14 million m³/a utilising surplus water in the system, which is pumped into an off-channel storage dam near Haib Mine.

A maximum pumping rate of 1.03 m³/s for the Haib off-channel storage dam was found to be sufficient for this scenario. On average, 0.789 m³/s was pumped over the simulation period, of which 85.4% was from the Vaal and 14.6% from the Orange River flows.

A comparison of the average system supply over the 85 years for the Base 2 Scenario, Scenario 3 and Scenario 3e is given in Table 4-5.

**Table 4-5: Average annual system supply comparison (2035)**

| Description | Base 2 million m³/a | Scenario 3 million m³/a | Scenario 3e million m³/a |
|---|---|---|---|
| Total ORP system demand | 3,567.46 | 3,567.46 | 3,573.46 |
| Total average ORP system supply | 3,324.94 | 3,324.25 | 3,327.81 |
| Percentage average ORP system supply | 93.20% | 93.18% | 93.13% |
| Worst year ORP system sypply | 46.10% | 45.79% | 45.79% |
| Haib Demand | 0 | 20.00 | 20.00 |
| Haib supply | 0 | 20.00 | 19.79 |
| Percentage Haib average supply | - | 100% | 98.9% |
| Worst year system sypply | - | 100% | 90.4% |

From Table 4-5 it is evident that the average supply of 98.2% at the 2024 development level reduced to 93.2% at the 2035 development level, while the year with the worst supply (1933) reduced from 64% (2024 development level) to 46% (2035 development level) when comparing the two Base Scenarios.

Table 4-6 lists all the years within the 85-year analysis period which required restrictions for the Base 2 Scenario, Scenario 3 and Scenario 3e, as well as the related % restrictions and water supply for each of the years. The restrictions required for Base 2 Scenario, Scenario 3 and Scenario 3e are, for practical purposes, the same. The long-term average restriction difference between the Base 2 Scenario and Scenario 3 is only 0.1% but increases to 0.4% for Scenario 3e (Table 4-6), thus still a very small impact.

This is also evident from Figure 4-5 showing that the impact on the water supply to downstream users such as Alexander Bay remains the same with and without the 20 million m$^3$/a supply to Haib Mine. This is, however, under the condition that abstractions for Haib Mine only take place in times when there is surplus flow available in the Orange River, which is then stored in an off-channel storage dam. With the off-channel storage dam in place, supply to Haib Mine can be provided at a higher security than the supply received by the other users.

For Scenario 3e, where 6 of the 20 million m$^3$/a Haib requirements are supplied directly from Vanderkloof and Gariep dams, results confirmed (Figure 4-5) that the impact on the existing users for this scenario is very similar to that of Base 2 Scenario and Scenario 3. The water supply to Haib Mine for Scenario 3e is still good, however, not as good as for Scenario 3. Scenario 3e, however, has the advantage that less water needs to be pumped into the off-channel storage dam and that a smaller off-channel storage is required.

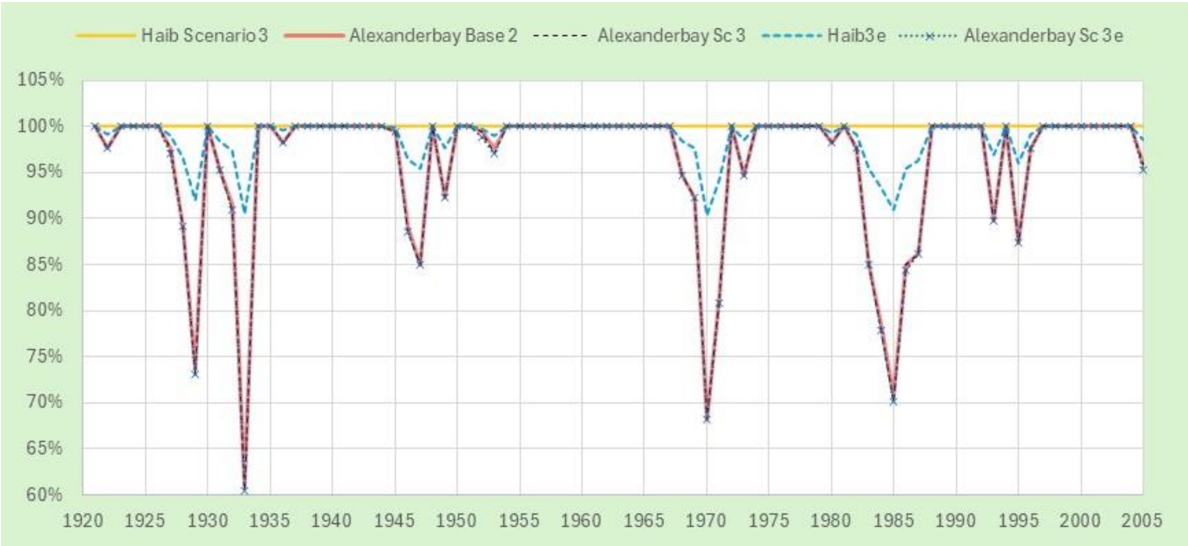


**Figure 4-5: Alexander Bay water supply comparison of the Base 2 Scenario versus Scenario 3 and Haib Mine supply for Scenario 3.**

**Table 4-6: Years when restrictions were required for the ORP System and the related severity of the restrictions (2035 development level)**

| Years | % Supplied | | | % Restriction | | | Supply volume reduction (million m$^3$/a) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Base 2 | Scenario 3 | Scenario 3e | Base 2 | Scenario 3 | Scenario 3e | Base 2 | Scenario 3 | Scenario 3e |
| 22 | 95.5% | 95.4% | 95.1% | 5% | 4.6% | 4.9% | 161 | 163 | 173 |
| 1927 | 95.2% | 95.0% | 94.6% | 5% | 5.0% | 5.4% | 171 | 180 | 192 |
| 1928 | 80.4% | 80.1% | 79.8% | 20% | 19.9% | 20.2% | 698 | 708 | 721 |
| 1929 | 57.9% | 57.9% | 57.5% | 42% | 42.1% | 42.5% | 1502 | 1502 | 1,520 |
| 1930 | 99.8% | 99.7% | 99.4% | 0% | 0.3% | 0.6% | 6 | 12 | 21 |
| 1931 | 91.0% | 90.9% | 90.6% | 9% | 9.1% | 9.4% | 320 | 326 | 336 |
| 1932 | 84.2% | 83.9% | 83.7% | 16% | 16.1% | 16.3% | 565 | 573 | 583 |
| 1933 | 46.1% | 46.1% | 45.7% | 54% | 53.9% | 54.3% | 1923 | 1923 | 1,940 |
| 1936 | 96.9% | 96.8% | 96.5% | 3% | 3.2% | 3.5% | 111 | 114 | 125 |
| 1945 | 99.1% | 99.0% | 98.7% | 1% | 1.0% | 1.3% | 33 | 37 | 48 |
| 1946 | 79.8% | 79.5% | 79.2% | 20% | 20.5% | 20.8% | 722 | 730 | 742 |
| 1947 | 73.3% | 73.0% | 72.8% | 27% | 27.0% | 27.2% | 954 | 962 | 973 |
| 1949 | 85.8% | 85.7% | 85.4% | 14% | 14.3% | 14.6% | 505 | 509 | 520 |
| 1952 | 98.5% | 98.3% | 98.0% | 1% | 1.7% | 2.0% | 52 | 59 | 71 |
| 1953 | 95.0% | 94.8% | 94.5% | 5% | 5.2% | 5.5% | 178 | 185 | 196 |
| 1968 | 90.4% | 90.3% | 90.0% | 10% | 9.7% | 10.0% | 342 | 344 | 356 |
| 1969 | 85.8% | 85.7% | 85.4% | 14% | 14.3% | 14.6% | 508 | 511 | 522 |
| 1970 | 53.2% | 53.2% | 52.8% | 47% | 46.8% | 47.2% | 1670 | 1670 | 1,686 |
| 1971 | 66.7% | 65.9% | 65.2% | 33% | 34.1% | 34.8% | 1188 | 1216 | 1,243 |
| 1973 | 89.7% | 90.1% | 89.9% | 10% | 9.9% | 10.1% | 369 | 354 | 362 |
| 1980 | 96.6% | 96.5% | 96.2% | 3% | 3.5% | 3.8% | 120 | 124 | 137 |
| 1982 | 95.6% | 95.4% | 95.0% | 4% | 4.6% | 5.0% | 157 | 165 | 177 |
| 1983 | 73.0% | 72.6% | 72.3% | 27% | 27.4% | 27.7% | 965 | 976 | 990 |
| 1984 | 62.2% | 62.2% | 61.7% | 38% | 37.8% | 38.3% | 1349 | 1349 | 1,368 |
| 1985 | 55.0% | 55.0% | 54.6% | 45% | 45.0% | 45.4% | 1605 | 1605 | 1,621 |
| 1986 | 72.5% | 72.3% | 72.0% | 28% | 27.7% | 28.0% | 983 | 989 | 1,000 |
| 1987 | 75.3% | 75.2% | 74.9% | 25% | 24.8% | 25.1% | 881 | 886 | 896 |
| 1993 | 81.7% | 81.6% | 81.3% | 18% | 18.4% | 18.7% | 652 | 656 | 670 |
| 1995 | 77.1% | 76.9% | 76.6% | 23% | 23.1% | 23.4% | 815 | 823 | 837 |
| 1996 | 95.3% | 95.2% | 95.0% | 5% | 4.8% | 5.0% | 169 | 171 | 180 |
| 2005 | 91.8% | 91.7% | 91.3% | 8% | 8.3% | 8.7% | 292 | 295 | 310 |
| **Average** | **81.9%** | **81.8%** | **81.5%** | **18.1%** | **18.2%** | **18.5%** | **644** | **649** | **662** |

For Scenario 3, the average pumping from the surplus water in the Orange River amounts to 1.11 m$^3$/s over the 85-year analysis period (See Figure 4-6). The storage projection for the off-channel storage dam for Scenario 3 is given in Figure 4-7, showing that with the 35 million m$^3$ gross storage, the dam almost emptied in 1933. The detailed monthly pumping for Scenario 3 is given in Appendix A Table A- 3.

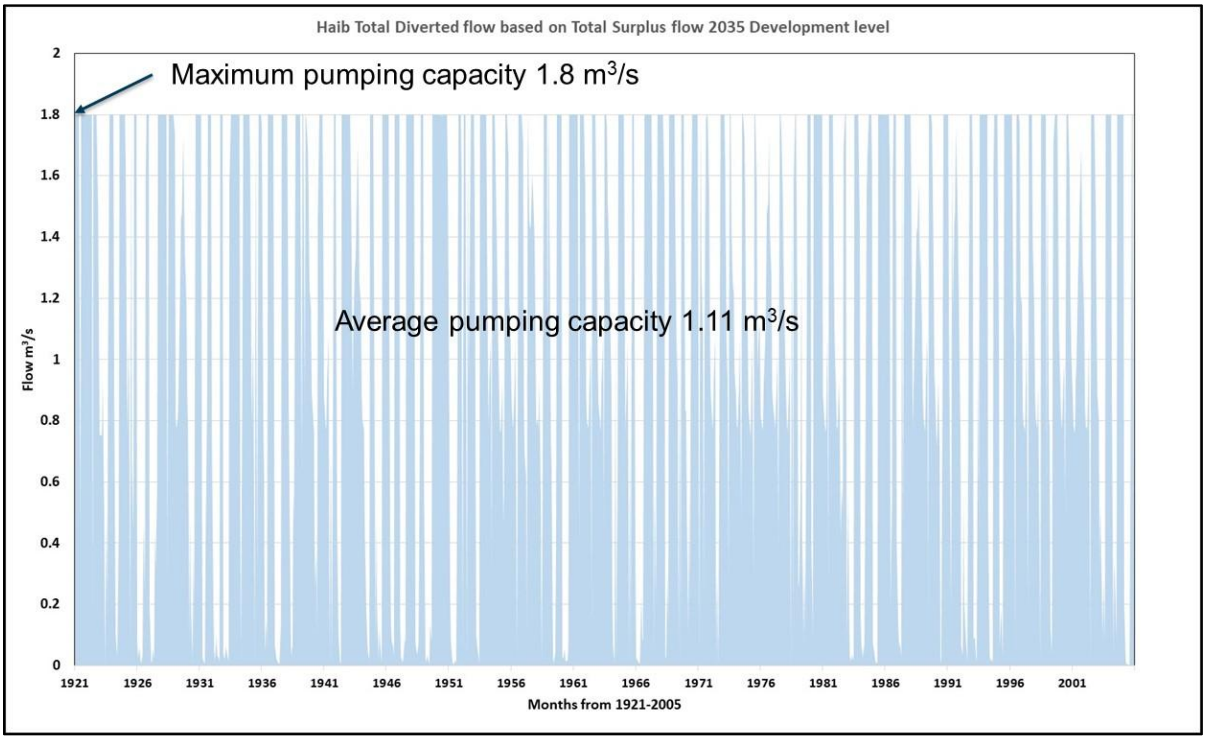


**Figure 4-6: Scenario 3 – Pumped inflow into the off-channel storage**

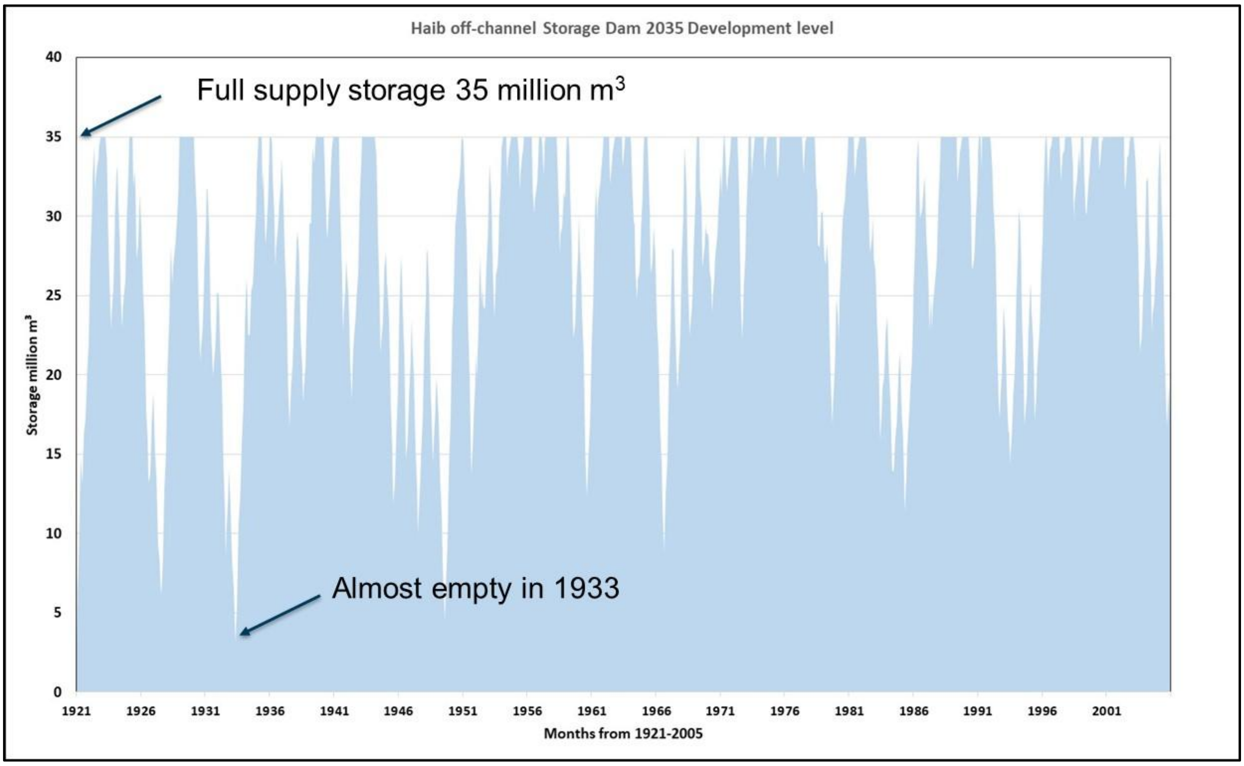


**Figure 4-7: Scenario 3 – Haib Mine off-channel dam storage over the simulation period**

The bulk of the pumped surplus water was obtained from the Vaal River inflows and incremental flows downstream of the Bloemhof and Vanderkloof dams. For Scenario 3, this represented 86% of the pumped inflows, while only 14% of the pumped surplus flows came from the surplus flow in the Orange River (Vaal contributions excluded).

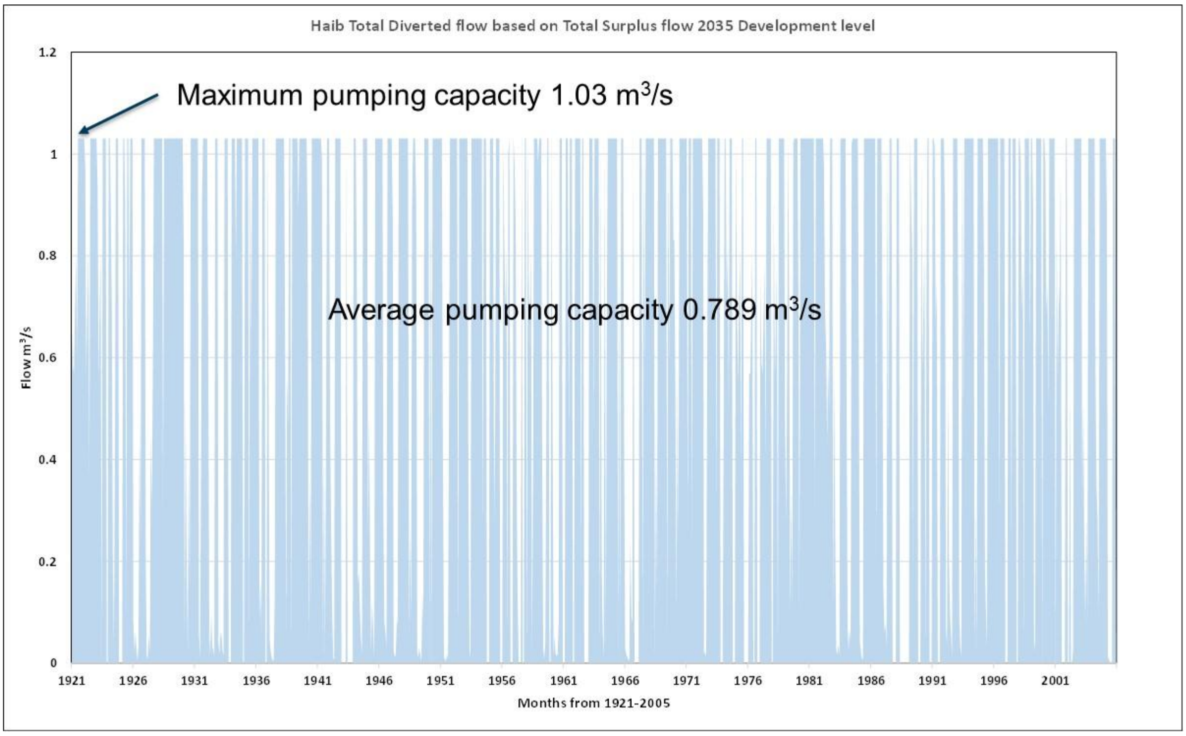


**Figure 4-8: Scenario 3e – Pumped inflow into the off-channel storage**

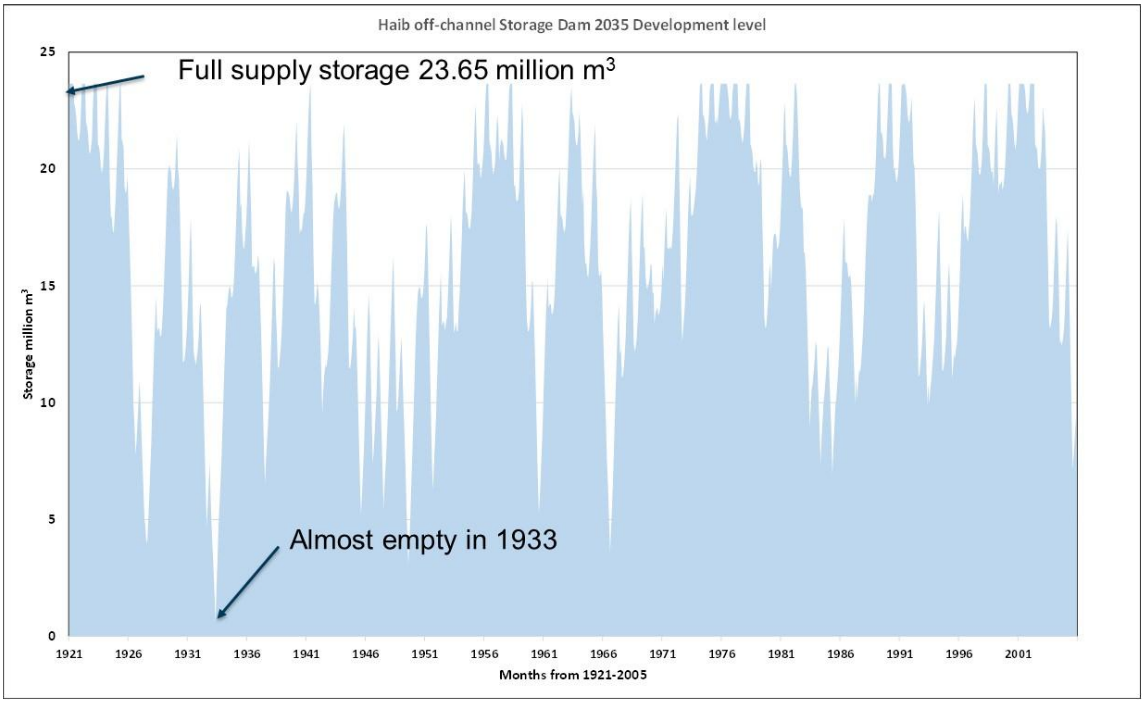


**Figure 4-9: Scenario 3e – Haib Mine off-channel dam storage over the simulation period**

For Scenario 3e, the average pumping from the surplus water in the Orange River amounts to 0.79 $m^3/s$ over the 85-year analysis period (See Figure 4-8). The monthly storage projection plot for the off-channel storage dam (Scenario 3e) is given in Figure 4-9. The most severe dry period occurred between Jun 1930 to June 2036 when the dam almost reached empty in September 1933.

The much lower average pumping and smaller off-channel storage required for Scenario 3e versus Scenario 3 is due to the 6 million $m^3/a$ supplied directly from Vanderkloof Dam, requiring only 14 million $m^3/a$ to be supplied from the off-channel storage dam.

For Scenario 3e, the bulk of the pumped surplus water was, similar to that of Scenario 3, obtained from the Vaal River inflows and incremental flows downstream of the Bloemhof and Vanderkloof dams. This represented 85% of the pumped inflows, while only 15% of the pumped surplus flows came from the surplus flow in the Orange River (Vaal contributions excluded). The detailed monthly pumping for Scenario 3e is given in Appendix A Table A-4.

The typical flows from the Vaal River contributions and downstream incremental flows contributing to the 2035 surplus flows available in the Lower Orange are given in Figure 4-10. The average of the Vaal River surplus flows over the analysis period amounts to 58 $m^3/s$ and varies from 0 $m^3/s$ to as high as 1 510 $m^3/s$. At the 2024 development level, the average surplus flow was slightly higher at 61 $m^3/s$.

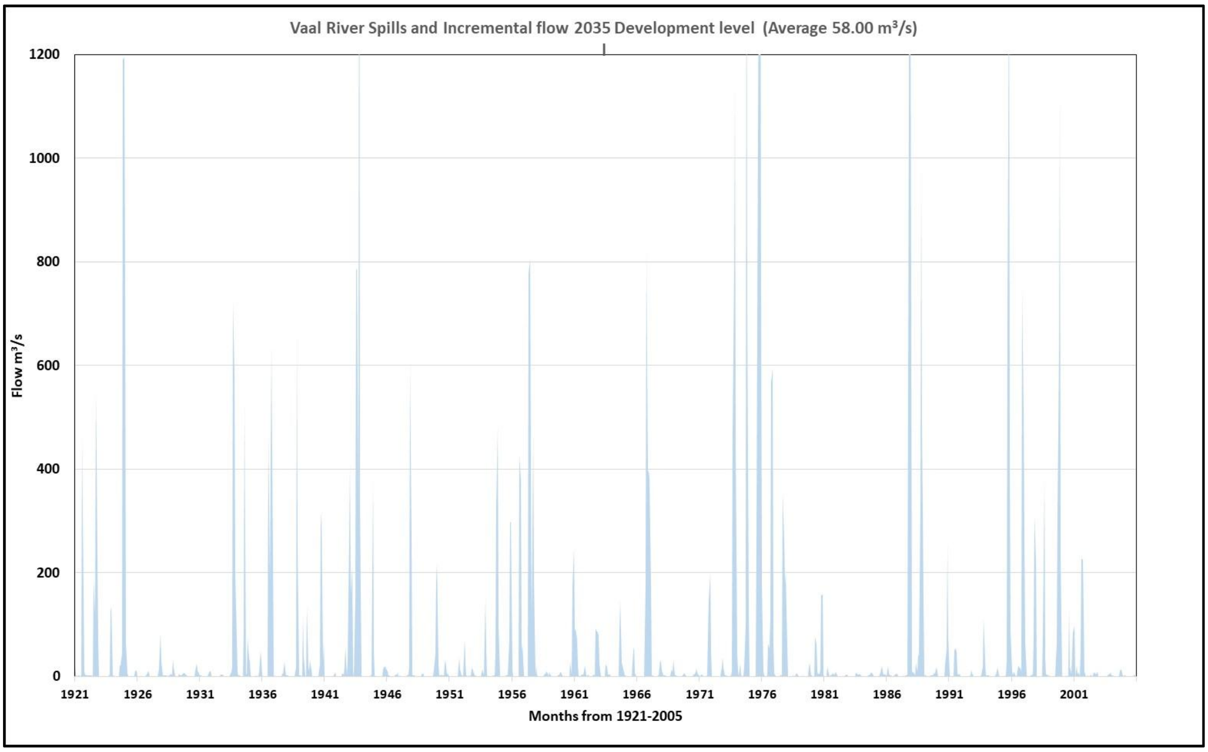


**Figure 4-10: Surplus flow from the Vaal River, including incremental flows available in the Lower Orange close to the Haib Mine abstraction point**

The flow in the Lower Orange at Blouputs is shown in Figure 4-11 and excludes the contributions from the Vaal River as given in Figure 4-10. The base flows evident in Figure 4-11 are the flows required to supply the downstream water requirements. Only flows above that are surplus flows from the Orange River contributions that can be stored in the Haib Mine off-channel storage dam.

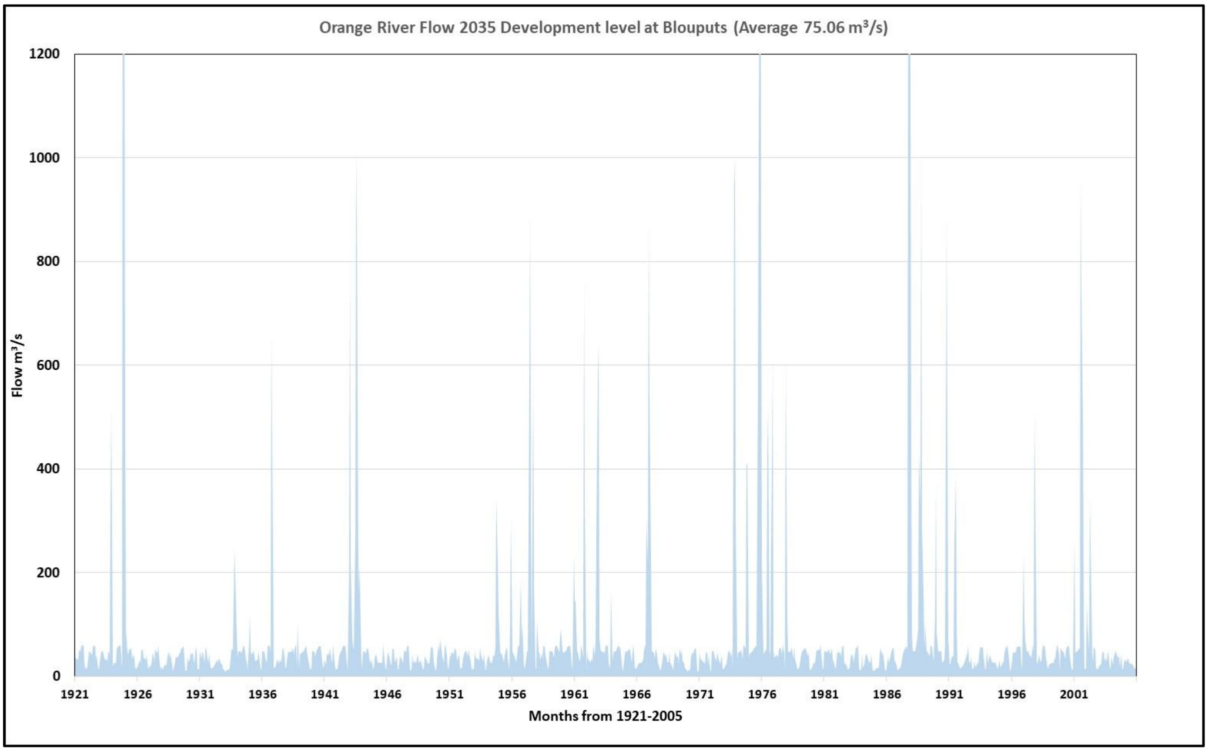


**Figure 4-11: Flows in the Orange River at Blouputs in the Lower Orange. This excludes the Vaal River contributions as given in Figure 4-10**

### 4.2.4 Scenario 3 Sensitivity Analysis

After the presentation and discussion of the results from the agreed-upon scenarios, it was requested to carry out two more scenarios to provide some sensitivity around the results, focusing on Scenario 3.

These included the following scenarios:

- Scenario 3b: As Scenario 3, but increase the diversion pump capacity to 2 $m^3$/s to divert surplus water into the Haib off-channel storage. Determine the reduced storage required for the off-channel storage dam.
- Scenario 3c: As Scenario 3, but decrease the Haib off-channel storage to 20 million $m^3$ and determine the impact on the related assurance of supply to Haib Mine.
- Scenario 3d: As Scenario 3, but reduce the Haib Mine water requirement to 10 million $m^3$. Determine the storage capacity required for the Haib off-channel storage dam.
- Scenario 3f was introduced much later when the actual surveyed data for the Haib off-channel storage was available for the first time. Scenario 3f is as Scenario 3e, with the only difference that the surveyed area capacity data is used for the Haib off-channel storage dam for the first time.

**Scenario 3b** results showed that with a higher pump capacity of 2 $m^3$/s in place, the required storage for the Haib off-channel storage dam was reduced to 25 million $m^3$. For this scenario, Haib Mine will receive the full 20 million $m^3$/a over the total 85-year analysis period. It is expected that the assurance of supply to Haib Mine should be in the order of 99%. Stochastic analysis is required to obtain the correct assurance of supply. The detailed monthly pumping sequence is given in Appendix A, Table A-5.

**Scenario 3c** results for the historic analysis showed that the full 20 million $m^3$/a to Haib Mine could not be supplied for three out of the 85-year analysis period. Based on the simulated historic supply, this will present a 96% supply assurance. To determine a more accurate assurance of supply, stochastic analysis is required. The detailed monthly pumping sequence is given in Appendix A, Table A-6.

**Scenario 3d** considered a reduced Haib Mine water requirement of 10 million $m^3/a$. The results from this scenario showed that the required Haib off-channel storage dam was then reduced to only 10 million $m^3/a$. For this scenario, Haib Mine received its full requirement of 10 million $m^3/a$ over the entire 85-year analysis period. It is thus expected that the assurance of supply to Haib Mine should be in the order of 99% as for Scenario 3b. Stochastic analysis is required to obtain the correct assurance of supply.

**Scenario 3f** is as Scenario 3e, with the only change being the characteristics of the off-channel storage dam. As no information was initially available on the actual off-channel dam characteristics, a typical dummy normally used to simulate a combination of farm dams was used for this purpose. The actual surveyed dam storage characteristics were received towards the end of the analyses and were therefore included as one of the sensitivity analyses carried out for this study.

**Scenario 3f** thus includes, as Scenario 3e, the near-future developments that will significantly impact the water supply downstream of Gariep and Vanderkloof dams. The near future developments are the following:

Polihali Dam and the tunnel to Katse Dam. The related increased volume to be transferred to the Vaal River System will form part of the analysis.

- Transfer water from the Gariep Dam to the Greater Bloemfontein area, including the improvements in the Greater Bloemfontein water supply system.
- Neckartal Dam irrigation and hydro-power generation are in place.
- All water requirements at the 2035 development level.

For this scenario, the 20 million $m^3/a$ Haib water requirement will be supplied from two sources as indicated below.

- A requirement of 14 million $m^3/a$ will be imposed on the off-channel storage dam.
- An additional annual abstraction of 6 million $m^3/a$ will be taken directly from the Orange River and will be supported through releases from Vanderkloof Dam.

Results from Scenario 3 and the related Scenario 3 sensitivity analyses are summarised in **Table 4-7.**

**Table 4-7: Scenario 3 sensitivity analyses results**

| Scenario | Off-channel Storage (million $m^3$) | Haib Mine water requirement (million $m^3/a$ | Diversion pump capacity ($m^3/s$) | Volume pumped million $m^3/a$ | Assurance of supply to Haib Mine (%) |
|---|---|---|---|---|---|
| Scenario 3 | 35 | 20 | 1.80 | 35.1 | 99% |
| Scenario 3b | 25 | 20 | 2.00 | 35.1 | 99% |
| Scenario 3c | 20 | 20 | 1.80 | 33.8 | 96% |
| Scenario 3d | 10 | 10 | 1.80 | 25.2 | 99% |
| Scenario 3e* | 23.6 | 14 + 6=20 | 1.03 | 30.9 | 100% & 96% |
| Scenario 3f* | 14.61 | 14 + 6=20 | 1.03 | 20.9 | 100% & 96% |

Note * - Scenario 3e used the dummy dam characteristics as used in all the scenarios that included the Haib off-channel storage dam. Scenario 3f used the actual surveyed information for an off-channel storage dam at Haib.

The sensitivity analyses for Scenarios 3 to 3d showed that the required storage capacity of the Haib Mine proposed off-channel storage dam is quite sensitive to diversion pump capacity, the required water demand of Haib Mine, as well as the assurance of supply required for Haib Mine. The detailed monthly pumping sequence is given in Appendix A, Table A-7.

Scenario 3f versus Scenario 3e shows that the required storage capacity for the Haib off-channel storage dam reduced significantly to only 23.65 million $m^3$ when the actual surveyed area capacity characteristics of the Haib off-channel storage Dam are used. This is due to the much smaller surface area and related reduction in evaporation when using the surveyed dam characteristics. This further resulted in a much-reduced total average volume pumped per annum.

## 4.3 WRPM Scenario Results to be used for Design Purposes

### 4.3.1 Improvement of Existing Scenarios

Two of the existing scenarios with results given in Section 4.2 were improved by including the surveyed area capacity versus dam height characteristics for the off-channel storage dam at Haib Mine. These include Scenario 2 and Scenario 3.

**Scenario 2** represents the current system with water requirements at 2024 development level but including Haib Mine with a 20 million $m^3/a$ water requirement. Water will be pumped from the Orange River into an off-channel storage facility at Haib Mine. Pumping will only occur when there is surplus flow available in the river. Different maximum pumping rates from 1.5 $m^3/s$ to 2.3 $m^3/s$ were analysed and the related storage capacity of the off-channel storage facility determined for each of the pumping rates. No releases will be made from Vanderkloof Dam in support of the abstractions for Haib Mine.

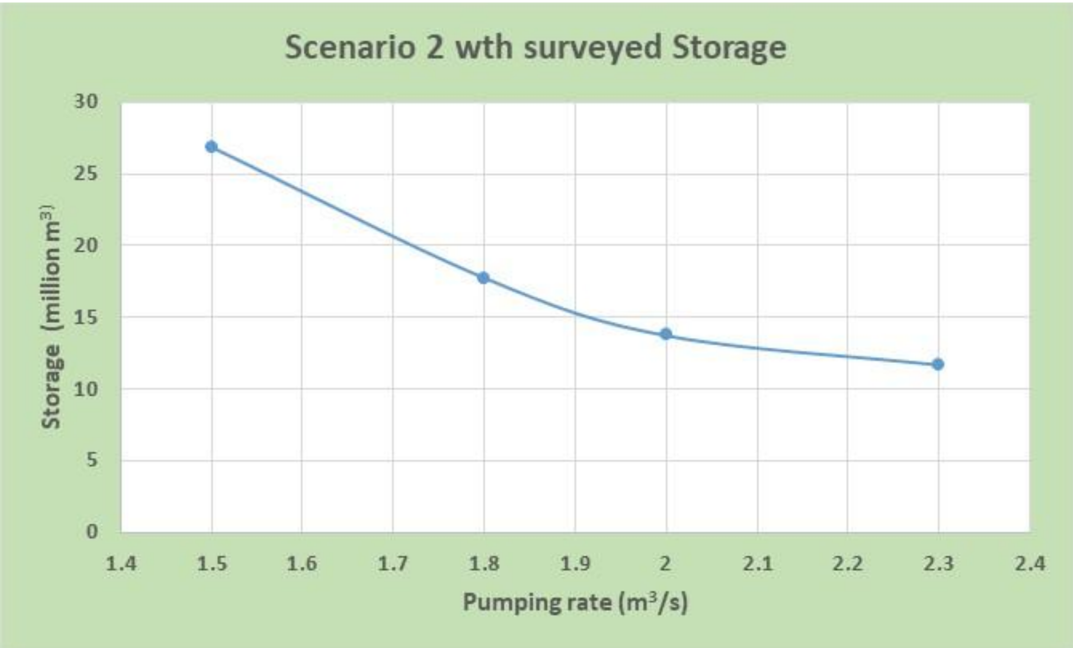


**Figure 4-12: Storage capacity required versus maximum pumping rate – Scenario 2**

From Figure 4-12 it is evident that when increasing the pumping rate beyond 2.3 $m^3/s$ will not contribute significantly to a reduction in the storage capacity required for the off-channel storage dam at Haib as the curve is starting to flatten off. To determine the most suitable pumping capacity an economic analysis is required by comparing the cost of the dam to the pumping and related infrastructure costs.

Using the surveyed dam storage characteristics and not the initially assumed "dummy" dam characteristics, significantly reduced the storage capacity required for the off-channel storage dam. The initial results using the dummy dam characteristics showed a storage required of 35 million $m^3$ for a 1.8 $m^3/s$ maximum pumping rate and a 25 million $m^3$ storage for a 2.0 $m^3/s$ maximum pumping rate in comparison with a 17.7 million $m^3$ storage for a 1.8 $m^3/s$ maximum pumping rate and 13.7 million $m^3$ storage for a 2.0 $m^3/s$ maximum pumping rate when using the actual dam characteristics. The main reason for the reduction in storage is the much lower evaporation losses for the off-channel storage dam based on the actual storage characteristics compared with those of the assumed "dummy" configuration dam.

The typical behaviour of the off-channel storage dam when a maximum pumping rate of 2 $m^3/s$ is used is shown in Figure 4-13.

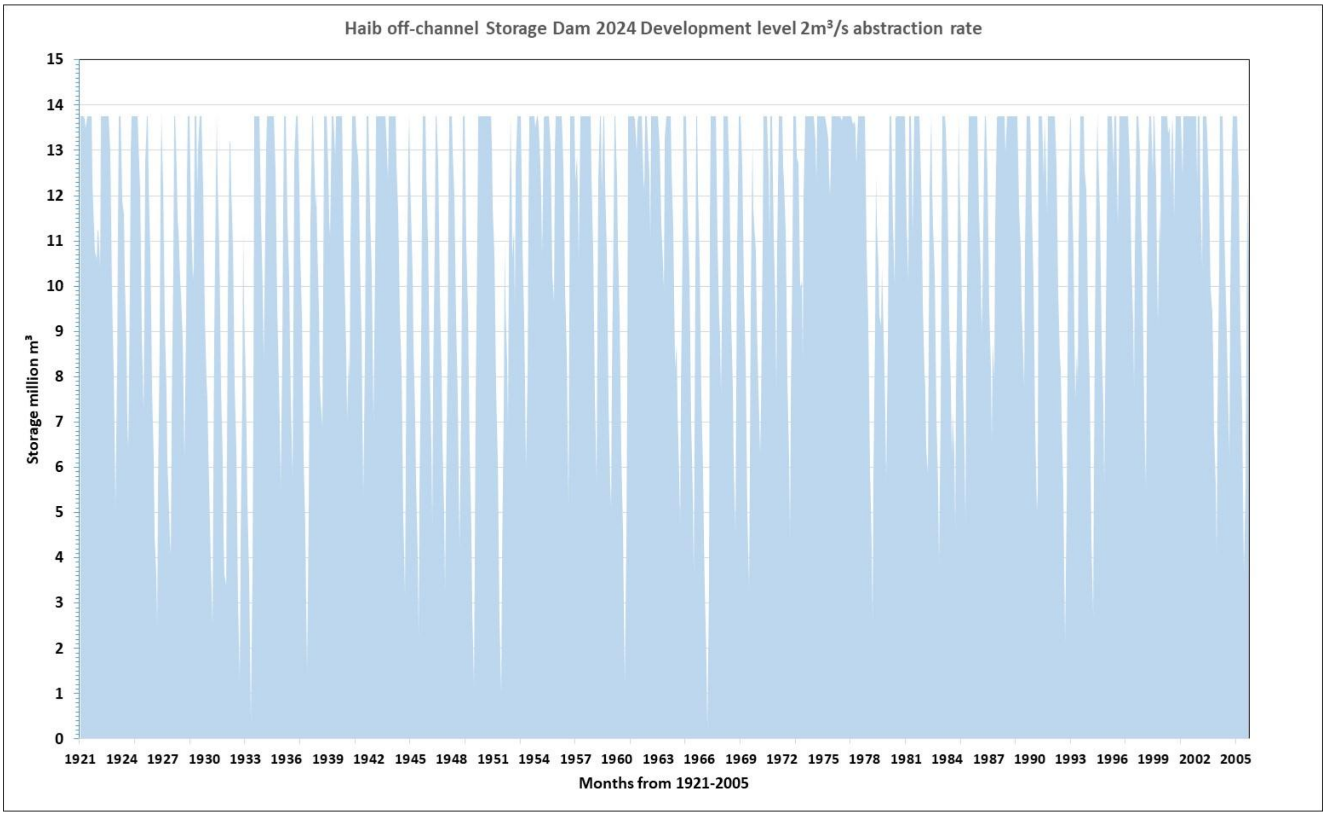


**Figure 4-13: Haib off-channel dam storage over the simulation period – Scenario 2 & 2m$^3$/s pumping rate**

The two lowest storage levels over the simulation period were 0.39 million $m^3$ in October 1932 and 0.22 million $m^3$ in December 1966.

With a 2 $m^3/s$ maximum pumping rate for Scenario 2 with actual storage characteristics used, the average pumping over the simulation period was 0.655 $m^3/s$. This is significantly less than the 1.10 $m^3/s$ average pumping from the initial Scenario 2 when the dummy dam characteristics were used in the analysis. The required pumping over the simulation period is given in Figure 4-14.

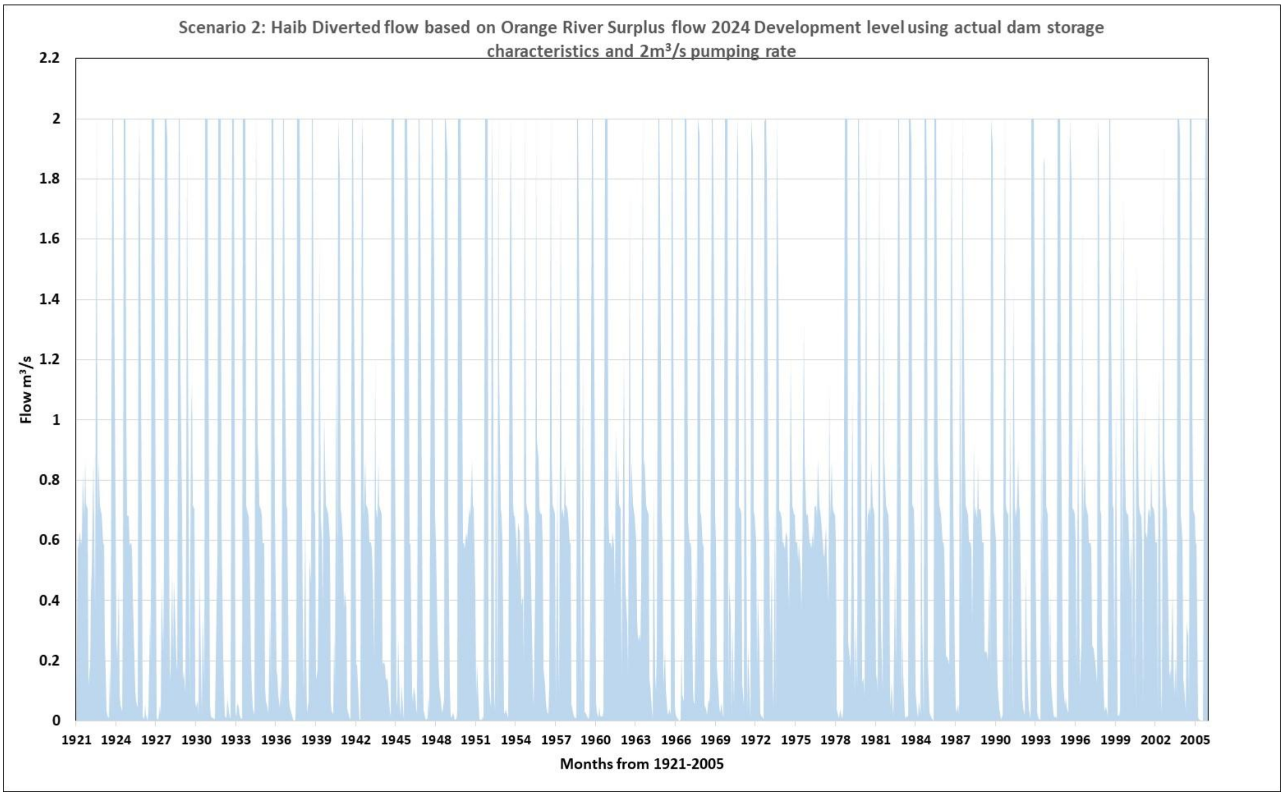


**Figure 4-14: Pumping into Haib off-channel dam storage over the simulation period – Scenario 2 & 2m$^3$/s pumping rate**

The detailed monthly pumping rates representing Figure 4-14 are given in Appendix A.

**Scenario 3** represents the current system with near future developments in place, such as Polihali Dam and a tunnel to the IVRS, the transfer from Gariep Dam to the Greater Bloemfontein System, with Neckartal irrigation in place and water requirements at the 2035 development level as well as Haib Mine included with a 20 million m$^3$/a water requirement. Water will be pumped from the Orange River into an off-channel storage facility at Haib Mine. Pumping will only occur when there is surplus flow available in the river. Different maximum pumping rates from 1.5 m$^3$/s to 2.3 m$^3$/s were analysed, and the related storage capacity of the off-channel storage facility was determined for each of the pumping rates. No releases will be made from Vanderkloof Dam in support of the abstractions for Haib Mine

The results from the analysis of different pumping rates versus the off-channel storage requirement are shown in Figure 4-15. Results obtained from both Scenarios 2 and 3 were included for comparison purposes. It is interesting to note that for scenario 3 the off-channel storage required reduced for pumping rates below 2 m$^3$/a, and increases above 2 m$^3$/a in comparison with the Scenario 2 results. This is as result of the different flow characteristics from both the Vaal and Orange rivers as Scenario 2 represents the flow characteristics at the 2024 development level and Scenario 3 the flows at 2035 development level including significant upstream developments such as Polihali Dam and transfer tunnel to the IVRS as well as the transfer from Gariep to the Greater Bloemfontein.

Due to these developments, the spills from the Vaal River reduced by 1.9% and the flows in the Orange River at Blouputs reduced by 9.1%.

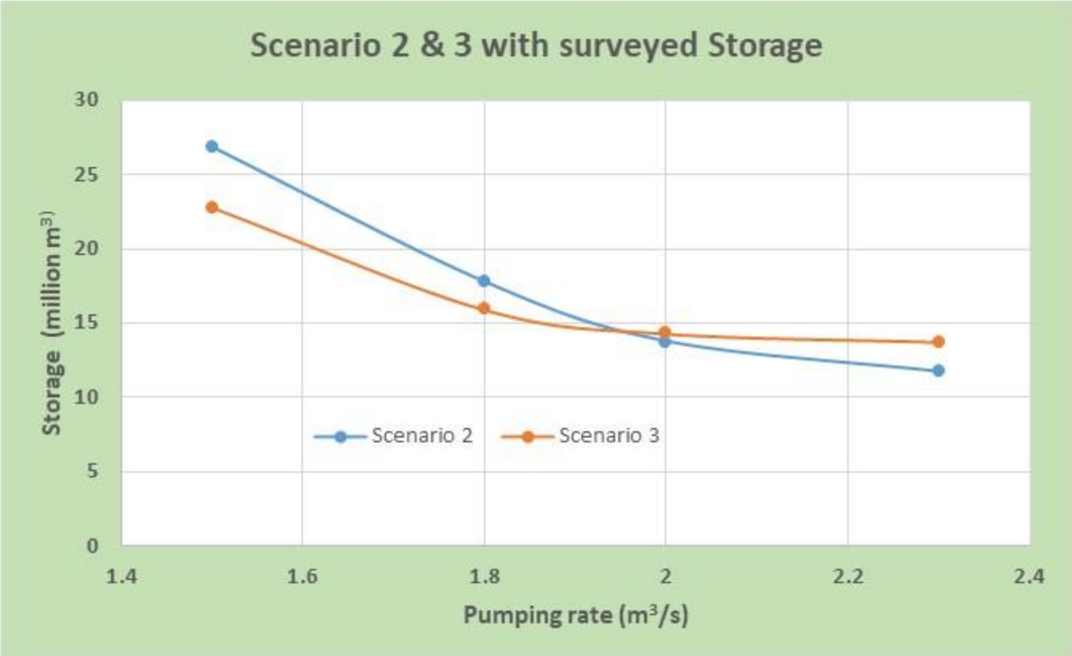


**Figure 4-15: Storage capacity required versus maximum pumping rate – Scenario 2 & 3**

From Figure 4-15 it is evident that by increasing the pumping rate to above 2 $m^3/s$, very little advantage will be achieved in reducing the required off-channel storage specifically for Scenario 3.

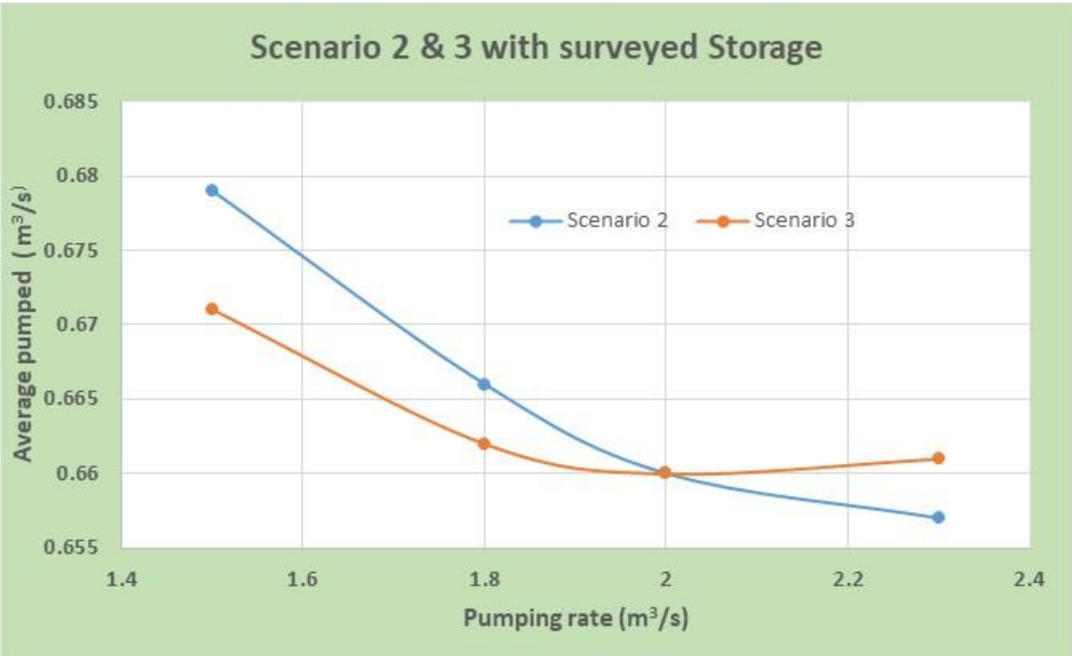


**Figure 4-16: Average pumping required versus maximum pumping rate – Scenario 2 & 3**

A similar graph was prepared to show the average pumping rate over the simulation period versus the maximum installed pumping rate. This graph revealed that for both scenarios the 2 $m^3/s$ maximum installed pumping rate required the least pumping over the analysis period (See Figure 4-16) in combination with an off-channel storage of 13.75 million $m^3$ for scenario 2 and 14.31 million $m^3$ storage for Scenario 3.

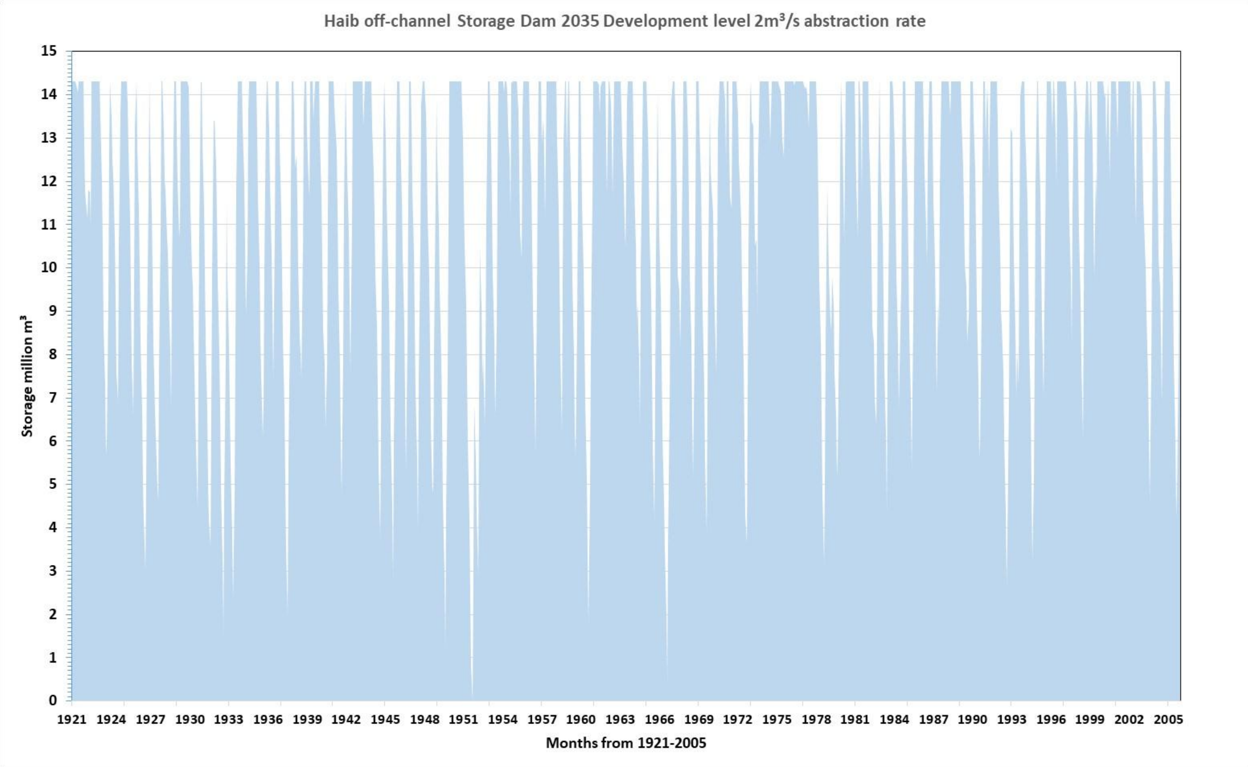


**Figure 4-17: Haib off-channel dam monthly storage over the simulation period – Scenario 3 & 2$m^3/s$ pumping rate**

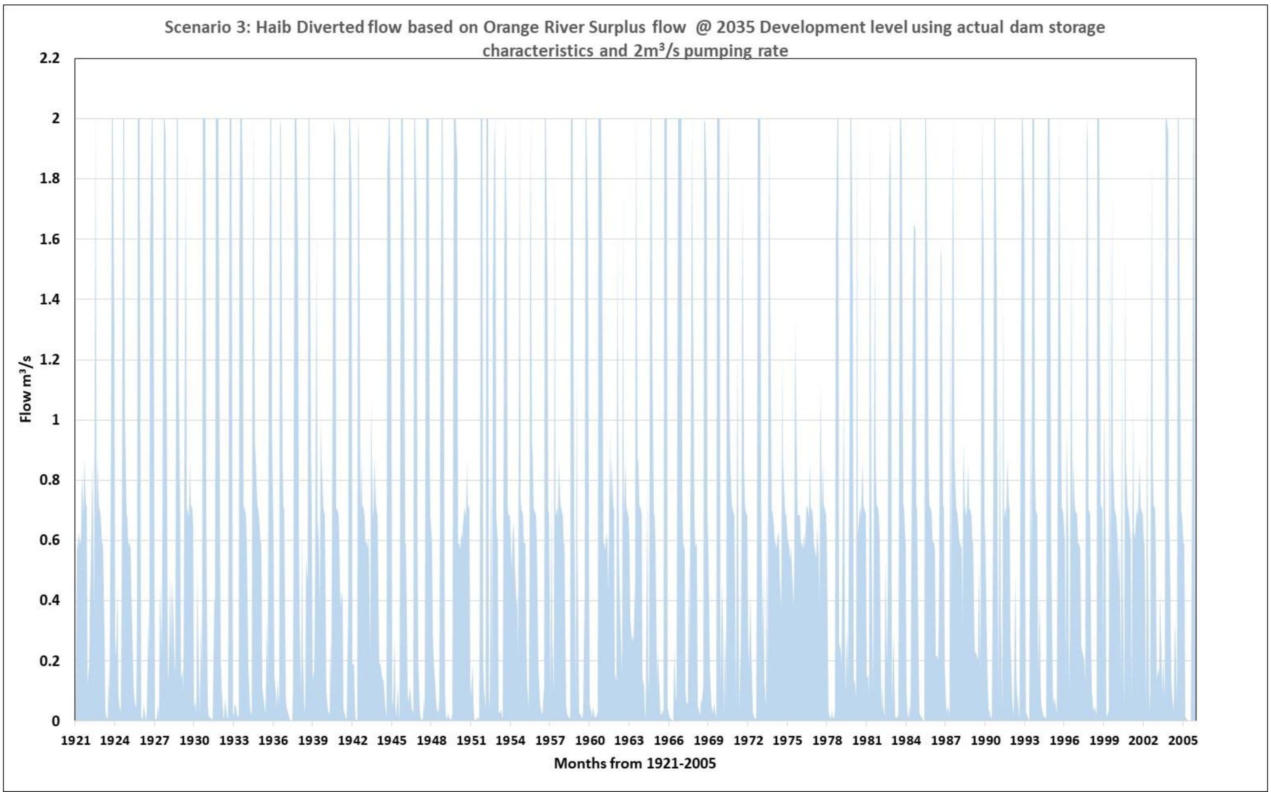


**Figure 4-18: Monthly pumping into Haib off-channel dam storage over the simulation period – Scenario 3 & 2m$^3$/s pumping rate**

The two lowest storage levels over the simulation period were 0.01 million m$^3$ in January 1952 and 0.45 million m$^3$ in December 1966.

The detailed monthly pumping rates representing Figure 4-18 are given in Appendix A.

The Blouputs streamflow gauge (D8H014) is located on the main Orange River downstream of the Augrabies Falls, just before the Namibia border. This is a key gauging station used for monitoring and operating purposes of the ORP system. Each year, as part of the annual operating analysis of the ORP, minimum monthly flows are set for observed flows at Blouputs. These flows are the minimum flow required to satisfy all the water requirements downstream of Blouputs to the River Mouth. During the operation of this system, DWS needs to monitor the flow at this site on a continuous basis. If the flow drops below the minimum flow specified, more water needs to be released from Vanderkloof Dam to increase the flow at Blouputs.

To control the pumping from the Orange River at Haib Mine, these minimum flows at Blouputs were used as the trigger for pumping to the Haib off-channel storage. Only if the flow at Blouputs is higher than the required minimum flow will pumping at Haib be allowed. This minimum flow at Blouputs comprises:

- All the user water requirements between Blouputs and the estuary.
- The EWR at the River mouth.
- River evaporation and evapotranspiration from riparian growth between Blouputs and the estuary

This is illustrated in Figure 4-19 showing the annual outflow at Blouputs as well as the minimum required downstream flow (Orange line). The flow pumped to the Haib off-channel storage is shown by the blue line with an average annual pumping rate of 0.66 m$^3$/s or 20.84 million m$^3$/a.

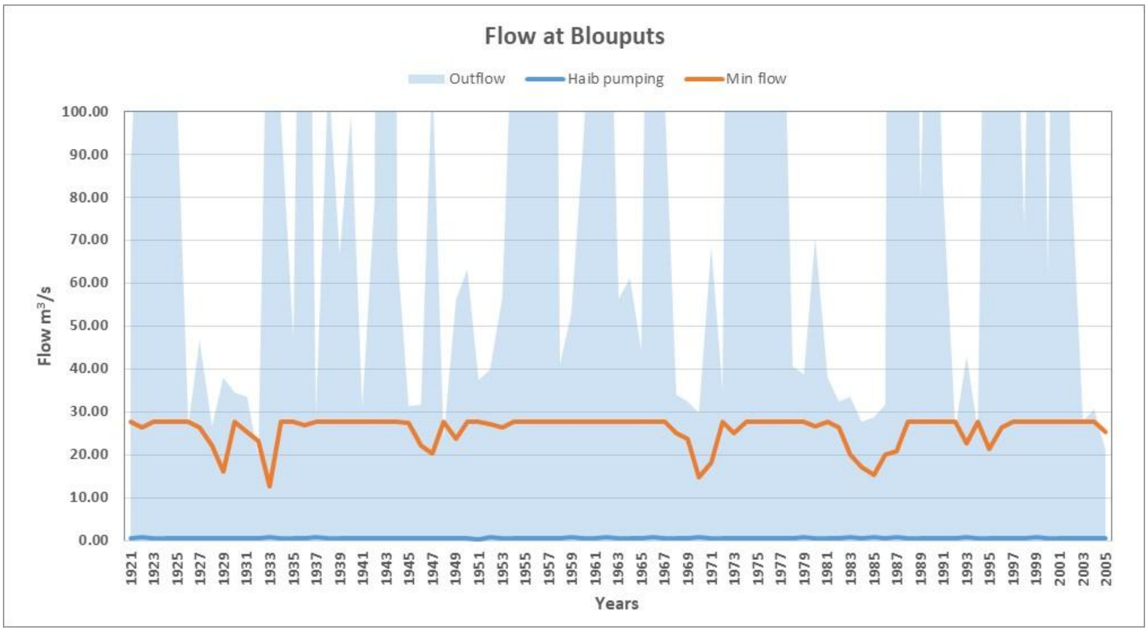


**Figure 4-19: Scenario 3 - Annual outflow from Blouputs with Haib abstraction taken into account**

From Figure 4-19, it is evident that the flow just downstream of Blouputs minus the pumped flow, as shown in the figure, is for most of the years above the given minimum flows and in a few years equal to the minimum flow. In normal years, the minimum annual flow (orange line) is 27.72 m$^3$/s and varies from month to month. In years when restrictions are imposed on the system, the minimum flow is reduced in line with the restrictions imposed on the system.

Although the average annual pumping is only 20.84 million m$^3$/a it easily reaches 5.4 million m$^3$/month or 2 m$^3$/s during the summer months, November to March (see Figure 4-18).

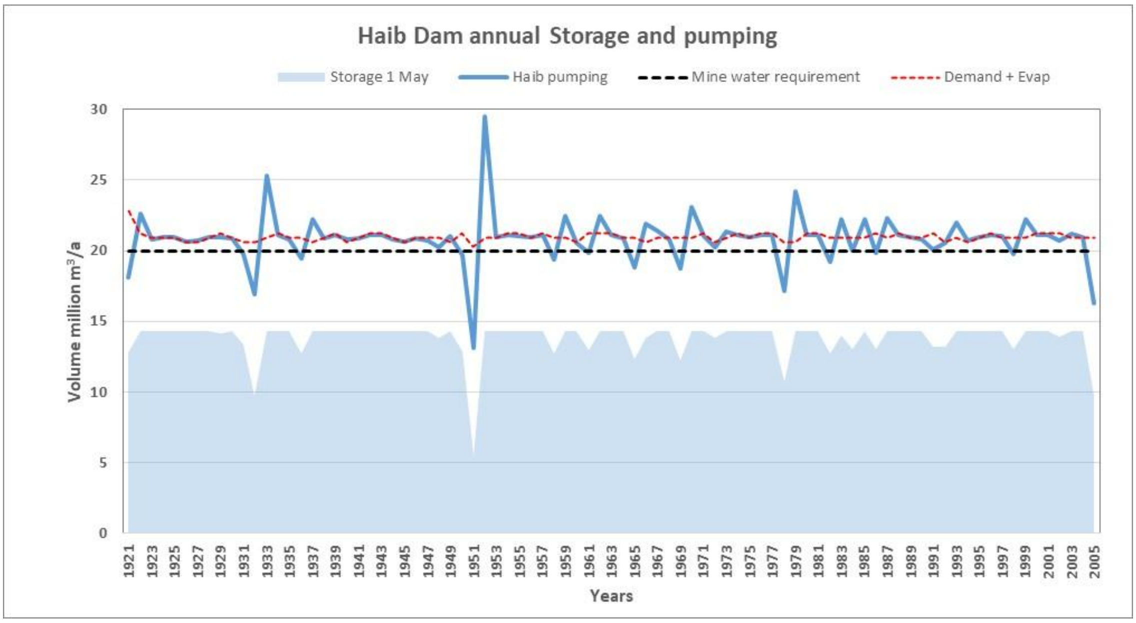

**Figure 4-20: Scenario 3 - Annual storage, pumping from the Orange River and demand imposed on the dam**

The annual storage as of 1 May each year is given in Figure 4-20. The off-channel storage required for Scenario 3 is 14.31 million $m^3$. The volume pumped per annum (blue line) varies from year to year and depends on the availability of the water above the minimum flow in the river, as well as the storage level in the off-channel storage dam. The mine water requirement for this scenario was given as 20 million $m^3$/a (black dashed line), and the net evaporation from the dam on top of the mine demand is given by the red dashed line, resulting in a total average demand of 21 million $m^3$/a.

The Blouputs streamflow gauge (D8H014) is a relatively new flow gauge, and observed data is only available for the period February 2014 to December 2025. When working according to operating years (May to April), there are only 11 years of complete annual flow data available from May 2014 to May 2024. The observed data at Blouputs is compared with the simulated flow data in Figure 4-21 and with the minimum flow required at Blouputs, as well as the volume pumped to the Haib off-channel storage Dam for Scenario 3.

In terms of the dryer observed flows between the May 2014 and May 2020 operating years, the average monthly flows for October to December are equal to and slightly below the minimum flows required at Blouputs. This highlights the critical months in which pumping from the Orange into the Haib off-channel storage dam might not be able to take place. If sufficient flow is available over these critical months, great care should be taken with any pumping taking place.

Considering the average monthly flows from the entire observed flow record (2014 to 2024), it is evident that surplus flows are available for most months except for October, which remains a critical month for pumping. When focusing on the three wet years 2022 to 2024, the average monthly flows for all months are significantly higher, except for October, where they are only slightly higher. October thus remains a critical month for pumping.

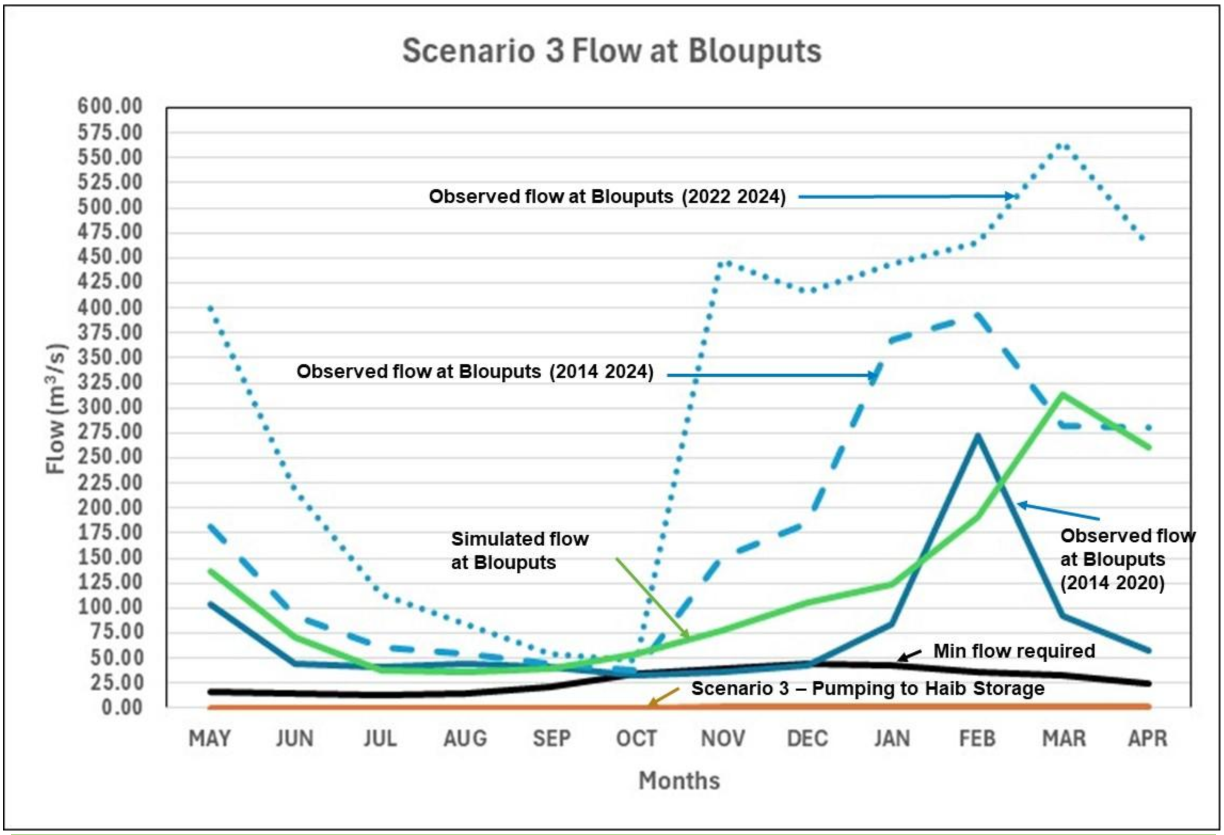

**Figure 4-21: Observed and simulated flows at Blouputs**

The average monthly simulated flows over the 85-year simulation period are lower than the average observed flow over the 11-year period 2014 to2024. This is to be expected as the observed flows represent the actual development level demand as it increased from 2014 to 2025, while the simulated flows represent demands expected for the 2035 development level. Furthermore, Scenario 3 of the simulated flow also includes Polihali Dam and its transfer to the Vaal, as well as the transfer from Gariep to the Greater Bloemfontein. Polihali Dam has a large storage capacity of just over 2 300 million m$^3$, which will capture high flows or parts thereof, and at the same time will result in lower storage levels in Gariep and Vanderkloof dams, which will lead to the capturing of more high flows. The impact of this is clearly evident from the monthly average simulated flows showing fewer peaks over the summer rainfall period, with high flow peaks taking place more towards the end of the rain season. The average simulated flow is close to the October minimum flows but slightly higher than the observed flows in October. It is important to note that the simulated flow record is much longer than the observed flow record. Over the 85 years of simulated flow in October, there were only 5 months with extremely high flows of between 112 and 809 m$^3$/s. For the remainder of the months, the October flow varied between 20 and 55 m$^3$/s. These 5 years of very high flows, therefore, pushed the average flow over the 85 years up to a slightly distorted higher value. The highest October observed flow is only 159 m$^3$/s, which is still small in comparison with the highest simulated value of 809 m$^3$/s.

From both Figures 4-21 and 4-19, it is evident that the volume pumped to Haib off-channel storage is a very small percentage of the minimum flow required at Blouputs.

### 4.3.2 New Scenarios

A total of four new scenarios were defined for analysis, which include the following (See Section 4.1.2):

- Scenario 3g2 Haib water requirement of 6 million m$^3$/a with off-channel Storage Dam at 2035 development level. Not supported by Vanderkloof Dam.
- Base Scenario 3. This scenario is as Base Scenario 2 with water requirements at the 2035 development level, but with Noordoewer-Vioolsdrift and Verbeeldingskraal dams in place, as well as the utilising of the Vanderkloof Dam lower-level storage, but with no abstraction for Haib Mine.
- Scenario 4 is as Base Scenario 3 but with a 6 million m$^3$/a continuous abstraction by Haib Mine supported from the Noordoewer-Vioolsdrift Dam.
- Scenario 5 is the same as Scenario 4, with the only difference that a 20 million m$^3$/a continuous abstraction by Haib Mine will be supported from the Noordoewer-Vioolsdrift Dam

#### 4.3.2.1 Scenario 3g2

Scenario 3g2 analyses results showed that a much smaller off-channel storage of between 3.6 and 4 million m$^3$ is required when the Haib Mine water requirement is only 6 million m$^3$/a. The required off-channel storage does not decrease much for pumping rates of 1 m$^3$/s and higher.

The storage behaviour of the off-channel storage dam at Haib for Scenario 3g2 is shown in Figure 4-23 for a maximum pumping rate of 1 m$^3$/s to divert water from the Orange River to the Haib off-channel storage dam. The lowest storage levels were experienced in December 1949 (0.04 million m$^3$) and in December 1960 (0.08 million m$^3$).

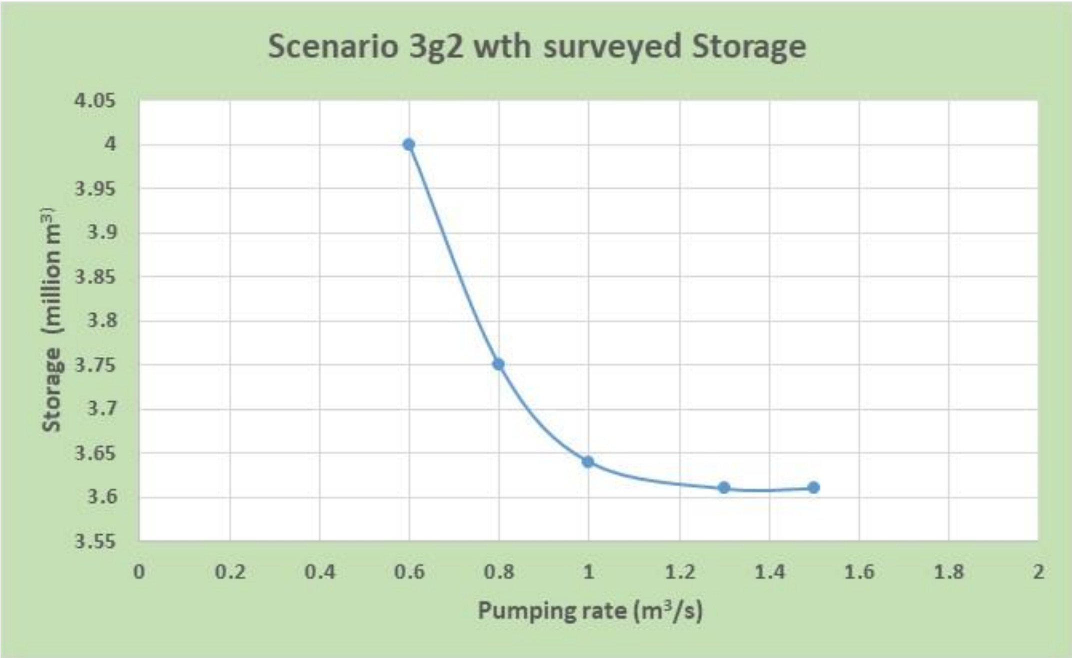


**Figure 4-22: Storage capacity required versus maximum pumping rate – Scenario 3g2**

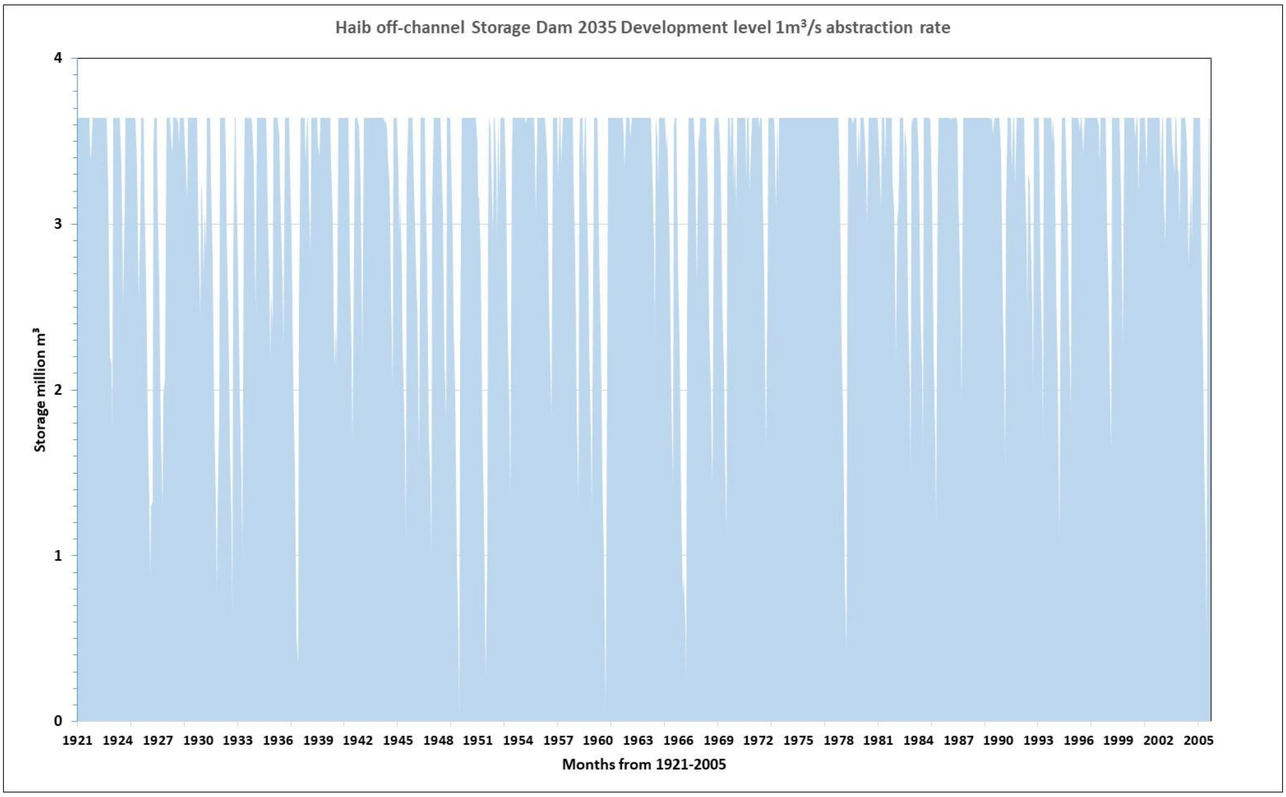


**Figure 4-23: Haib off-channel dam storage over the simulation period – Scenario 3g2 1m$^3$/s pumping rate**

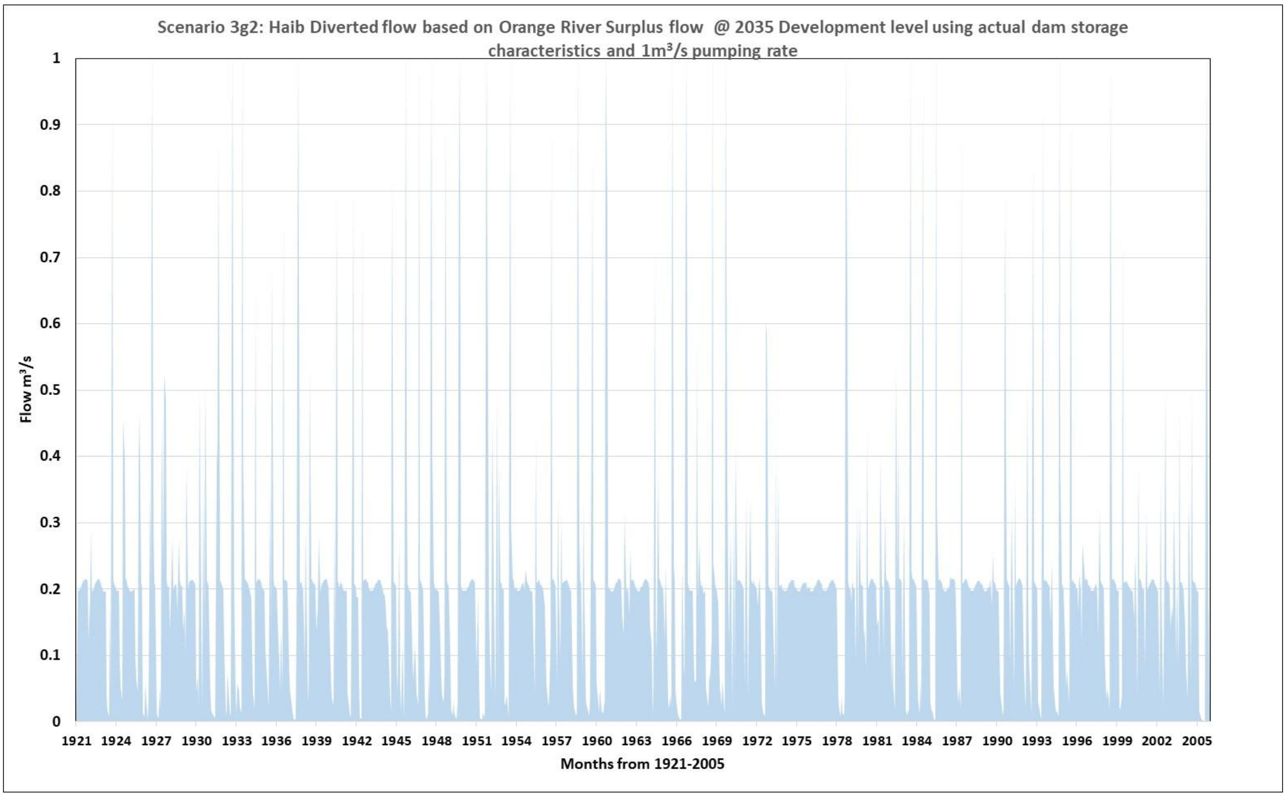


**Figure 4-24: Pumping into Haib off-channel dam storage over the simulation period – Scenario 3g2 for a 1m$^3$/s pumping rate**

The average annual pumping over the simulation period is 0.203 m$^3$/s. The detailed monthly pumping rates representing Figure 4-24 are given in Appendix A.

The Haib Mine water requirement of 6 million m$^3$/a was 100% supplied over the analysis period (See Figure 4-25).

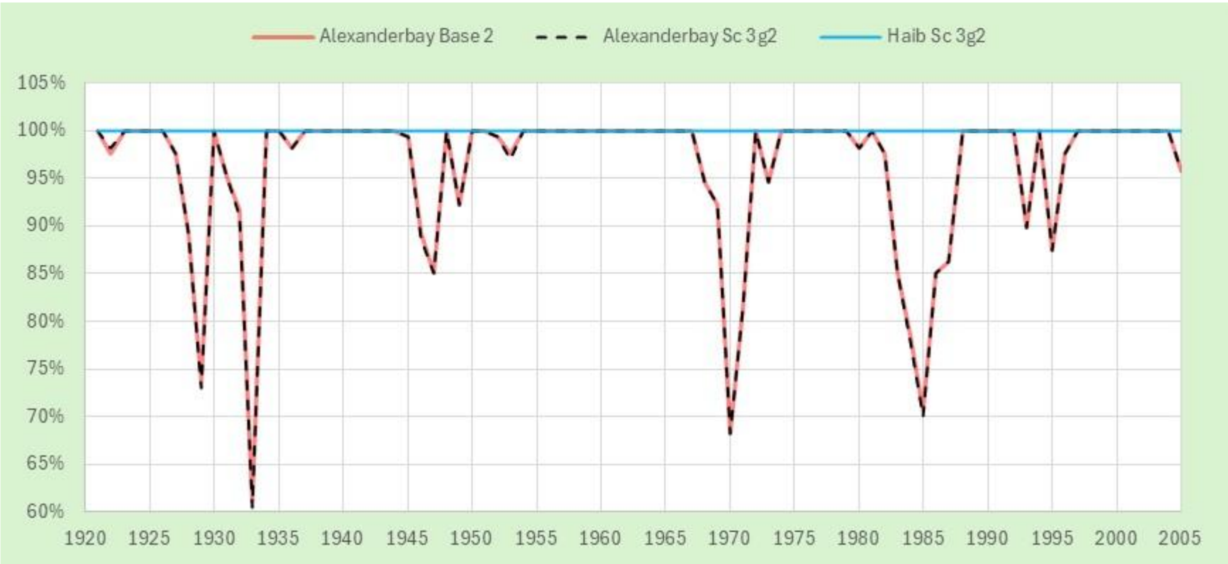


**Figure 4-25: Scenario 3g2 – Water supply to Alexander Bay and Haib Mine versus Base Scenario 2 Alexander Bay supply**

As only surplus water is pumped into the off-channel storage dam at Haib Mine, the river abstraction to fill the off-channel storage dam from the Orange River had no impact on the downstream users, such as Alexander Bay, as evident from Figure 4-25. The deficits in the supply to Alexander Bay for the Base Scenario 2 are due to the reduction in yield of the ORP system, mainly as a result of upstream developments such as Polihali Dam, the transfer of water to the Greater Bloemfontein system and the overall water requirements at the 2035 development level.

Table 4-8 lists all the years within the 85-year analysis period which required restrictions for the Base 2 Scenario, Scenario 3 and Scenario 3g2, as well as the related percentage restrictions and water supply for each of the years. The restrictions required for Base 2 Scenario, Scenario 3 and Scenario 3e are, for practical purposes, the same. The long-term average restriction difference between the Base 2 Scenario and Scenario 3 and Scenario 3g2 is only 0.1%, showing thus a very small impact.

**Table 4-8: Years when restrictions were required for the ORP System and the related severity of the restrictions (2035 development level) comparing Base Scenario 2, Scenario 3 and Scenario 3g2 results**

| Years | % Supplied | | | % Restriction | | | Supply volume reduction (million $m^3$/a) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Base 2 | Scenario 3 | Scenario 3g2 | Base 2 | Scenario 3 | Scenario 3g2 | Base 2 | Scenario 3 | Scenario 3g2 |
| 1922 | 95.5% | 95.4% | 96.1% | 5% | 4.6% | 3.9% | 161 | 163 | 139 |
| 1927 | 95.2% | 95.0% | 95.0% | 5% | 5.0% | 5.0% | 171 | 180 | 180 |
| 1928 | 80.4% | 80.1% | 80.1% | 20% | 19.9% | 19.9% | 698 | 708 | 708 |
| 1929 | 57.9% | 57.9% | 57.6% | 42% | 42.1% | 42.4% | 1,502 | 1,502 | 1,512 |
| 1930 | 99.8% | 99.7% | 99.7% | 0% | 0.3% | 0.3% | 6 | 12 | 12 |
| 1931 | 91.0% | 90.9% | 90.9% | 9% | 9.1% | 9.1% | 320 | 326 | 326 |
| 1932 | 84.2% | 83.9% | 83.9% | 16% | 16.1% | 16.1% | 565 | 573 | 573 |
| 1933 | 46.1% | 46.1% | 45.8% | 54% | 53.9% | 54.2% | 1,923 | 1,923 | 1,934 |
| 1936 | 96.9% | 96.8% | 96.8% | 3% | 3.2% | 3.2% | 111 | 114 | 114 |
| 1945 | 99.1% | 99.0% | 99.0% | 1% | 1.0% | 1.0% | 33 | 37 | 37 |
| 1946 | 79.8% | 79.5% | 79.5% | 20% | 20.5% | 20.5% | 722 | 730 | 730 |
| 1947 | 73.3% | 73.0% | 73.0% | 27% | 27.0% | 27.0% | 954 | 962 | 962 |
| 1949 | 85.8% | 85.7% | 85.7% | 14% | 14.3% | 14.3% | 505 | 509 | 509 |
| 1952 | 98.5% | 98.3% | 98.3% | 1% | 1.7% | 1.7% | 52 | 59 | 59 |
| 1953 | 95.0% | 94.8% | 94.8% | 5% | 5.2% | 5.2% | 178 | 185 | 185 |
| 1968 | 90.4% | 90.3% | 90.3% | 10% | 9.7% | 9.7% | 342 | 344 | 344 |
| 1969 | 85.8% | 85.7% | 85.7% | 14% | 14.3% | 14.3% | 508 | 511 | 511 |
| 1970 | 53.2% | 53.2% | 52.9% | 47% | 46.8% | 47.1% | 1,670 | 1,670 | 1,679 |
| 1971 | 66.7% | 65.9% | 65.9% | 33% | 34.1% | 34.1% | 1,188 | 1,216 | 1,216 |
| 1973 | 89.7% | 90.1% | 90.1% | 10% | 9.9% | 9.9% | 369 | 354 | 354 |
| 1980 | 96.6% | 96.5% | 96.5% | 3% | 3.5% | 3.5% | 120 | 124 | 124 |
| 1982 | 95.6% | 95.4% | 95.4% | 4% | 4.6% | 4.6% | 157 | 165 | 165 |
| 1983 | 73.0% | 72.6% | 72.6% | 27% | 27.4% | 27.4% | 965 | 976 | 976 |
| 1984 | 62.2% | 62.2% | 61.9% | 38% | 37.8% | 38.1% | 1,349 | 1,349 | 1,359 |
| 1985 | 55.0% | 55.0% | 54.8% | 45% | 45.0% | 45.2% | 1,605 | 1,605 | 1,613 |
| 1986 | 72.5% | 72.3% | 72.3% | 28% | 27.7% | 27.7% | 983 | 989 | 989 |
| 1987 | 75.3% | 75.2% | 75.2% | 25% | 24.8% | 24.8% | 881 | 886 | 886 |
| 1993 | 81.7% | 81.6% | 81.6% | 18% | 18.4% | 18.4% | 652 | 656 | 656 |
| 1995 | 77.1% | 76.9% | 76.9% | 23% | 23.1% | 23.1% | 815 | 823 | 823 |
| 1996 | 95.3% | 95.2% | 95.2% | 5% | 4.8% | 4.8% | 169 | 171 | 171 |
| 2005 | 91.8% | 91.7% | 91.7% | 8% | 8.3% | 8.3% | 292 | 295 | 295 |
| Average | **81.9%** | **81.8%** | **81.8%** | **18.1%** | **18.2%** | **18.2%** | **644** | **649** | **650** |

### 4.3.2.2 Base Scenario 3 and Related Scenarios 4 and 5

All the scenarios already analysed thus far made use of the option in the WRPM to restrict or curtail water requirements to protect the resources or storage dams from running empty. This methodology is used in all the large water supply systems in the RSA. To be able to use this option, the short-term stochastic yield characteristics as determined for the combination of storage dams used to supply a specific system are required. In the case of the ORP, this included Gariep and Vanderkloof Dams for all the previous scenarios already carried out. Short-term stochastic yield characteristics for the OPR system were available for all the scenarios carried out up to Scenario 3g2.

As described in Section 4.1.2, Base Scenario 3 is the first scenario which includes the use of Verbeeldingskraal, Noordoewer-Vioolsdrift and the Lower-Level Storage in Vanderkloof Dam. As soon as the new combined ORP system that includes Verbeeldingskraal, Noordoewer-Vioolsdrift and the Lower-Level Storage in Vanderkloof Dam is analysed, it means that a new set or sets of short-term stochastic yield characteristics will be required. For Base Scenario 3 it was assumed that following interventions are in place by 2035 to rebalance the ORP.

- Verbeeldingskraal Dam located in the Upper Orange River just upstream of Aliwal North with a gross storage capacity of 2 730 million $m^3$.
- Noordoewer-Vioolsdrift Dam located in the Lower Orange River just upstream if Vioolsdrift Weir with a storage capacity of 2 800 million $m^3$.
- Using the lower-level storage in Vanderkloof Dam.

These short-term stochastic yield characteristics are, in general, only determined when the final sizes of the new storage dams were determined and agreed upon by the related parties, as a substantial amount of work is required to create these sets of short-term curves. As the final storage capacities of both Verbeeldingskraal and the Noordoewer-Vioolsdrift Dams are still to be determined and agreed upon, no short-term stochastic yield characteristics have yet been determined for these development options.

To be able to determine the impact of Haib Mine water use on existing users for Base Scenario 3 and related Scenarios 4 and 5, a slightly different approach therefore needed to be followed. This approach will exclude the option to restrict or curtail water users during dry periods. The users will then always be supplied at their full allocation or requirement, and only once the dams reach their minimum operating levels will less water be supplied, based on what is available in the system at the time. The water requirements will thus not be supplied at different assurance levels as explained before for the scenarios already analysed. All users will be supplied at more or less the same assurance level, which will be in line with that for the historic firm yield of the system, which is in the order of a 99% assurance or a recurrence interval for a possible failure in supply of 1 in 100 years.

The results from Base Scenario 3 showed that when the Verbeeldingskraal, Noordoewer-Vioolsdrift and the Lower-Level Storage of Vanderkloof Dam were included to increase the ORP system yield, the system was in balance again, and all the users could be fully supplied over the entire analysis period (this is the intended purpose of the Verbeeldingskraal and Noordoewer-Vioolsdrift Dams). If the Lower-Level Storage of Vanderkloof Dam was excluded, a deficit in water supply within the system still occurred. This is in line with results from the Orange Reconciliation Strategy Study that included all these development options to ensure a positive water balance in the ORP system.

By including the Noordoewer-Vioolsdrift Dam, additional yield is created in the ORP system, which is partly used to rebalance the system but also to allow for growth in irrigation demand in the lower Orange, specifically on the Namibian side of the river. Although Base Scenario 2 and Base Scenario 3 are both based on the 2035 development level water requirements, the total system water requirement for Base Scenario 3 is higher than that for Base Scenario 2, as additional irrigation requirements of about 191 million $m^3$/a were added to Base Scenario 3 to utilise the water from Noordoewer-Vioolsdrift Dam. Another advantage of the Noordoewer-Vioolsdrift Dam is that it will reduce the operation losses in the ORP system by 71 million $m^3$/a in comparison with those applicable to Base scenario 2. The net increase in the overall system demand is thus 120 million $m^3$/a, resulting in a total ORP system demand of 3 687 million $m^3$/a, for Base Scenario 3.

Scenarios to be compared with Base Scenario 3 are Scenario 4 and Scenario 5 as described in Section 4.1.2. The differences between the scenarios are that Scenario 4 includes a 6 million $m^3$/a abstraction from the Noordoewer-Vioolsdrift Dam in support of Haib Mine, and for Scenario 5, the Haib Mine abstraction is increased to 20 million $m^3$/a. Results from the water supply to the users and to Haib Mine are summarised in Table 4-9. For comparison purposes, the results from Base Scenario 2 were also included in Table 4-9.

Although Base Scenario 2 was also carried out at the 2035 development level, it showed much higher deficits than Base Scenario 3. This is a result of the inclusion of Verbeeldingskraal, Noordoewer-

Vioolsdrift dams and the Lower-Level Storage in Vanderkloof Dam in Base Scenario 3, with the purpose of rebalancing the ORP.

For practical purposes, it can be assumed that for Base Scenario 3 as well as for Scenarios 4 & 5, the ORP demand is 100% supplied. By checking the water supply to all the users, it was found that only the irrigators supplied from Douglas weir were not fully supplied, as they are also dependent on water from the Vaal System. The rest of the users, including the supply to Haib Mine, were fully supplied over the total analysis period.

**Table 4-9: Average annual system supply comparison (2035, including Noordoewer-Vioolsdrift Dam)**

| Description | Base 2 million $m^3/a$ | Base 3 million $m^3/a$ | Scenario 4 million $m^3/a$ | Scenario 5 million $m^3/a$ |
|---|---|---|---|---|
| Total ORP system demand | 3,567.46 | 3,686.94 | 3,686.94 | 3,686.94 |
| Total average ORP system supply | 3,324.94 | 3,657.97 | 3,657.97 | 3,657.97 |
| Percentage average ORP system supply | 93.20% | 99.21% | 99.21% | 99.21% |
| Worst year ORP system sypply | 46.10% | 99.00% | 99.00% | 99.00% |
| Haib Demand | 0 | 0 | 6 | 20 |
| Haib supply | 0 | 0 | 6 | 20 |
| Percentage Haib average supply | - | | 100% | 100% |
| Worst year system sypply | - | | 100% | 100% |

Including an increased water requirement of 6 million $m^3/a$, or even 20 million $m^3/a$ to support Haib Mine, did not impact the other users.

The operating rules between the four dams, Verbeeldingskraal, Gariep, Vanderkloof and Noordoewer-Vioolsdrift Dams are very important to maximise the yield and hydro-power generation from the dams. These operating rules will be refined once these dams are in place. For the analysis, the following basic operating rules were followed.

- Keep the water in Verbeeldingskraal Dam for as long as possible and only release water from Verbeeldingskraal Dam once the water levels in the downstream dams are very low.
- Support the Gariep Dam with releases from Verbeeldingskraal Dam to keep the Gariep Dam just above the minimum level required for hydro-power generation purposes.
- Support Vanderkloof Dam from Gariep Dam to keep Vanderkloof Dam above the minimum level required for hydro-power generation purposes.
- Only when there is not sufficient water in Gariep and Verbeeldingskraal dams, start to utilise the lower-level storage in Vanderkloof Dam.
- Vanderkloof Dam is used to supply all downstream water requirements between Vanderkloof Dam and the Noordoewer-Vioolsdrift Dam. Only when the water level in the Noordoewer-Vioolsdrift Dam drops below MOL 1 will additional releases be made from Vanderkloof Dam to support the Noordoewer-Vioolsdrift Dam if Vanderkloof Dam is above the minimum hydro-power generation level.
- All the demands downstream of the Noordoewer-Vioolsdrift Dam are to be supplied from the dam. This will include all the downstream users, the river mouth environmental requirements, as well as the river requirements (including losses).

- Only when the Noordoewer-Vioolsdrift Dam drops below MOL 2 can water from Vanderkloof and Gariep Dams below their MOL for hydro-power generation be released in support of the Noordoewer-Vioolsdrift Dam.

The storage dam plots were prepared for all four of the major dams in the ORP system for Base Scenario 3 and are shown in Figures 4-26 to 4-29. From these plots, it is evident that for Base Scenario 3, the MOL in Gariep Dam was not reached, the lower-level storage in Vanderkloof Dam was not used, and the storage in the Noordoewer-Vioolsdrift Dam did not drop below MOL 2.

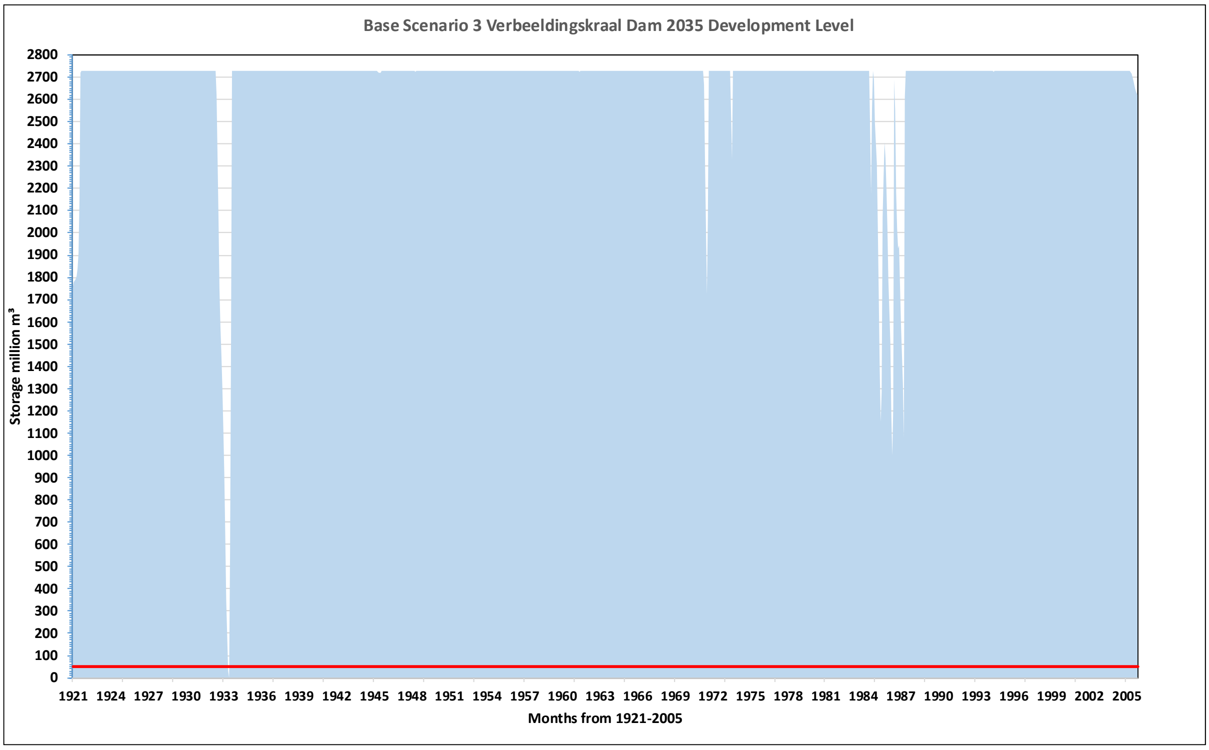


**Figure 4-26: Base Scenario 3: Verbeeldingskraal Dam storage projection plot**

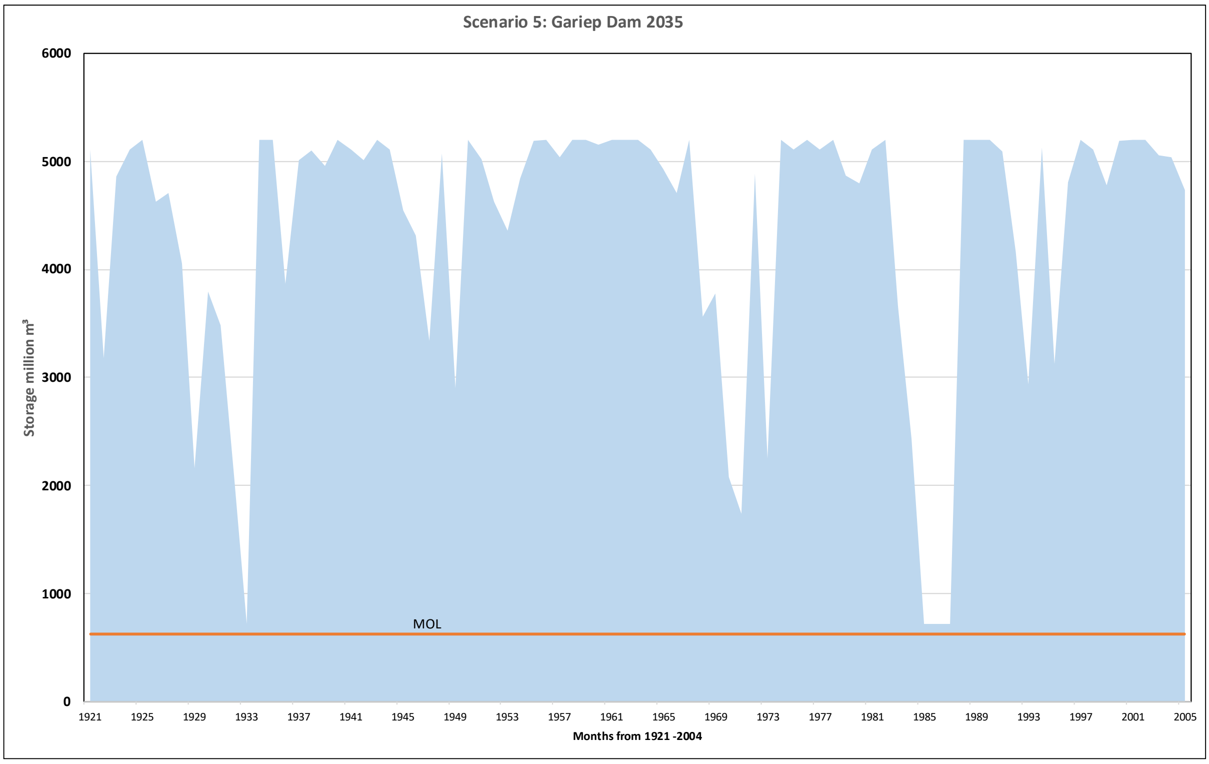


**Figure 4-27: Base Scenario 3: Gariep Dam storage projection plot**

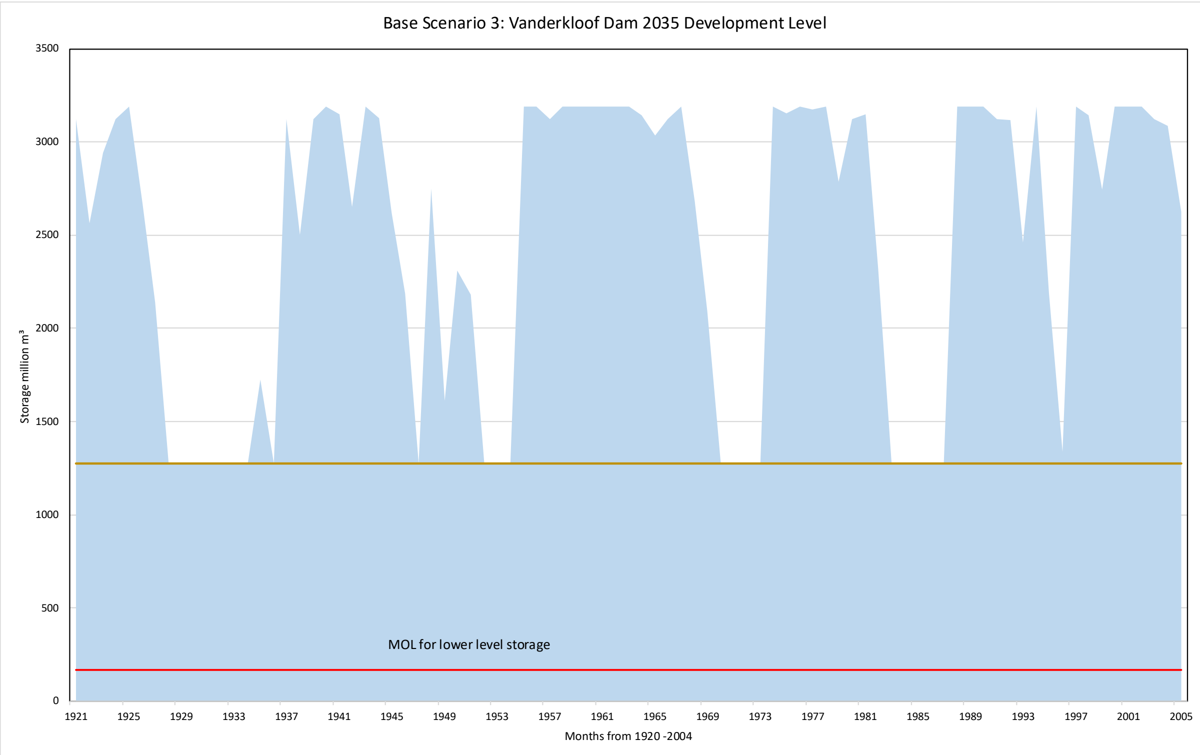


**Figure 4-28: Base Scenario 3: Vanderkloof Dam storage projection plot**

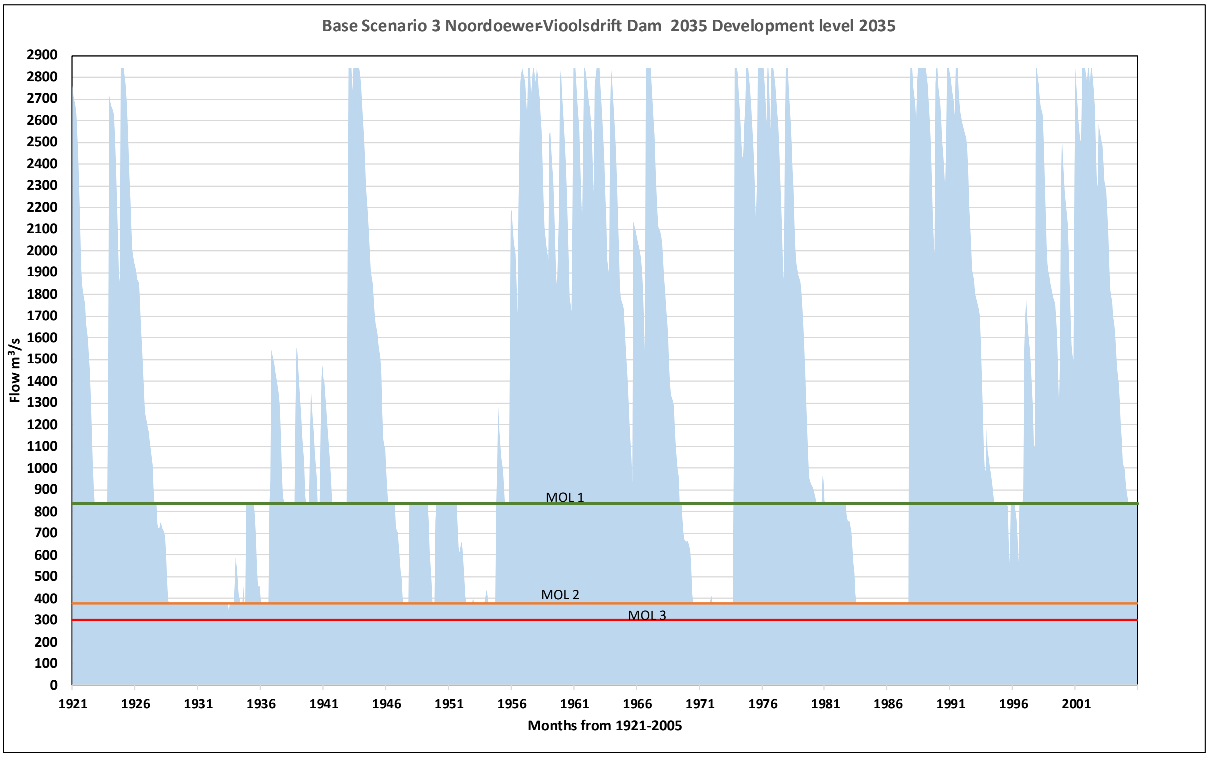


**Figure 4-29: Base Scenario 3: Noordoewer-Vioolsdrift Dam storage projection plot**

The difference in the storage projection for Scenario 4 versus Base Scenario 3 is so small that it is not visible from the storage projection plots. Some small differences are, however, visible when comparing the storage projection plots from Scenario 5 versus Base Scenario 3.

The storage projection plots for the four storage dams for Scenario 5 are given in Figures 4-30 to 4-33.

From these plots, it is evident that Gariep Dam now reached its MOL in October 1933.

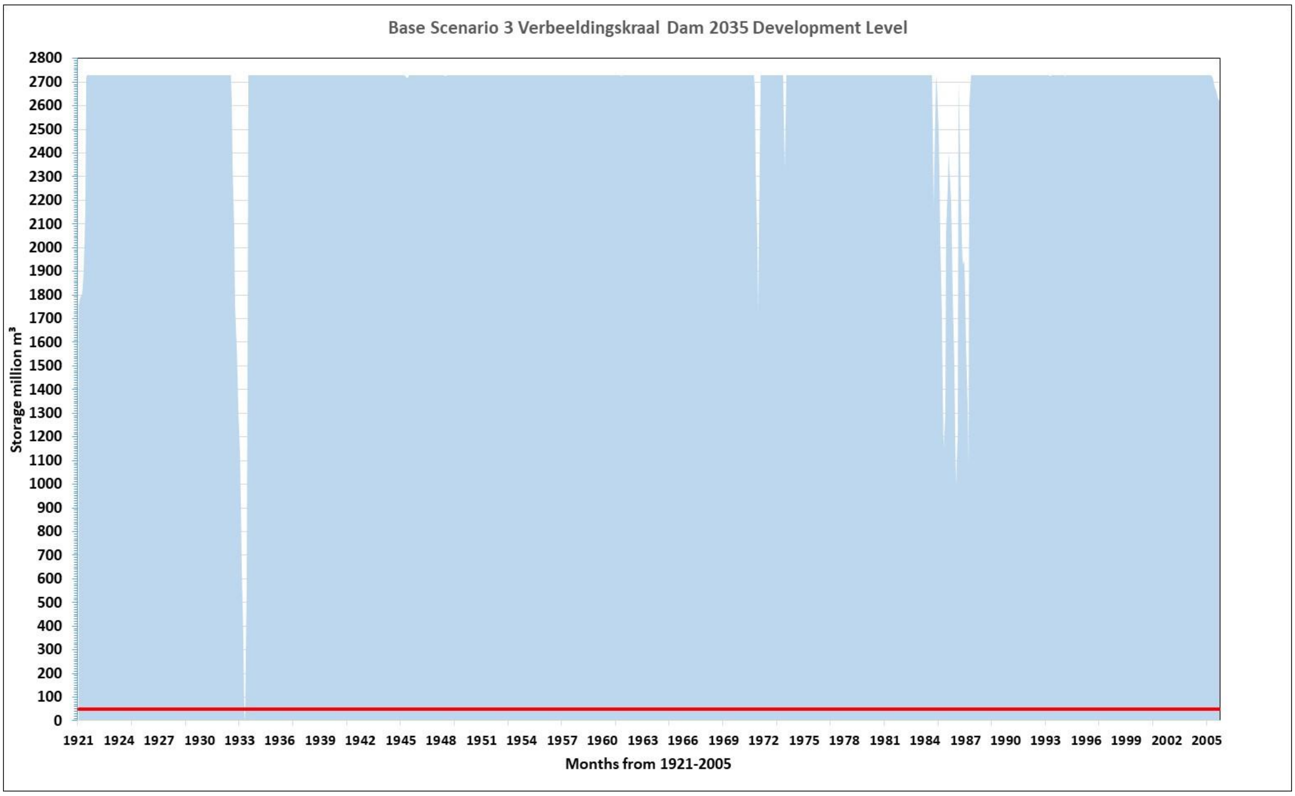


**Figure 4-30: Scenario 5: Verbeeldingskraal Dam storage projection plot**

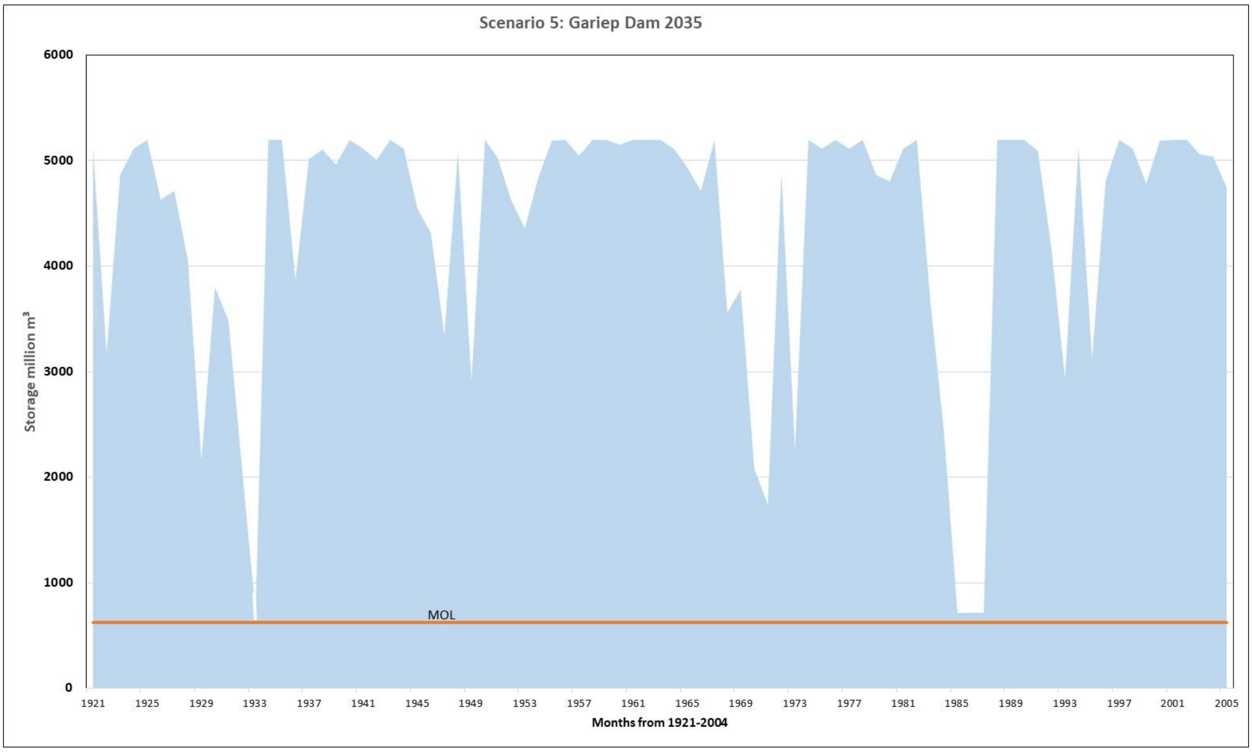


**Figure 4-31: Scenario 5: Gariep Dam storage projection plot**

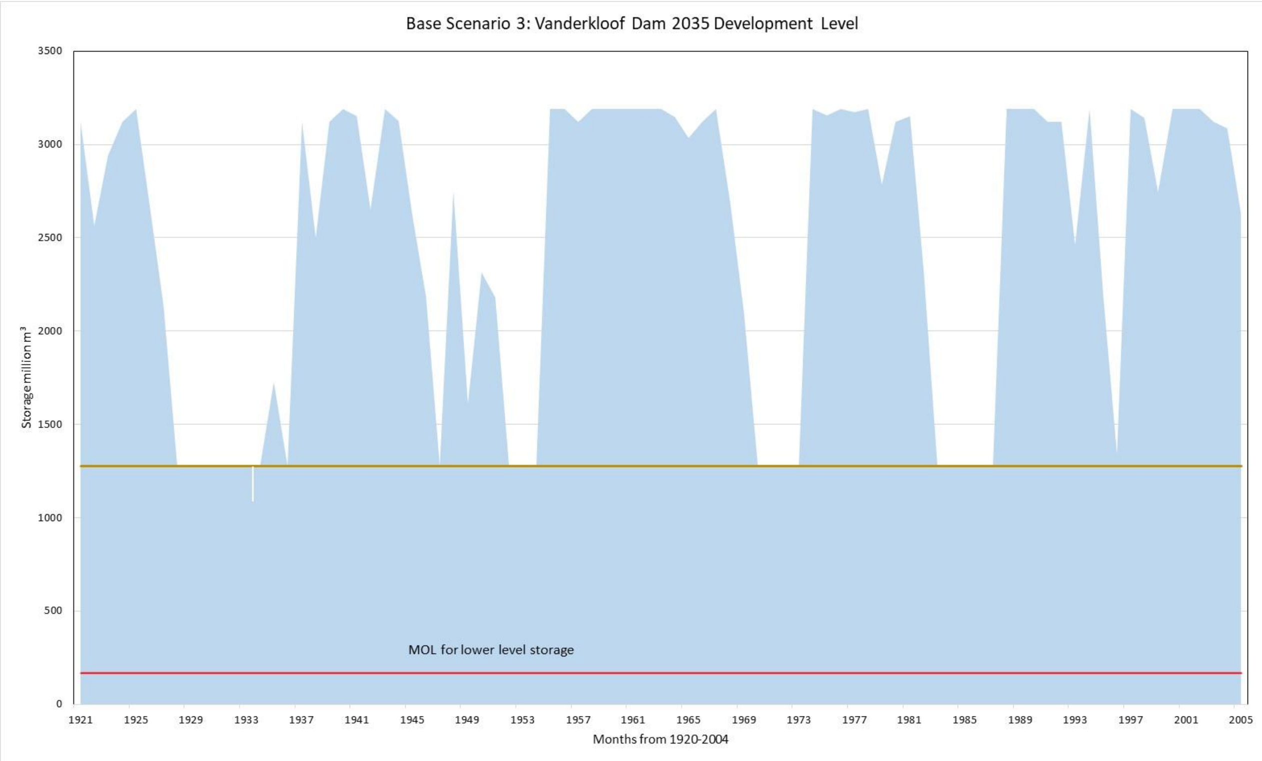


**Figure 4-32: Scenario 5: Vanderkloof Dam storage projection plot**

Vanderkloof Dam started to use the lower-level storage in October 1933, and the Noordoewer-Vioolsdrift Dam dropped below MOL 2 in October 1933.

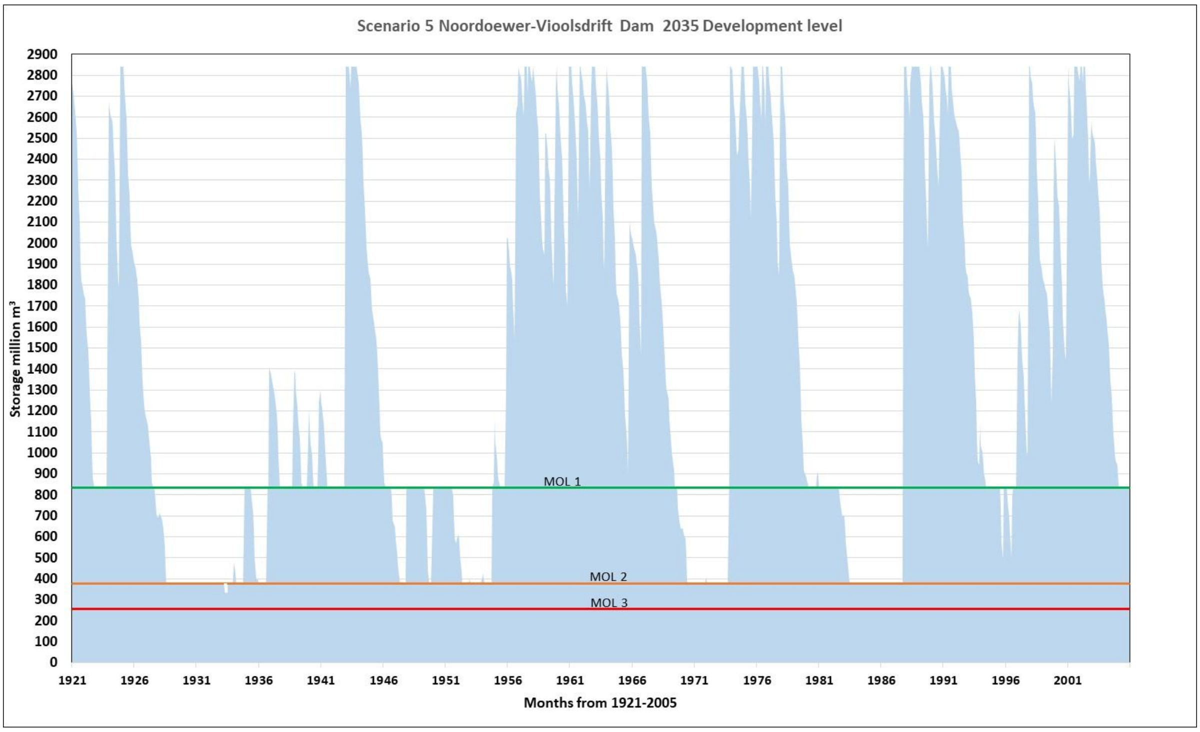


**Figure 4-33: Scenario 5: Noordoewer-Vioolsdrift Dam storage projection plot**

Although the dam levels dropped somewhat for Scenario 5 versus Base Scenario 3, it is clear from the storage projection plots that there is still water left in the Vanderkloof and Noordoewer-Vioolsdrift Dams to support an even higher demand. This is expected as the total expected growth in Namibia's future irrigation has not reached its limit by 2035. The expected growth in Namibia irrigation to be supplied from the Noordoewer- Vioolsdrift Dam between 2035 and 2050 amounts to a further 81 million $m^3$/a based on information from the Noordoewer- Vioolsdrift Dam Feasibility Study (March 2020)

The Noordoewer- Vioolsdrift Dam Feasibility Study Report mentioned that the water requirements for the future Haib Mine are included in its water requirement projections, but unfortunately the report does not indicate how much water was allowed for the Haib Mine. Base Scenario 3, which excludes the Haib Mine requirement, allowed for 5.93 million $m^3$/a for the Namibia mining/industrial water requirements, while the Noordoewer-Vioolsdrift Dam Feasibility Study Report showed 35.4 million $m^3$/a Namibia mining/industrial water requirements by 2035. The difference between the 35.4 and 5.93 million $m^3$/a of 29.47 million $m^3$/a is an indication of Namibia's mining/industrial sector growth, which includes Haib Mine. For Scenario 5, a Haib Mine demand of 20 million $m^3$/a was added, bringing the total Namibia mining/industrial requirement to 25.93 million $m^3$/a.

From the results obtained for Base Scenario 3, Scenario 4 and Scenario 5, it is clear that the Haib Mine requirement of 6 or 20 million $m^3$/a could be fully supplied at the 2035 development level without impacting the water use of all the other water users. It is, however, important to bear in mind that the final sizes of the Verbeeldingskraal and Noordoewer Vioolsdrift Dams were not yet agreed upon, and the final agreed storage capacities might thus differ from those analysed, which will impact the results given in this report.

# 5.0 STOCHASTIC ANALYSIS OF SELECTED SCENARIOS

In Section 4.1.2, the following Scenarios were agreed on with the client to carry out stochastic or risk analysis.

- Base Scenario 2
- Scenario 3
- Scenario 3g2
- Base Scenario 3
- Scenario 4
- Scenario 5

Historic analyses were carried out for all these scenarios, and results are given in Sections 4.2 and 4.3. The stochastic analyses and related results are given in Sections 5.1 and 5.2.

## 5.1 Base scenario 2, Scenario 3 & Scenario 3g2

Base Scenario 2 represents all the existing 2024 water resource development infrastructure plus the following expected near future developments (See Section 4.1.1 for more detail) that will significantly impact the water supply downstream of the Gariep and Vanderkloof dams. This scenario results in a deficit in the Orange River Project (ORP) water supply. The near future developments include the following:

- Polihali Dam and the tunnel to Katse Dam. The related increased volume to be transferred to the Vaal River System will form part of the analysis.
- Transfer water from the Gariep Dam to the Greater Bloemfontein area, including the improvements in the Greater Bloemfontein water supply system.
- Neckartal Dam irrigation and hydro-power generation are in place.
- Haib mine abstraction is not active.
- Water requirements at the 2035 development level.

Results from Base Scenario 2 will be compared against the results from Scenario 3 and Scenario 3g2.

Scenario 3 is as Base Scenario 2 but includes an off-channel storage dam at Haib and a pumpstation with a maximum capacity of 2 $m^3/s$. Water will be abstracted from the Orange River only during peak flows to ensure that downstream users are not negatively impacted. The Haib Mine water requirement of 20 million $m^3/a$ is supplied from the off-channel storage dam with a live storage capacity of 14.31 million $m^3$.

**Scenario 3g2** is as Base Scenario 2 but includes an off-channel storage dam at Haib and a pumpstation with a maximum pumping capacity of 0.8 $m^3/s$. Water will be abstracted from the Orange River only during peak flows to ensure that downstream users are not negatively impacted. The Haib Mine water requirement of 6 million $m^3/a$ is supplied from the off-channel storage dam with a live storage capacity of 3.75 million $m^3$.

The purpose of these three scenarios is to determine the impact of the two Haib Mine requirement scenarios of 6 million $m^3/a$ and 20 million $m^3/a$ on the ORP system and its users when using an off-channel storage dam receiving water from the Orange only during periods of high flow in the Orange River.

The impact on the upstream storage dams, Gariep and Vanderkloof Dams, used to supply all the users from the ORP, will be illustrated by the storage projection plots for Gariep and Vanderkloof Dams and for the combined storage of the two dams.

Results from the stochastic analysis contain a wealth of information, and to be able to interpret these results, the box and whisker plots are used as explained in Section 3 of this report. This is briefly explained again below before presenting the stochastic results.

The results from the stochastic analysis were derived by using the WRPM and analysing 251 possible flow sequences (possible future natural rainfall runoff from each sub-catchment) with record lengths of 15 years. This means that the model will produce 251 different answers for each monthly storage volume, water supply, river flow, etc. To be able to put meaning to these vast numbers of results, box plots are used to describe the results in terms of exceedance probability (See Figure 5-1).

The vast number of results is represented by the encircled yellow dots in Figure 5-1. Using the box and whisker plots, meaning is given to these results. For example:

- The lowest solid line of the boxplot indicates that 100% of all the flow sequences analysed are at or above this line.
- The dashed line just above that states that 99.5% of all sequences are at or above this line. This represents a 1 in 200-year recurrence interval.
- The dot, dashed line combination shows the 99% exceedance probability, representing the 1 in 100-year recurrence interval.
- The lower whisker of the boxplot represents the 95% exceedance probability or a 1 in 20 years recurrence interval.
- The middle of the box shows the 50% exceedance probability or median value.

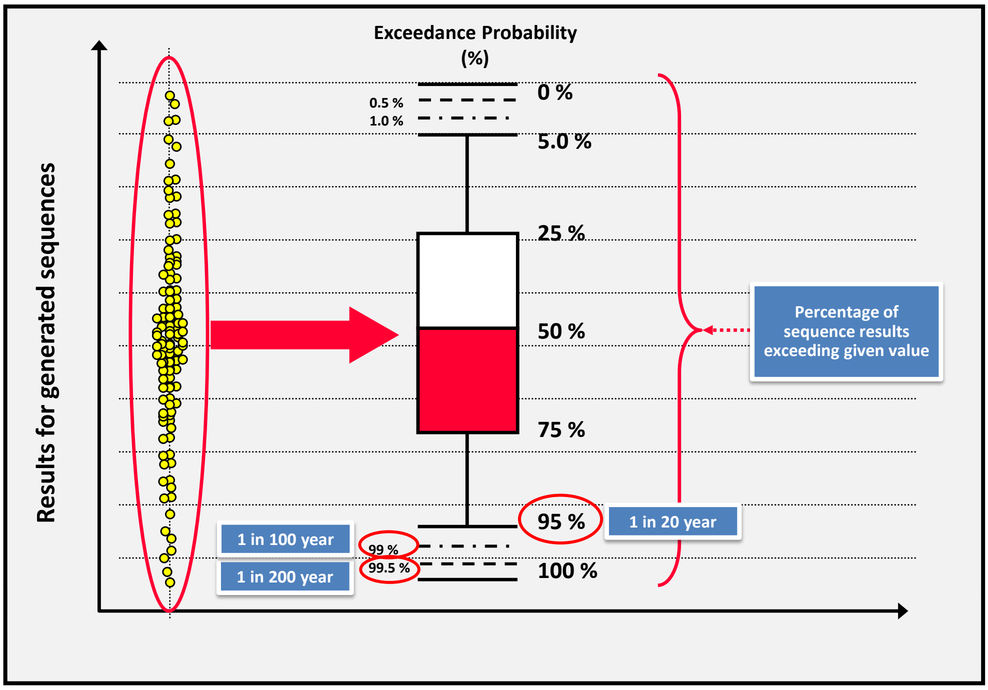


**Figure 5-1: Probability distribution of stochastic results**

The same approach applies to all the other percentage exceedance probabilities as given in Figure 5-1

The WRPM utilises the short-term yield characteristics from the water supply system, for example, the Orange River Project, to supply water to users at their required assurance levels, which will differ for different types of user groups. To be able to define the combinations of the different supply assurance levels, a priority classification table is used, as given in Table 5-1 for the ORP System

From Table 5-1, it is, for example, evident that 50% of irrigation is supplied at a low assurance of 95% (1 in 20-year risk of non-full supply), 40% at a medium assurance (99%) and 10% at a high assurance (99.5%). During severe droughts when restrictions need to be imposed, the water supply allocated to the low assurance class will first be reduced or restricted, followed by the medium, and finally the high assurance class. Restriction level 1 refers to the full restrictions imposed on the low assurance class. The restrictions will, however, be implemented gradually before imposing full level 1 restrictions.

**Table 5-1: Orange River Project current Priority Classification**

| Sector (Recurrence Interval of a restriction; Assurance of supply) | Priority Categories (Portion of the water requirements %) | | |
|---|---|---|---|
| | High | Medium | Low |
| | 1: 200 year (99.5%) | 1: 100 year (99%) | 1: 20 year (95%) |
| Irrigation | 10 | 40 | 50 |
| Urban | 50 | 30 | 20 |
| Operational requirements | 100 | 0 | 0 |
| Environmental | 68 | 0 | 32 |
| Restriction levels: 3 | 2 | 1 | 0 |

The assurance classes for the environmental requirements are only applicable to the current "old" Environmental Water Requirements (EWR) releases, which are based on a different methodology than the more recently determined EWRs. The latest EWRs follow the same pattern and probability of occurrence as the natural flows generated in the basin and do not require a specified fixed assurance.

The above-mentioned descriptions should be used to evaluate the results from the stochastic analyses provided in the sections below.

### 5.1.1 Results from the Stochastic Analysis

Bloemhof Dam is the most downstream dam on the Vaal River, and spills from this dam will also reach the Orange River just downstream of Douglas. No releases are, however, made from Bloemhof Dam in support of the users along the Orange River. For that reason, it would be expected that Scenarios 3 and 3g2 will have no impact on Bloemhof Dam. This is clear from the Bloemhof Dam storage plots given in Figures 5-11, 5-12 and 5-13.

When comparing the Gariep, Vanderkloof and combined ORP storage projection plots for the three different scenarios, it is evident that the inclusion of the Haib off-channel storage dam and related pumping from the Orange River did not impact the storage in those dams, as the storage projections between the three scenarios are identical. (For Gariep Dam see Figures 5-2, 5-3 and 5-4. For Vanderkloof Dam, see Figures 5-5, 5-6 and 5-7, and for the ORP system storage, see Figures 5-8, 5-9 and 5-10.

The operating rule for the ORP system makes use of the short-term yield characteristics to impose restrictions on the users during droughts to protect the resource from running empty. From the ORP storage projection plots for all three scenarios, it can be seen that even at a very severe drought of 1 in 200 years (99.5% exceedance probability), the combined storage of the two dams only touched the minimum operating level towards the end of the simulation. Although the ORP system is totally overloaded for these scenarios, the operating rule was still able to protect the resource from running empty.

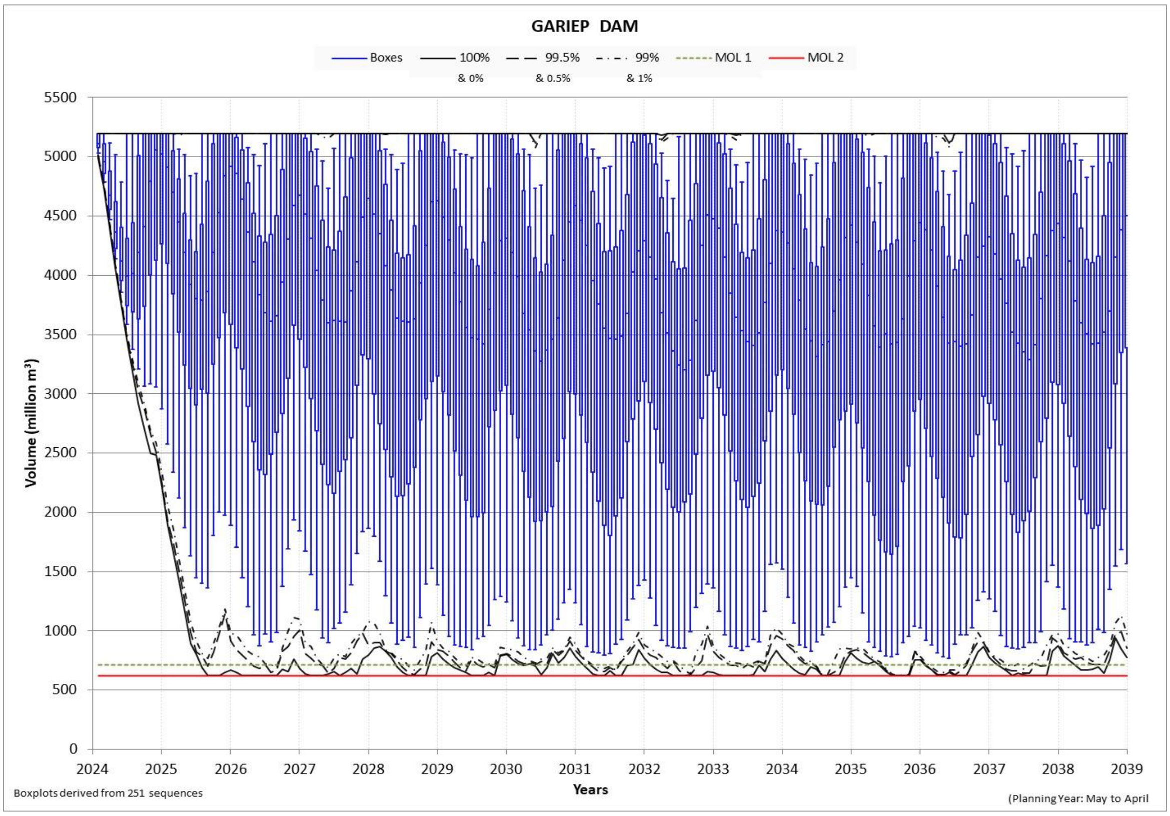


**Figure 5-2: Base Scenario 2 Gariep Dam storage projection plot**

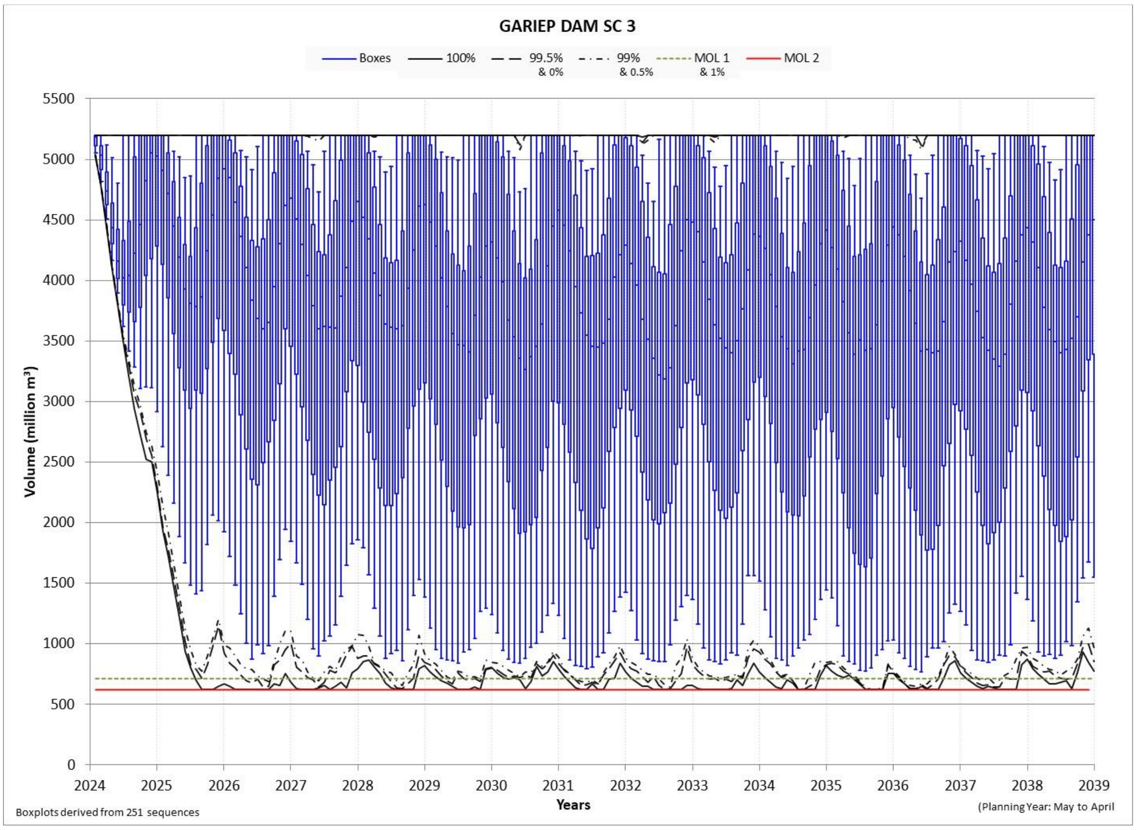


**Figure 5-3: Scenario 3 Gariep Dam storage projection plot**

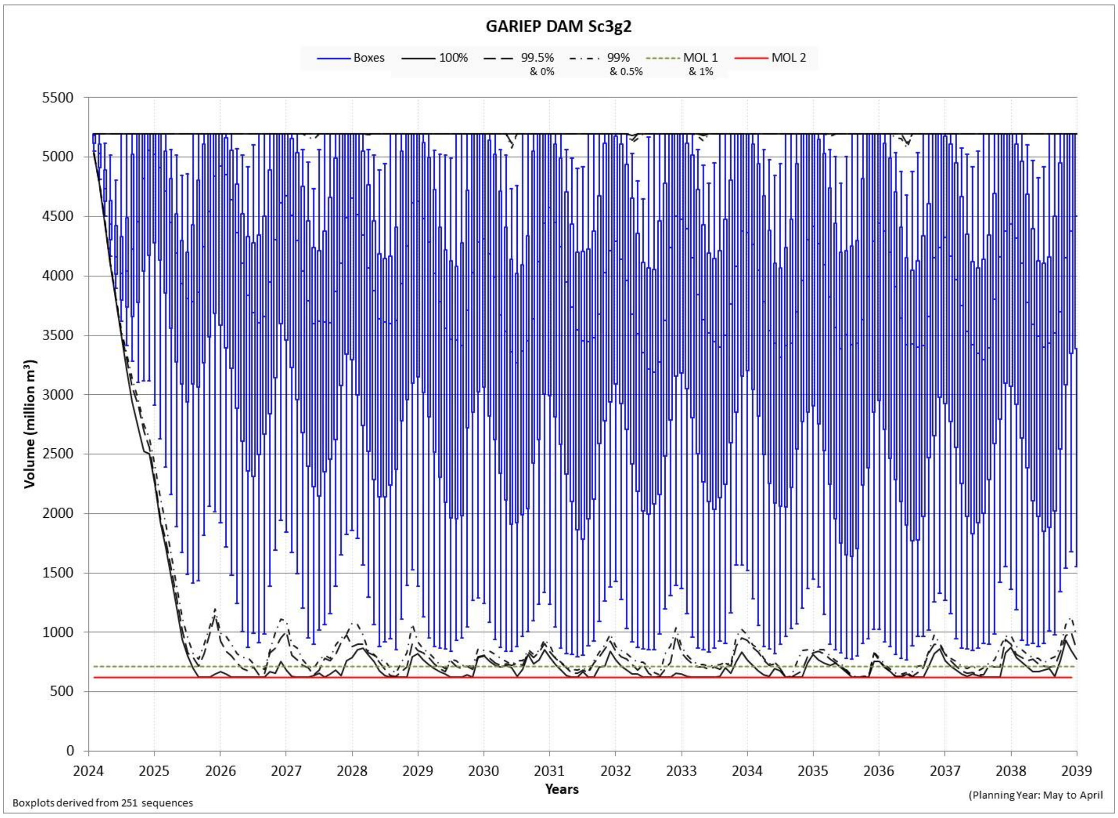


**Figure 5-4: Scenario 3g2 Gariep Dam storage projection plot**

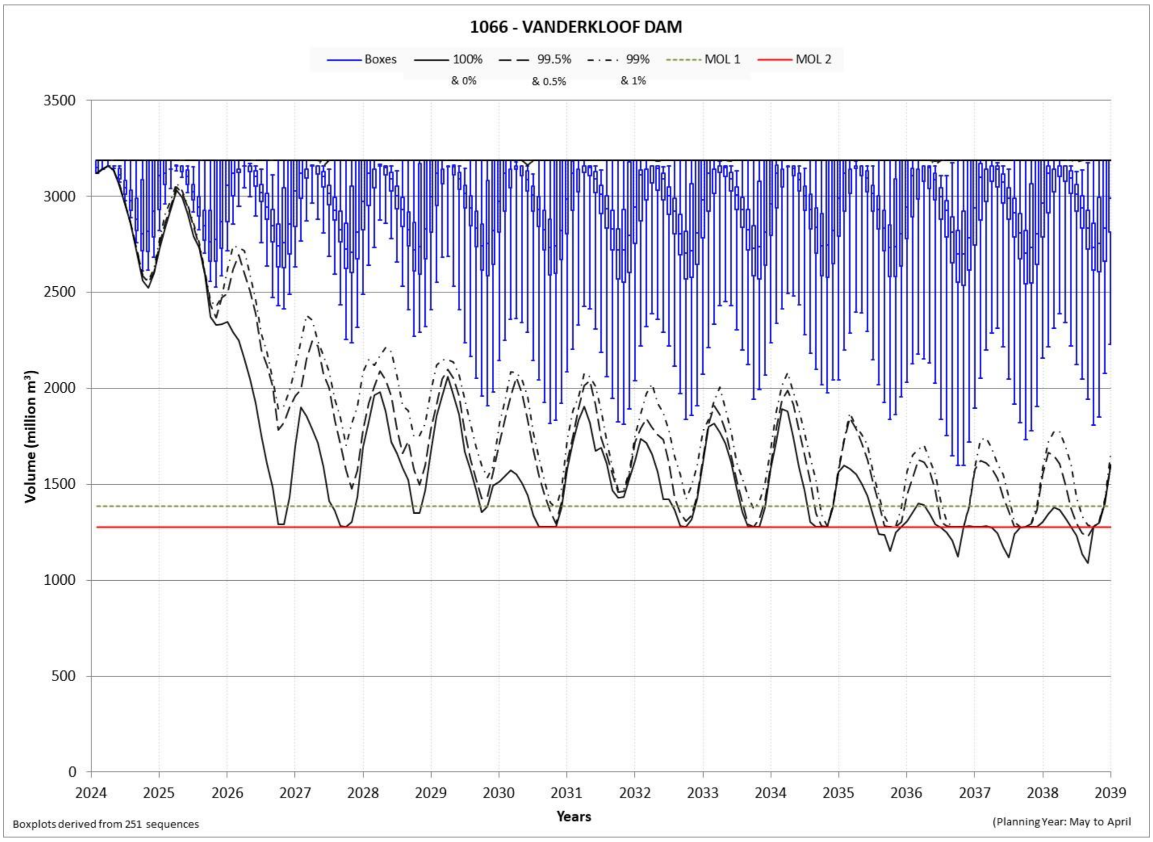


**Figure 5-5: Base Scenario 2 Vanderkloof Dam storage projection plot**

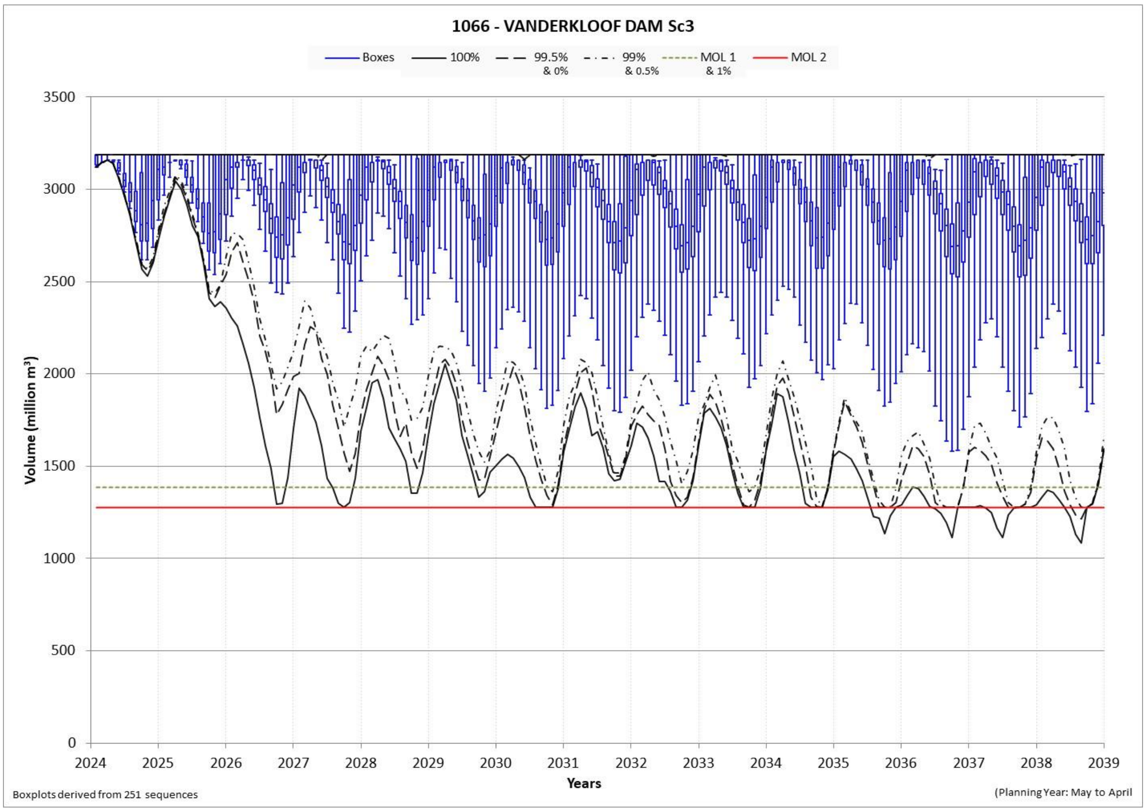


**Figure 5-6: Scenario 3 Vanderkloof Dam storage projection plot**

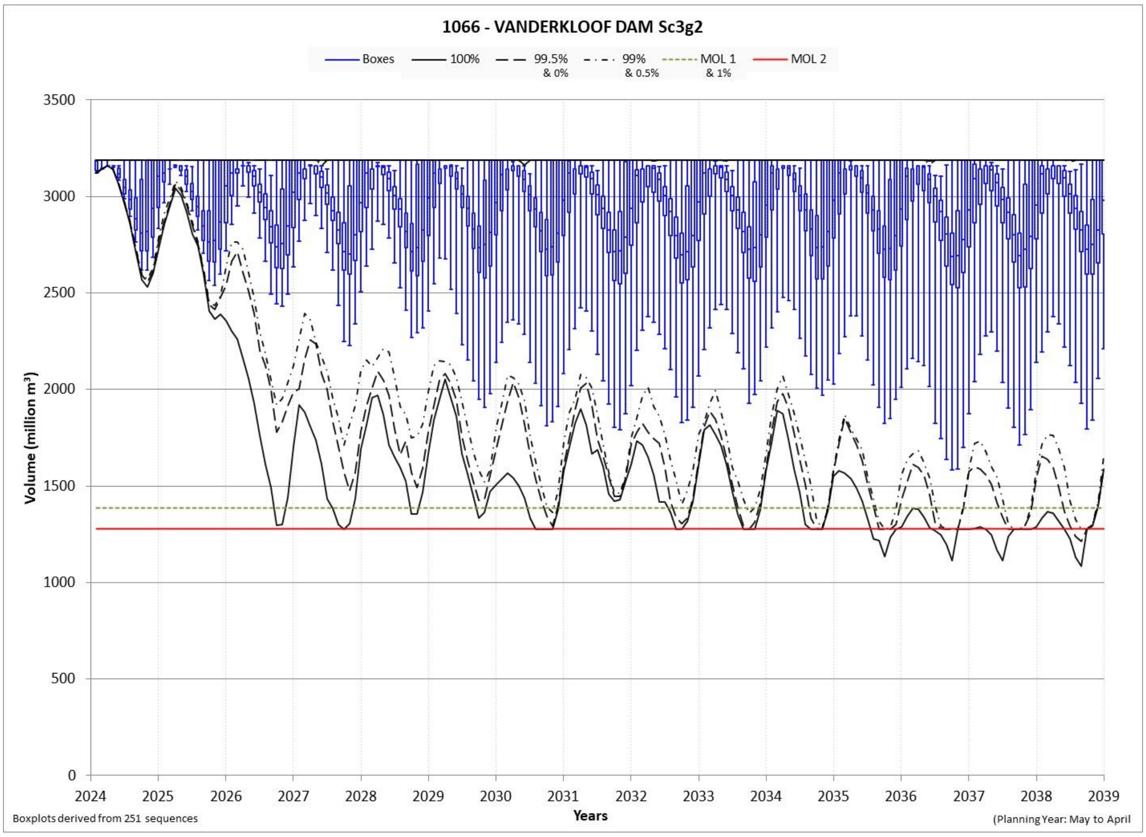


**Figure 5-7: Scenario 3g2 Vanderkloof Dam storage projection plot**

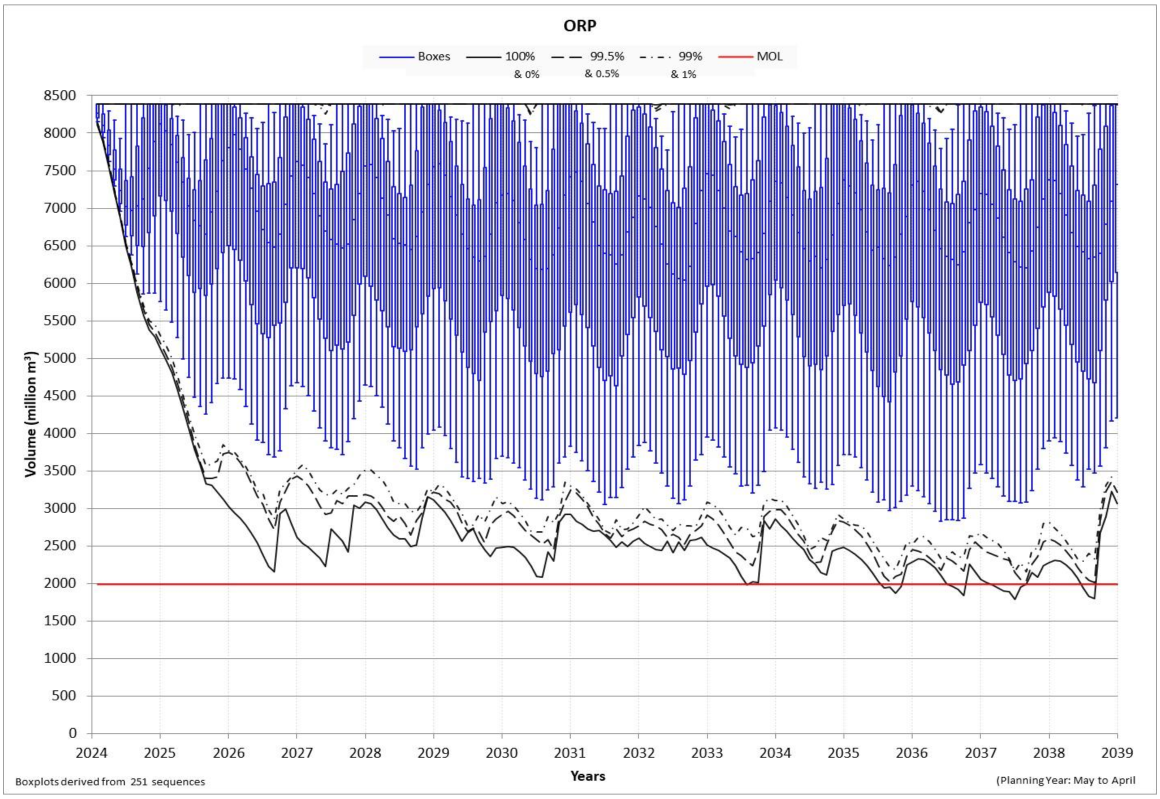


**Figure 5-8: Base Scenario 2 Combined Gariep and Vanderkloof storage projection plot**

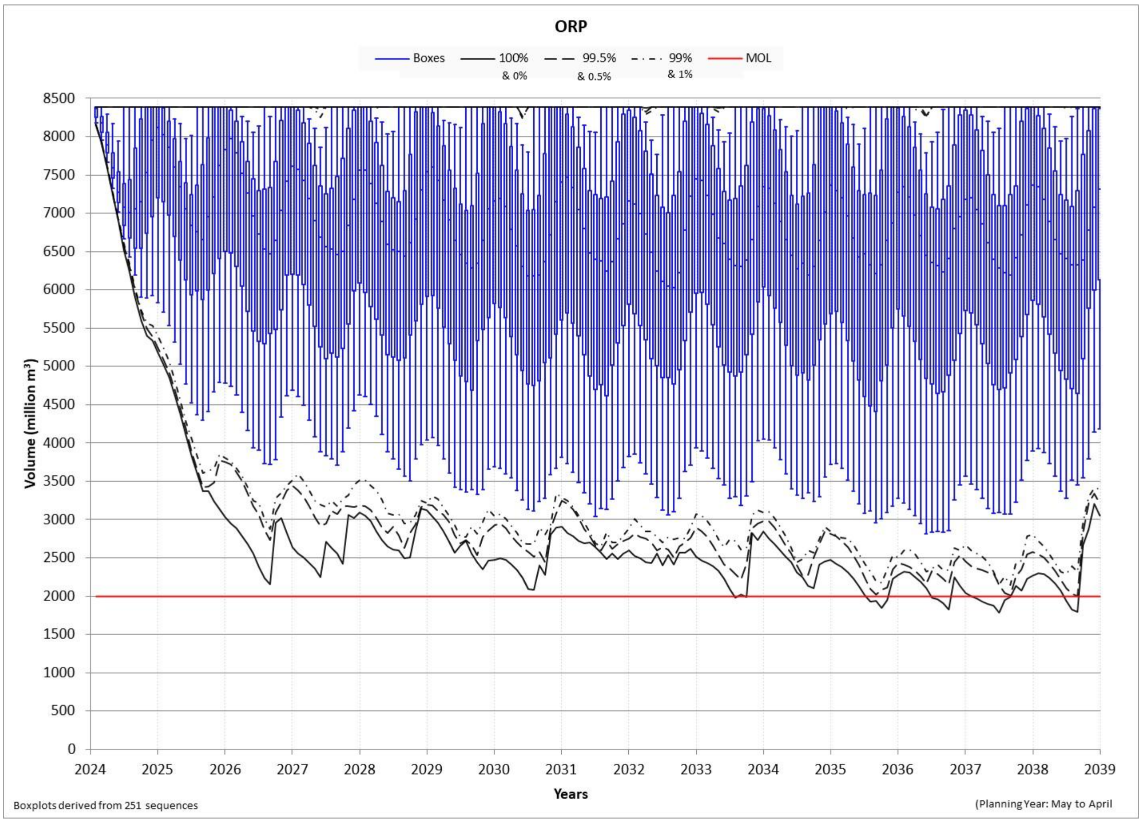


**Figure 5-9: Scenario 3 Combined Gariep and Vanderkloof storage projection plot**

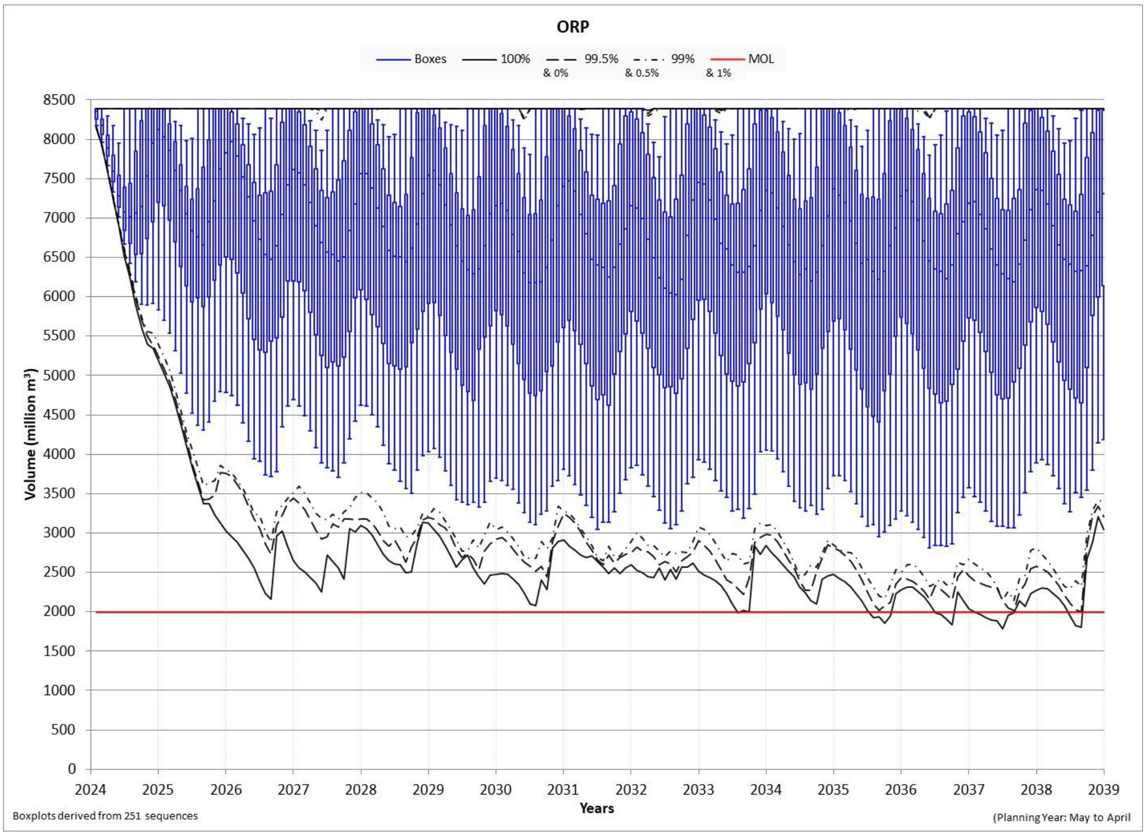


**Figure 5-10: Scenario 3g2 Combined Gariep and Vanderkloof storage projection plot**

At the 2035 development level, the water requirements to be supplied from the Gariep and Vanderkloof Dams already exceed the yield available of the ORP system. This is clearly evident from the curtailment plots produced for the three scenarios given in Figures 5-16, 5-17 and 5-18. The curtailment plots show that the curtailment criteria were violated from 2025 onwards. It is important to note that the curtailment plots for all three scenarios are identical, which means that the supply to the users from the ORP is identical. This confirms that the inclusion of the Haib Dam and associated water supply to Haib Mine did not impact the water supply to the other users.

When supplying a demand of 20 million $m^3/a$ from Haib off-channel storage to Haib Mine, a storage capacity of almost 14 million $m^3/a$ is required. Only during very severe droughts, such as a 1 in 200-year drought, did the storage in Haib Dam just reach the minimum operating level of the dam (Figure 5-14). This shows that the 20 million $m^3/a$ to Haib Mine can be supplied at a high assurance.

This also applies to the small Haib off-channel storage dam with a storage capacity of almost 4 million $m^3$ and a demand of 6 million $m^3/a$ imposed on the dam. (See Figures 5-14 and 5-15). The median storage level in the off-channel storage dams (red line) shows that the dam should be relatively full or above 70% most of the time, but will drop to about 20% during typical 1 in 20-year droughts.

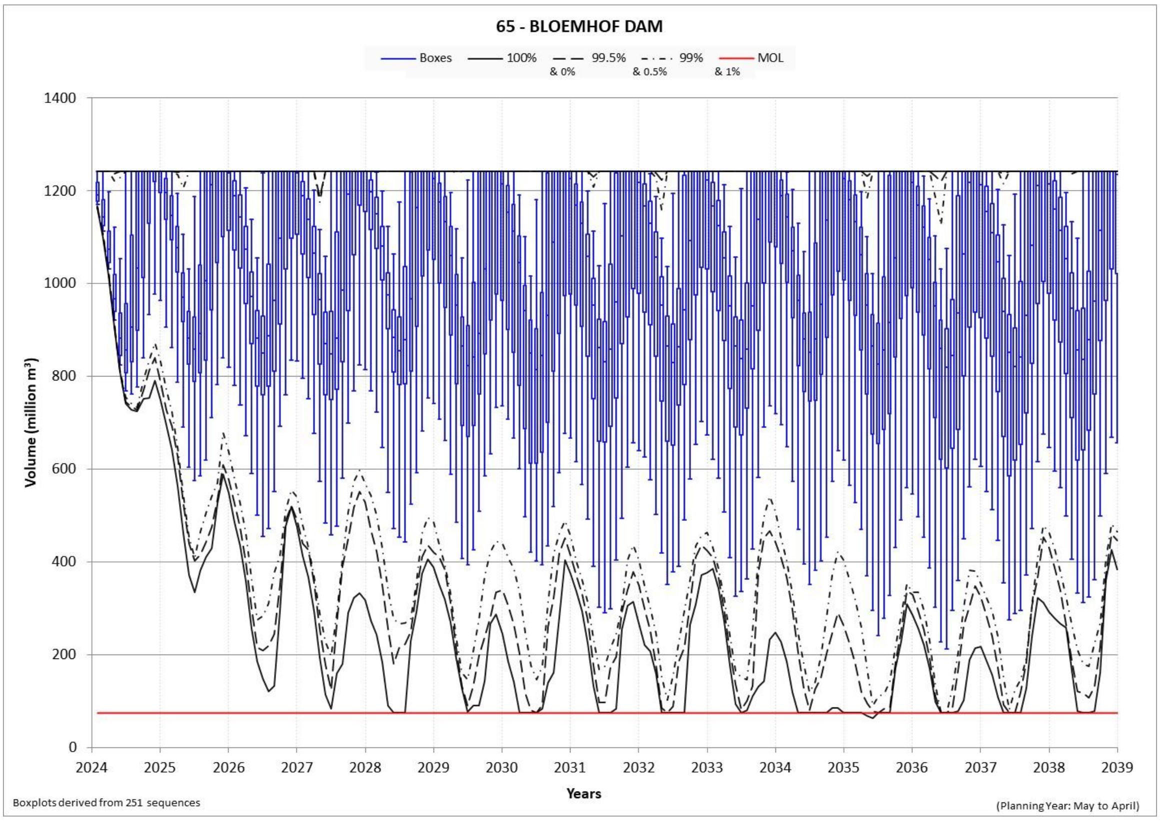


**Figure 5-11: Base Scenario 2 Bloemhof Dam storage projection plot**

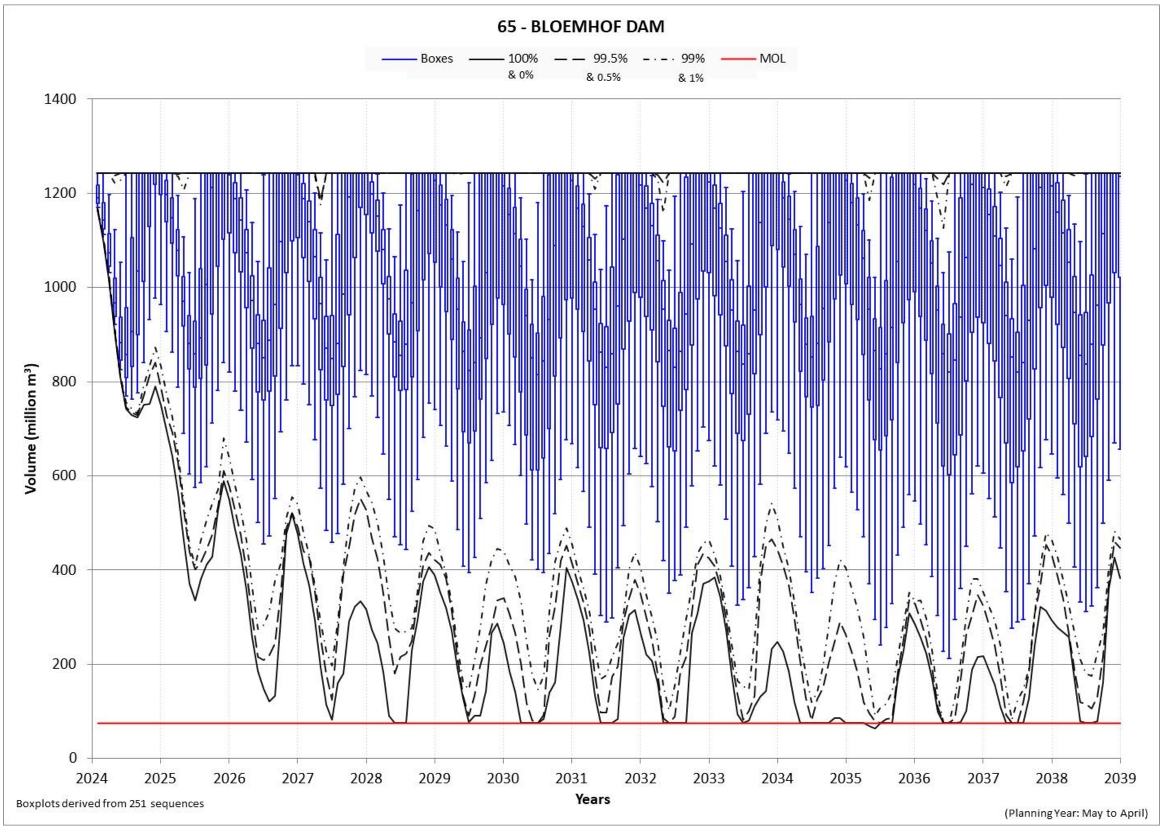


**Figure 5-12: Scenario 3 Bloemhof Dam storage projection plot**

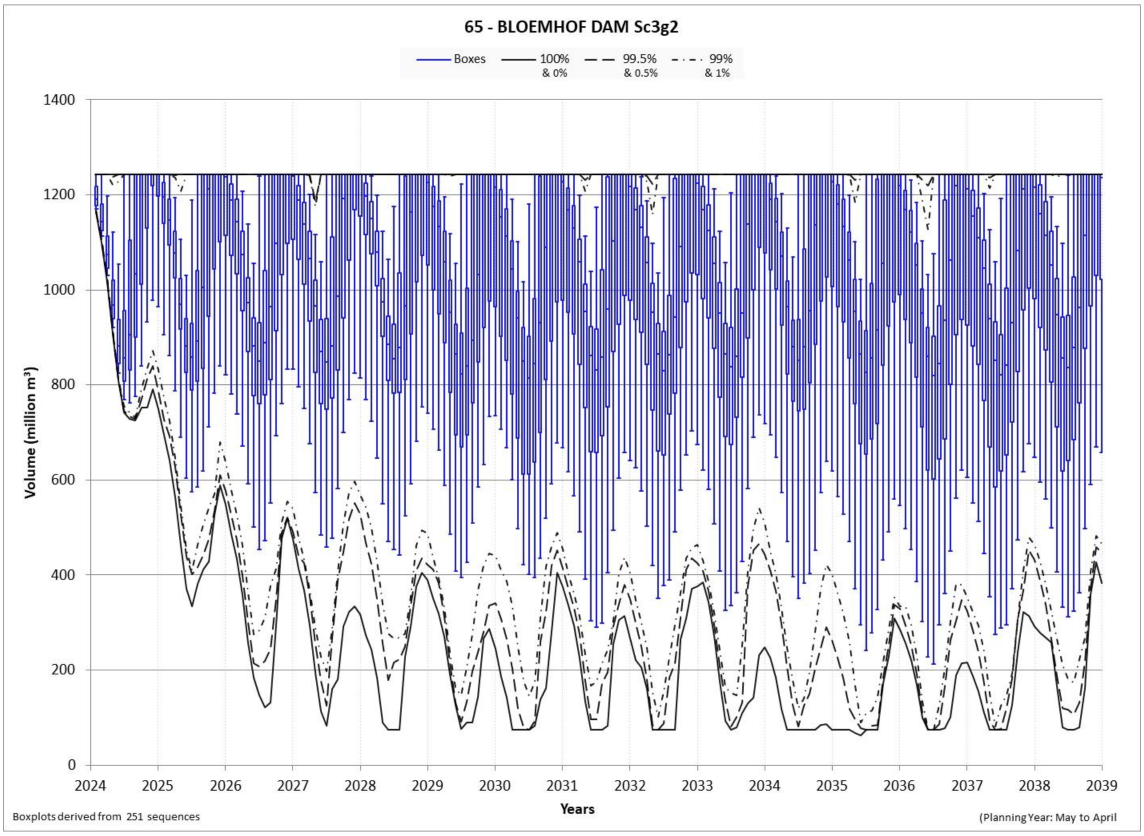


**Figure 5-13: Scenario 3g2 Bloemhof Dam storage projection plot**

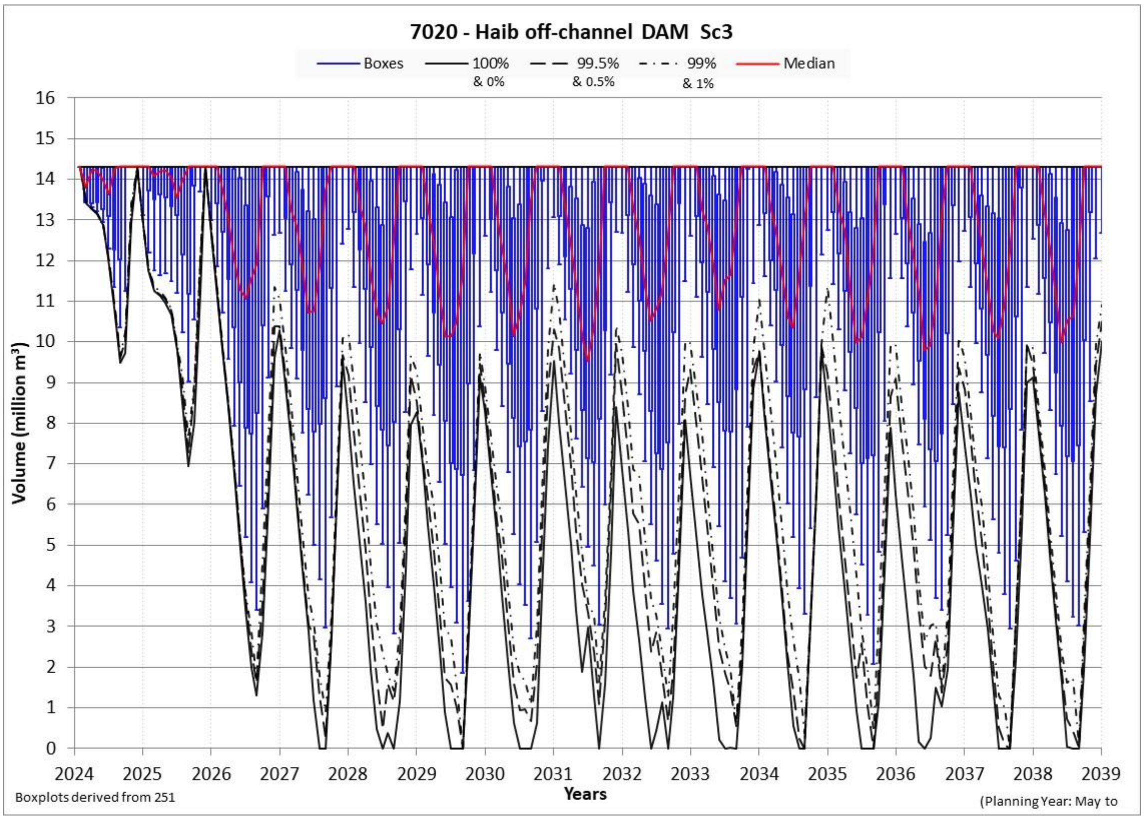


**Figure 5-14: Scenario 3 Haib Dam storage projection plot**

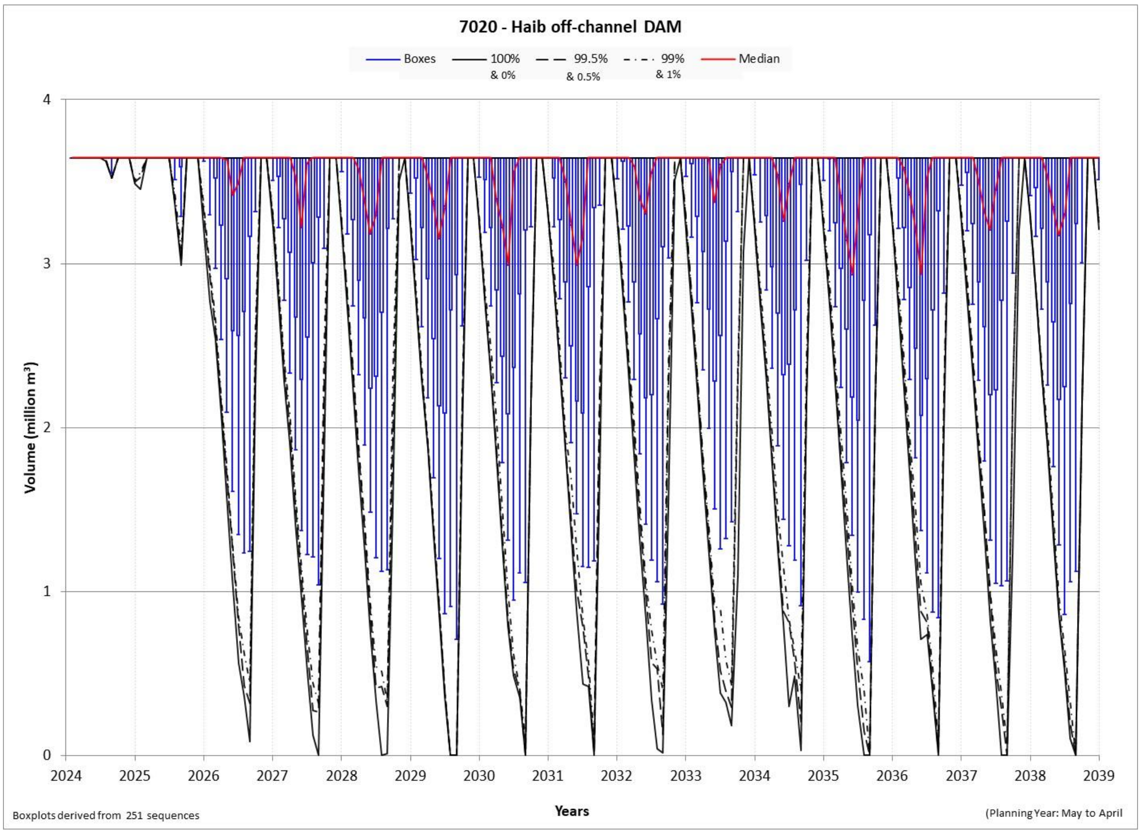


**Figure 5-15: Scenario 3g2 Haib Dam storage projection plot**

To illustrate the results from the WRPM relating to the restrictions or curtailments that were imposed on the ORP over time, a curtailment plot was generated from the model output. The curtailment plot shows how frequently curtailments were imposed on the system within each of the priority classes. When, for example, the low-priority class users were curtailed on average more often than only once in 20 years, it means that the system was not able to supply these users at their required assurance of 95%. A 95% assurance implies that the risk of restrictions should not exceed 5% (of the time), which also means that, on average, the restrictions should not occur more often than once in 20 years.

When the curtailment criteria are violated as described above, it indicates that the current system is no longer able to support the growing demand of the users at the defined or required assurance.

In Figure 5-16, the low assurance zone is shown in red, the medium assurance level in blue and the high assurance zone in green. The top whisker of the boxplot represents the 5% exceedance probability (1 in 20-year recurrence interval). When this whisker enters the low assurance zone, as highlighted in red, it means that the curtailment criteria have been violated. This means that restrictions occurred more often than 1 in 20 years. From Figure 5-16, it can be seen that the low assurance supply was violated from 2025 onwards at increasing levels.

The 1% line represents the 1 in 100-year recurrence interval. If this line enters the medium assurance zone, it means the curtailment criteria regarding the medium assurance are violated. This started to occur from 2026 onwards with an increasing trend.

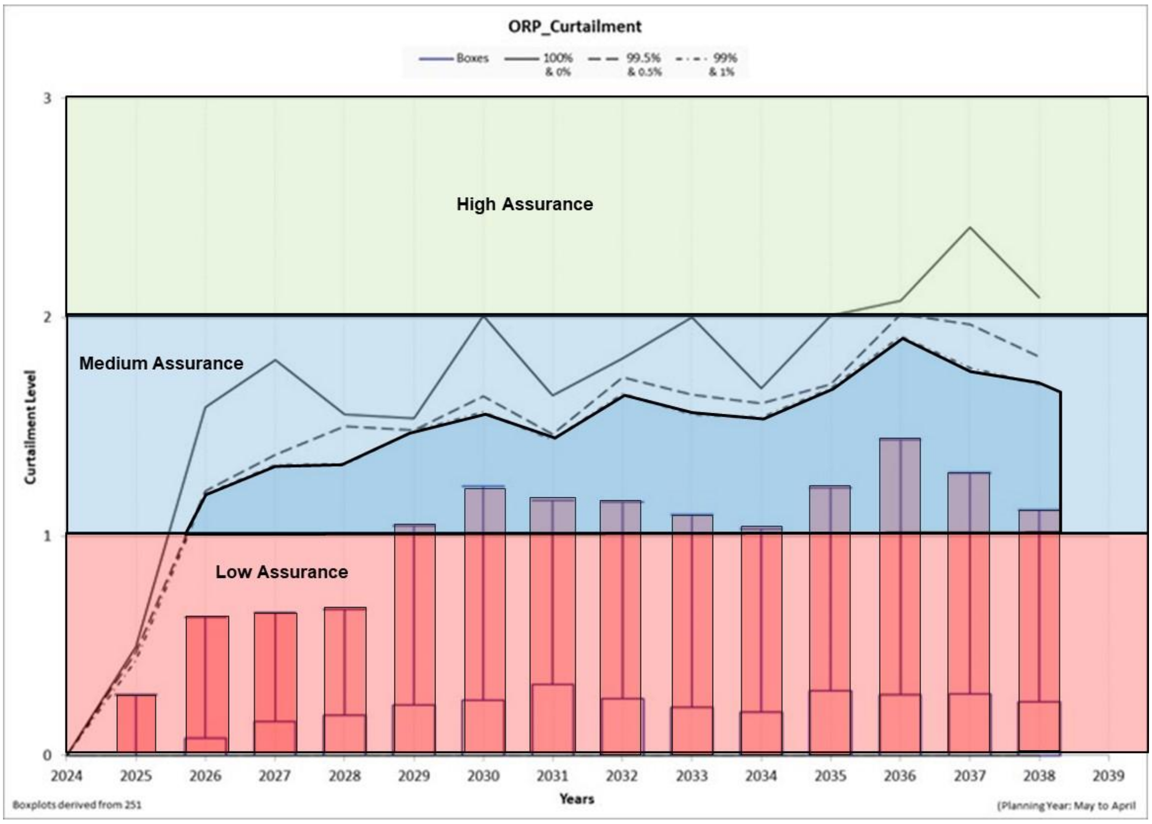


Figure 5-16: Base Scenario 2 ORP Curtailment plot

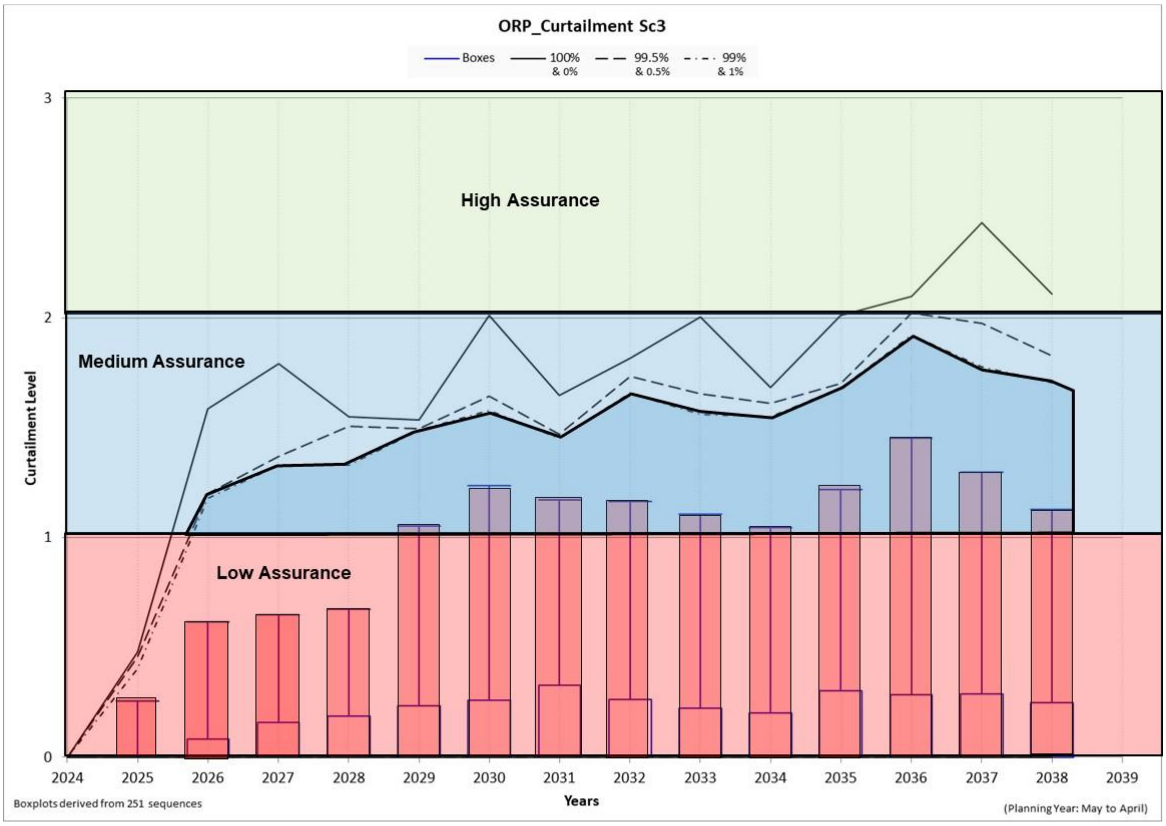


Figure 5-17: Scenario 3 ORP Curtailment plot

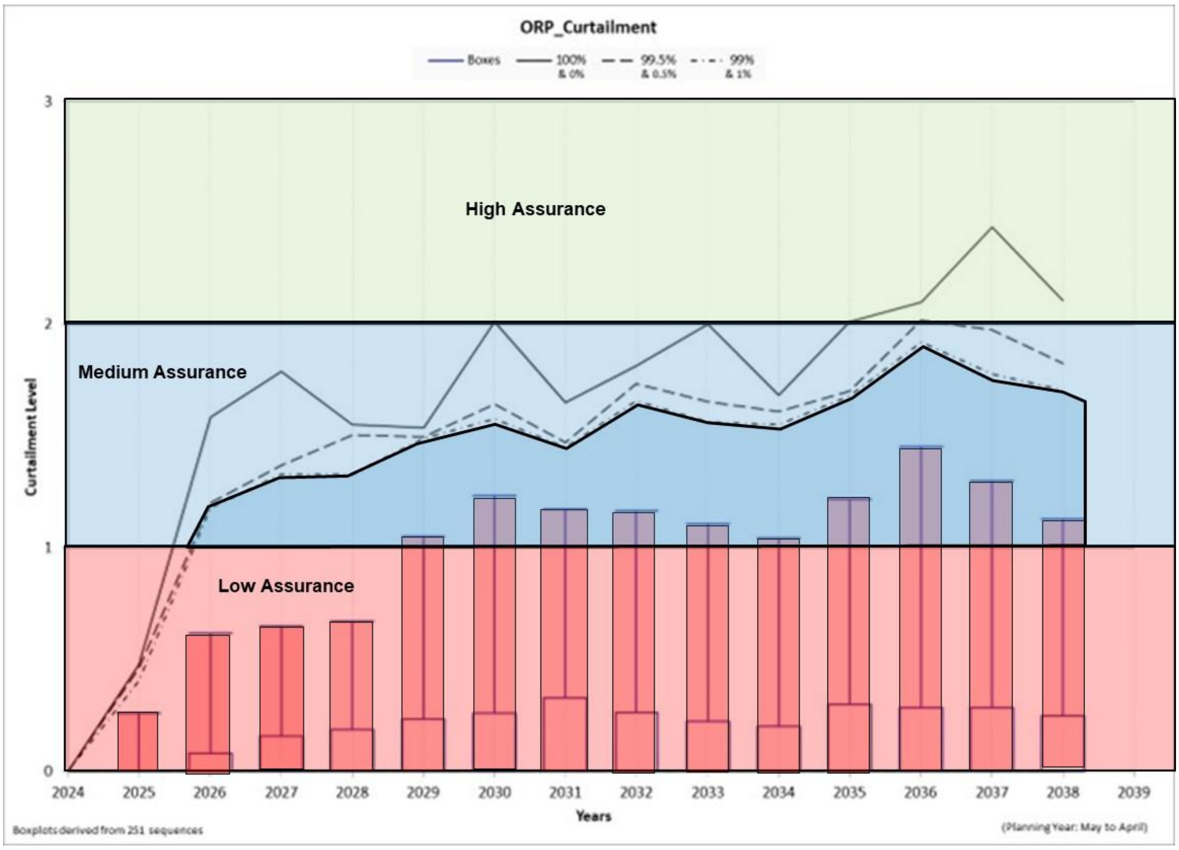


**Figure 5-18: Scenario 3g2 ORP Curtailment plot**

The 0.5% line represents the 1 in 200-year recurrence interval. When this line enters the high assurance zone, it means that the curtailment criteria for the high assurance supply are violated. This however did not occur over the entire simulation period, and the high assurance component of the demand could thus always be supplied in full. This applies to the curtailment plots of all three scenarios analysed, as these plots are identical.

The two main flow streams supplying water to the Lower Orange are the releases and spills from Vanderkloof Dam, as well as spills from the Vaal River System. No releases are made from Bloemhof Dam in the Lower Vaal in support of users along the lower Orange. Currently, all downstream demands from Vanderkloof Dam are supplied from Vanderkloof Dam, not taking into account any spills from the Vaal System. To prevent the WRPM from using Vaal spills to supply Orange River water users, the Vaal spills are modelled by a separate channel parallel to the channel representing the flows in the Orange River originating from Vanderkloof Dam releases and spills. The Vaal spills, and the Lower Vaal incremental runoff are shown in Figure 5-19.

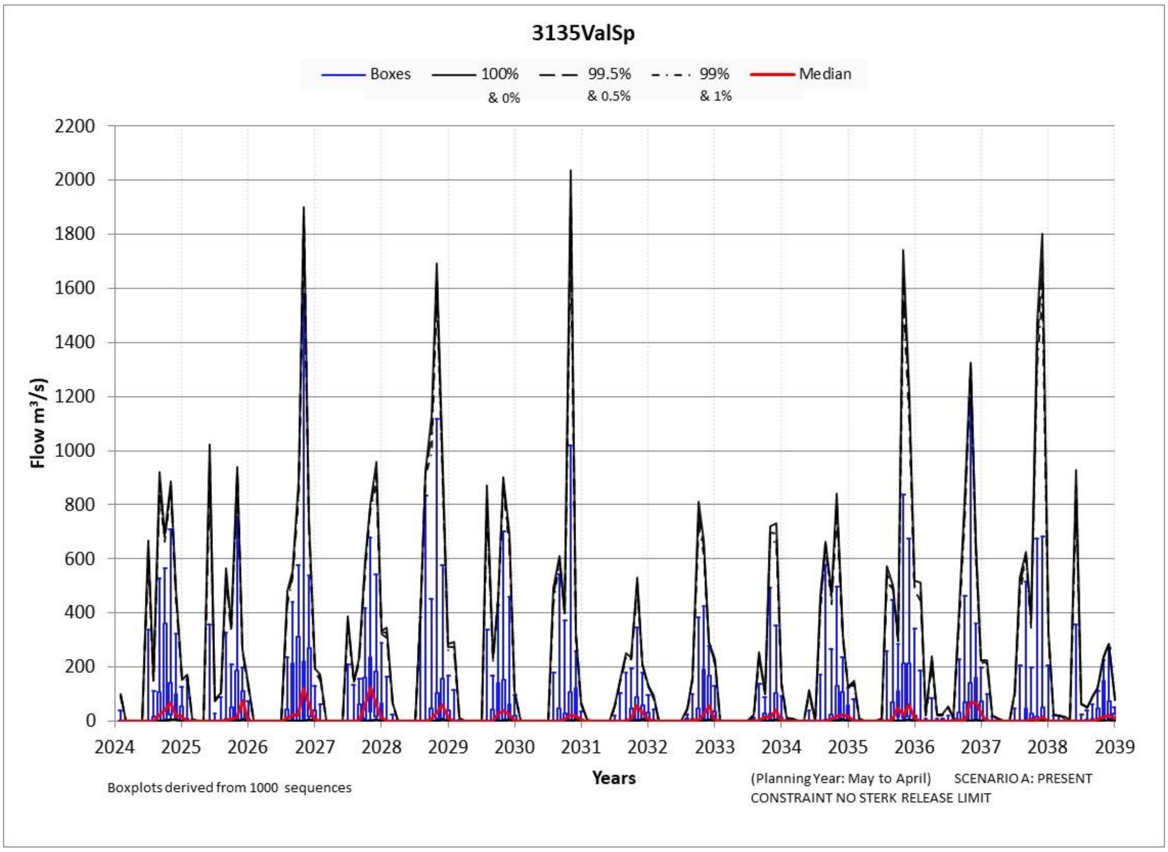


**Figure 5-19: Base Scenario 2 - Lower Vaal monthly incremental runoff and spills**

At first glance, it seems from Figure 5-19 as if there are a lot of flows entering the Orange from the Vaal. The median of these flows is highlighted by the red line and is much lower than the high flows representing the flows that occur once in 200, once in 100 and once in 20 years, etc. When zooming in on the low flows (Figure 5-20), it is evident that for typical dry years with a 1 in 20-year recurrence interval, the spills and incremental runoff from the Lower Vaal are much lower (green line), with peak flows in the order of 5 $m^3/s$ or smaller and with periods of 3 to 6 months of zero flows.

The flows just downstream of Vanderkloof Dam represent the typical flow in the Orange River before its confluence with the Vaal River. Similar to the Vaal River outflow, the Orange River flows also show high peak flows with relatively high recurrence intervals, as indicated by the flows above the median in Figure 5-21.

The lower flows in the Orange River are, however, quite different from the Vaal River low flows, as a strong base flow never reaching zero is evident (see Figure 5-22). The strong base flow represents the water required to satisfy all the downstream water requirements. Over the period 2031 to 2035, the base flows reduced due to the higher restrictions imposed on the system over that period (see Figure 5-16).

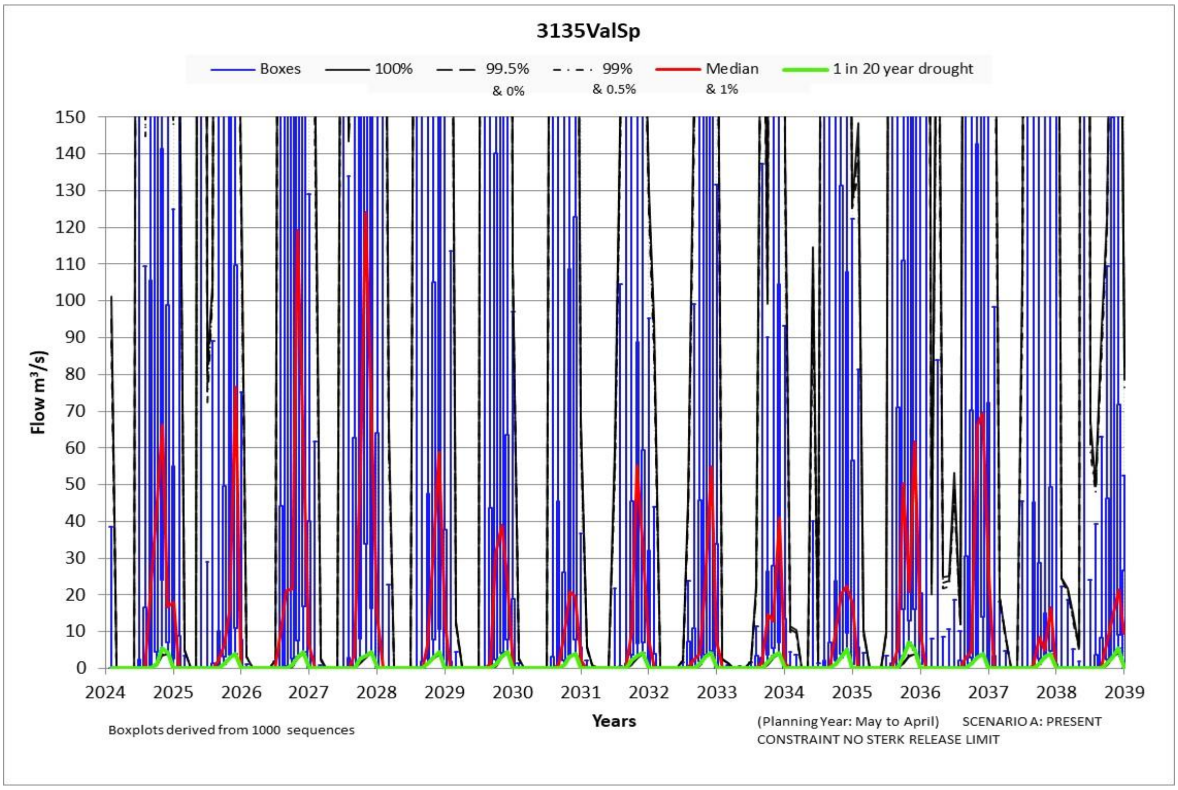


**Figure 5-20: Base Scenario 2 - Lower Vaal monthly incremental runoff and spills focussing on lower flows**

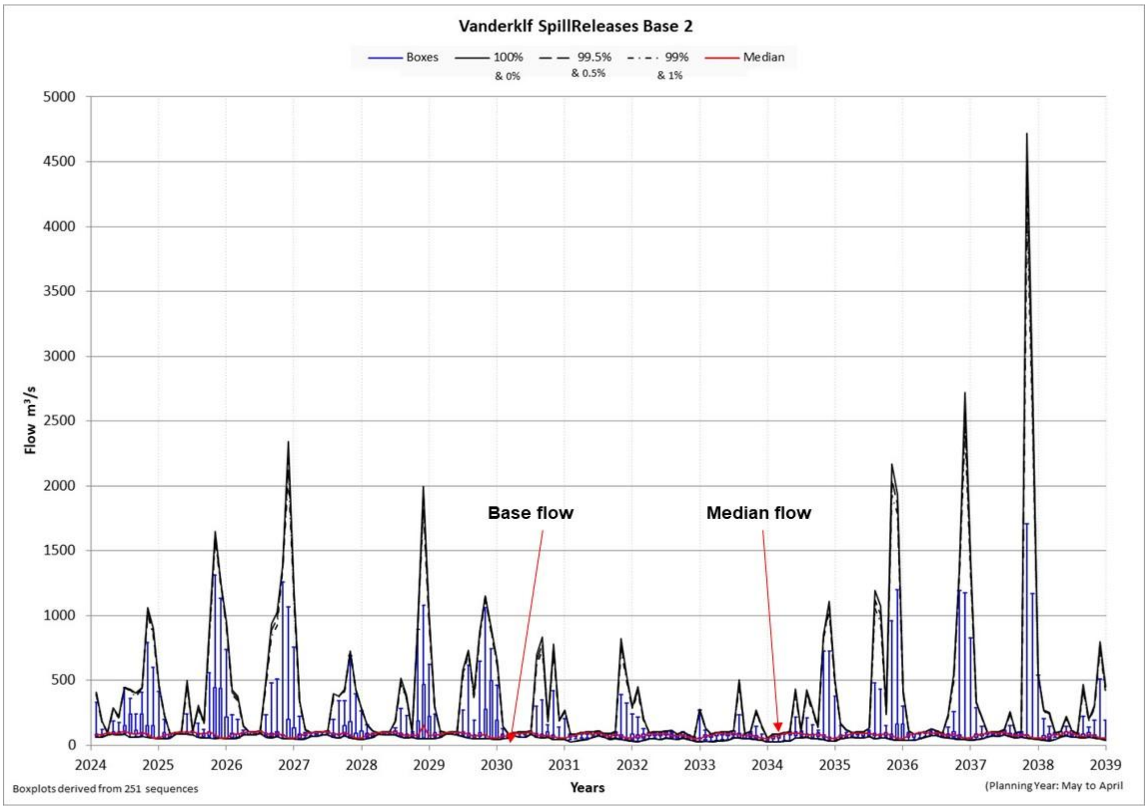


**Figure 5-21:Base Scenario 2 - Vanderkloof Dam monthly releases and spills**

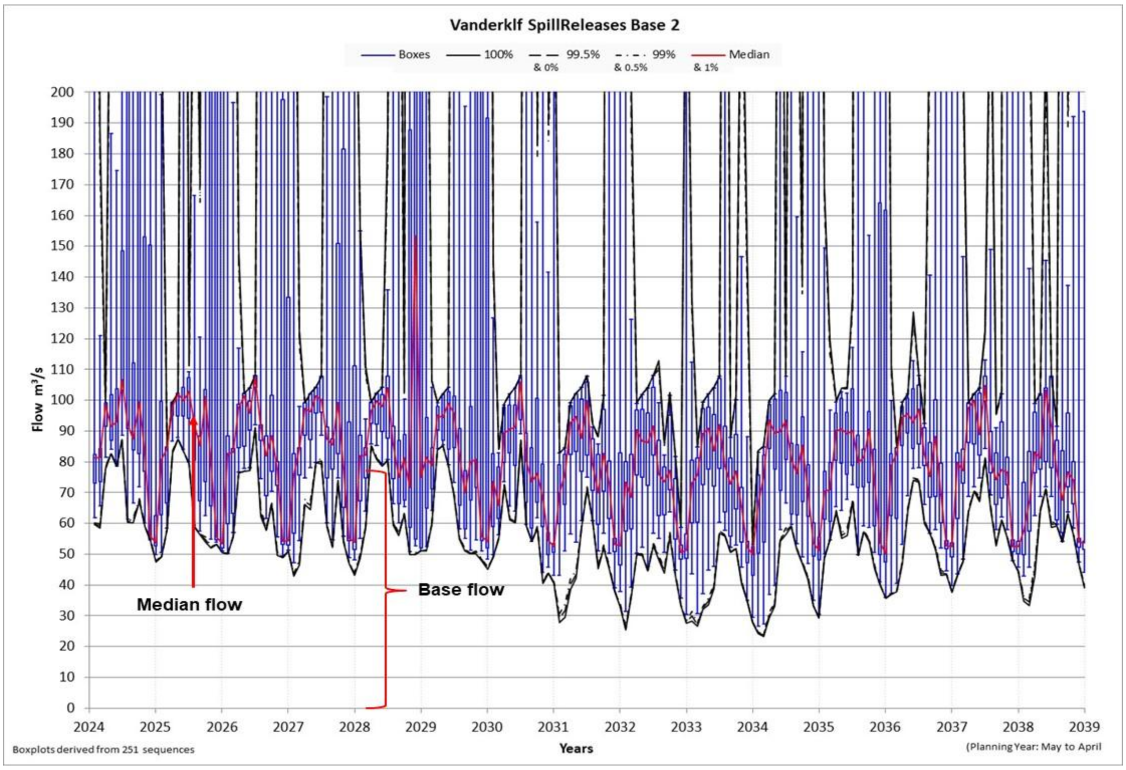


**Figure 5-22: Base Scenario 2 - Vanderkloof Dam monthly releases and spills focussing on lower flows**

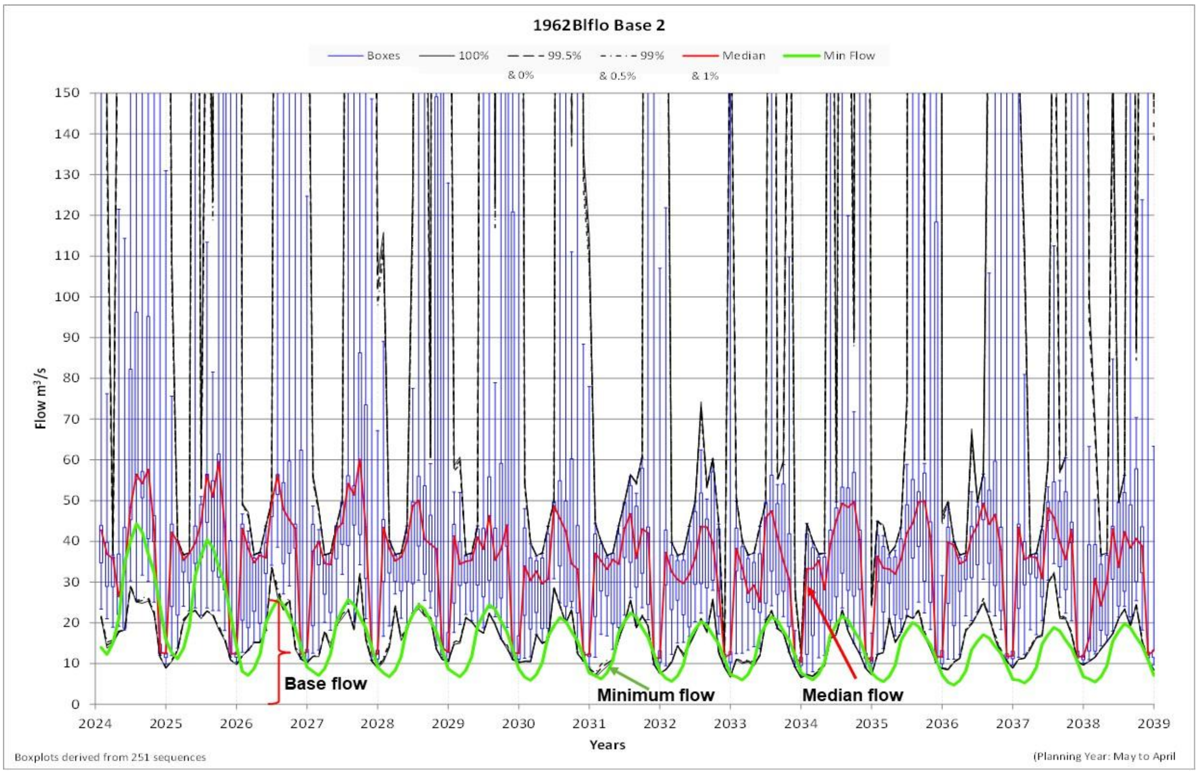


**Figure 5-23: Base Scenario 2 - Monthly low flows at Blouputs streamflow gauge (Vaal flows excluded)**

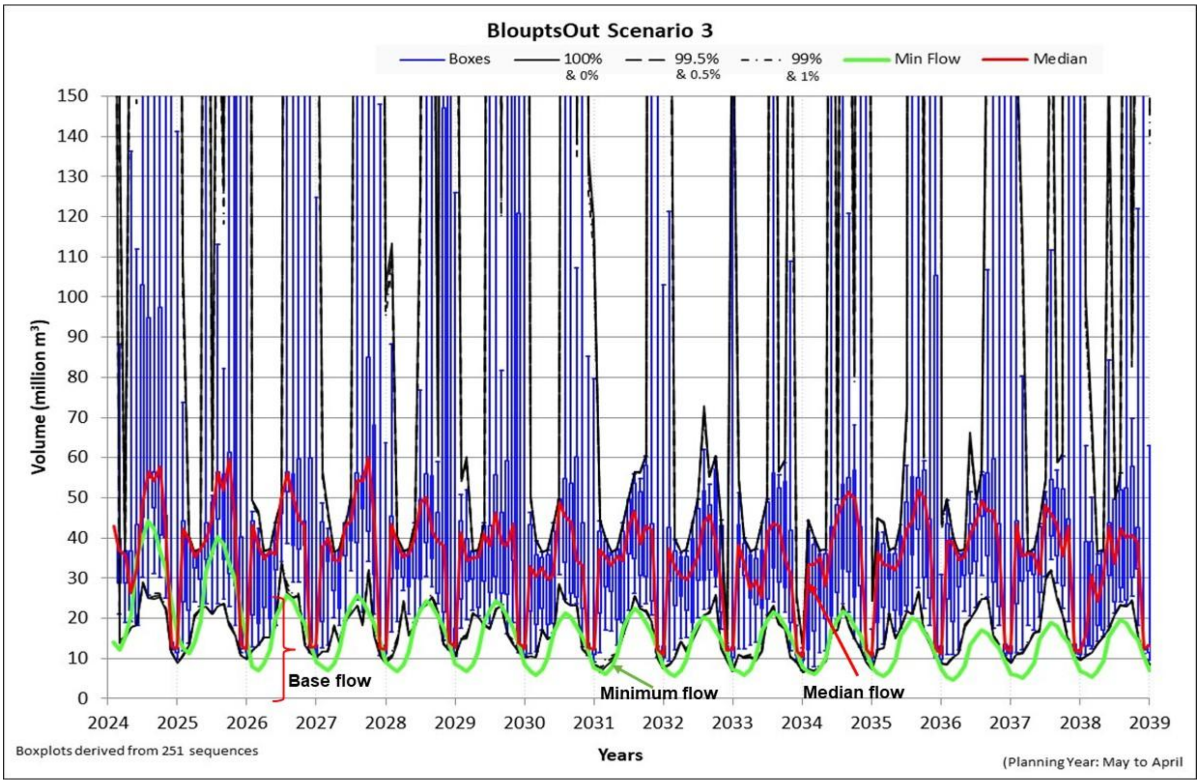


**Figure 5-24: Scenario 3 - Monthly low flows at Blouputs streamflow gauge (Vaal flows excluded)**

The Blouputs streamflow gauge (D8H014) is located on the main Orange River downstream of the Augrabies Falls, just before the Namibian border. This is a key gauging station used for the monitoring and operation of the ORP system. Each year, as part of the annual operating analysis of the ORP, minimum monthly flows are set for observed flows at Blouputs. These flows are the minimum flow required to satisfy all the water requirements downstream of Blouputs to the River Mouth. During the operation of the ORP system, DWS RSA needs to monitor the flow at this site on a continuous basis. If the flow drops below the minimum flow specified, more water needs to be released from Vanderkloof Dam to increase the flow at Blouputs.

To control the pumping from the Orange River at Haib Mine, these minimum flows at Blouputs were used as the trigger for pumping. Only if the flow at Blouputs is higher than the required minimum flow will pumping at Haib be allowed.

The minimum flow at Blouputs is sufficient to supply downstream users, including the environmental requirements. When restrictions are imposed on the ORP system, these minimum flows will be reduced in line with the proposed restrictions. For Base Scenario 2, Scenario 3 and Scenario 3g2, the ORP system is continuously running at a deficit due to the total demands imposed on the system at the 2035 development level and due to the negative impact of Polihali Dam on the ORP yield. For all three of these scenarios, restrictions were imposed on the system for all the years analysed except for the first year. The first year of the analysis did not require restrictions as the ORP system started the analysis at a 100% storage (refer to Figures 5-16, 5-17 & 5-18). From Figures 5-23 and 5-24, it is evident that the simulated flows are always higher than the required minimum flows (Green line) at Blouputs except for the first two years, which can be regarded as a warming-up period due to the ORP starting at a 100% storage. It should be noted that the minimum flows were reduced according to the restrictions imposed on the system each year.

The annual pumping from the Orange River to the Haib off-channel storage dam, as well as the 01 May storage level in the dam for each year, is shown in Figure 5-25.

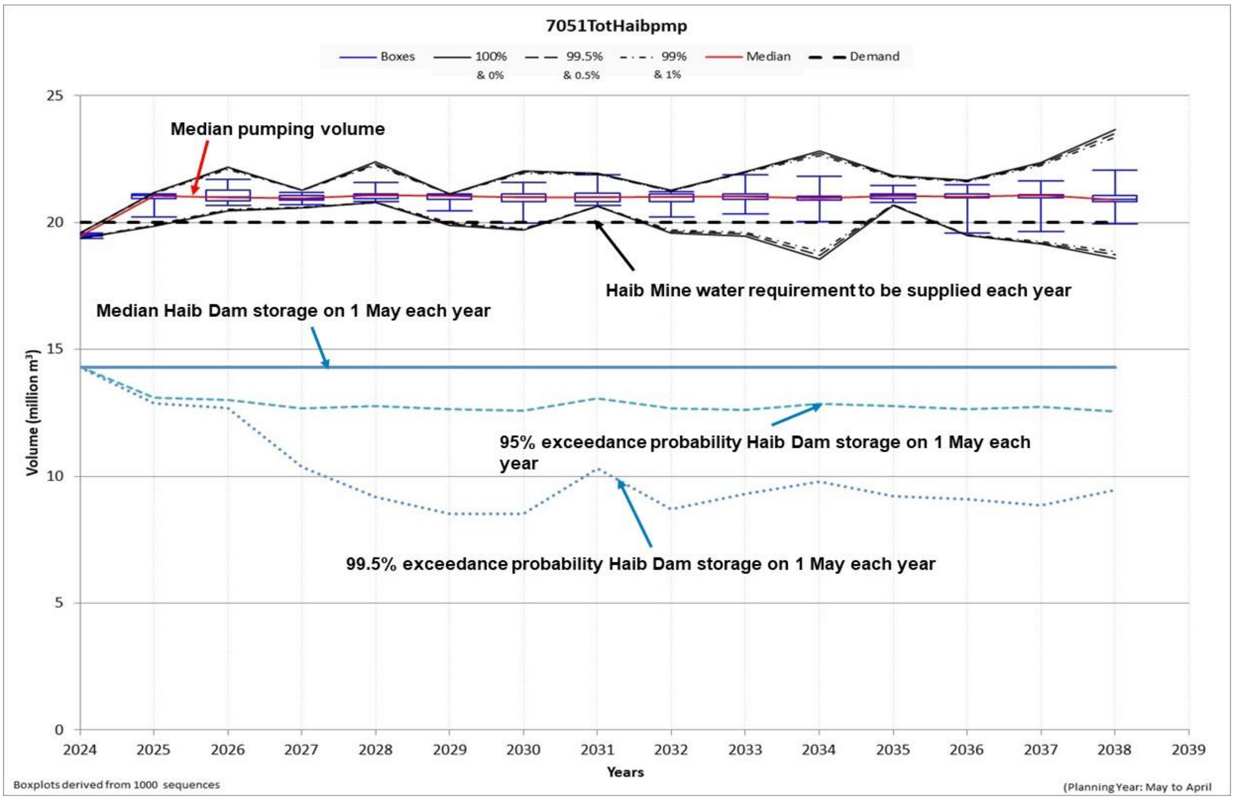


**Figure 5-25: Scenario 3 - Haib pumping, water requirements and expected storage levels for 01 May each year**

The Haib Mine water requirement of 20 million $m^3$/a is shown by the black dashed line. The volume pumped each year is indicated by the box plots with the red line showing the median pump volume. The pumping volume is slightly higher than the water requirement due to the evaporation losses from the dam, which also needs to be covered by the pumping.

The storage in the off-channel storage dam is, in most cases, the highest by 01 May each year as it marks the end of the rainy season. This is why the median storage shows the dam as 100% full for all the years simulated. The 95% exceedance probability represents the expected storage level for a 1 in 20-year drought, with the 99.5% exceedance probability representing a very severe drought of 1 in 200-years. This does not mean that the dam will not reach the minimum storage, as will happen in the other months, specifically around October, just before the summer rainfall and related runoff is experienced (See Figures 5-14 & 5-15).

The recent preliminary EWR, as determined by DWS RSA, was used for all the scenarios analysed. The spread of the annual water supply to the EWR is given in Figure 5.26, with the red line showing the median annual supply. The EWR requirement varies from month to month and year to year as it depends on the actual upstream rainfall. High rainfall years will result in high EWR requirements and low rainfall in low EWRs. This is the reason for the relatively high variation in EWR flows evident from Figure 5.26. This EWR is expected to be implemented soon by DWS RSA.

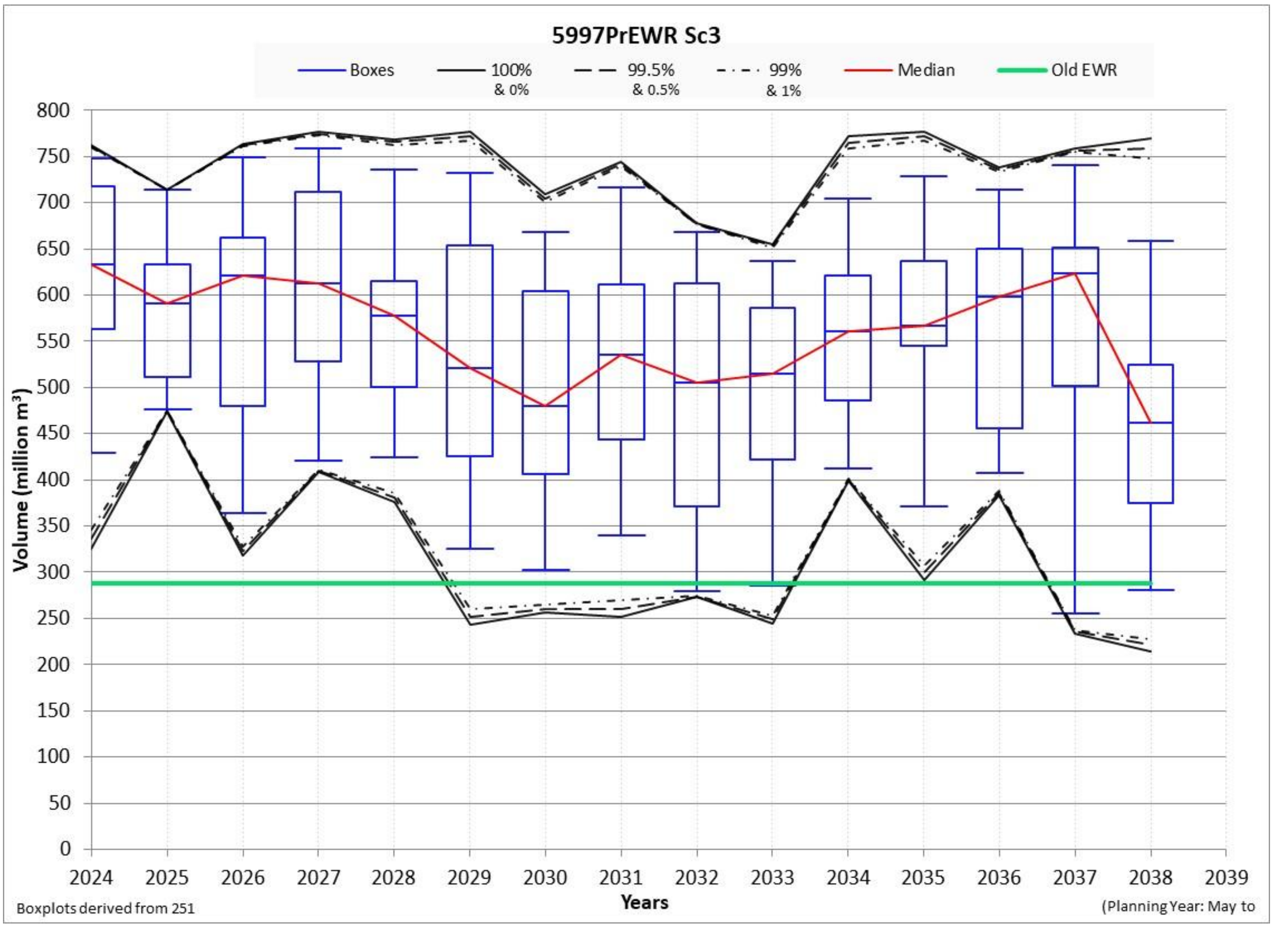


**Figure 5-26: Scenario 3 – Preliminary EWR at the Estuary**

Currently, however, the “old” EWR (unvarying volumes) are still released from Vanderkloof Dam as shown by the green line in Figure 5.26. The current minimum flows determined at Blouputs as part of the annual operating analysis, as determined by DWS RSA, still use the old EWR as one of the downstream demands to be supplied.

The EWR water supply boxplots produced for Base Scenario 2 and Scenario 3g2 are exactly the same as given in Figure 5-26 for Scenario 3. This proves that the pumping of water from the Orange River to the Haib off-channel storage dam did not impact the supply to/of the EWR, which is one of the largest water requirements downstream of Blouputs Weir.

This will also be illustrated by two other demands located downstream of Blouputs Weir; one on the Namibian side of the river and one on the RSA side of the river.

- Namibia supplies to the Noordoewer and Aussenkehr irrigation
- RSA supplies to Alexander Bay

From Figures 5-27, 5-28 & 5-29, it is evident that for all three scenarios (Base Scenario 2, Scenario 3 and Scenario 3g2) the water supply to Noordoewer and Aussenkehr is identical. The abstractions from the Orange River to fill the Haib off-channel storage dam had thus no impact on the water supply to Noordoewer and Aussenkehr.

Due to the high 2035 water requirements imposed on the ORP and the Polihali Dam and its transfer to the Vaal System, which is in place for all three scenarios, the ORP was not able to supply the Noordoewer and Aussenkehr water requirements in full, as illustrated in Figures 5-27, 5-28 & 5-29.

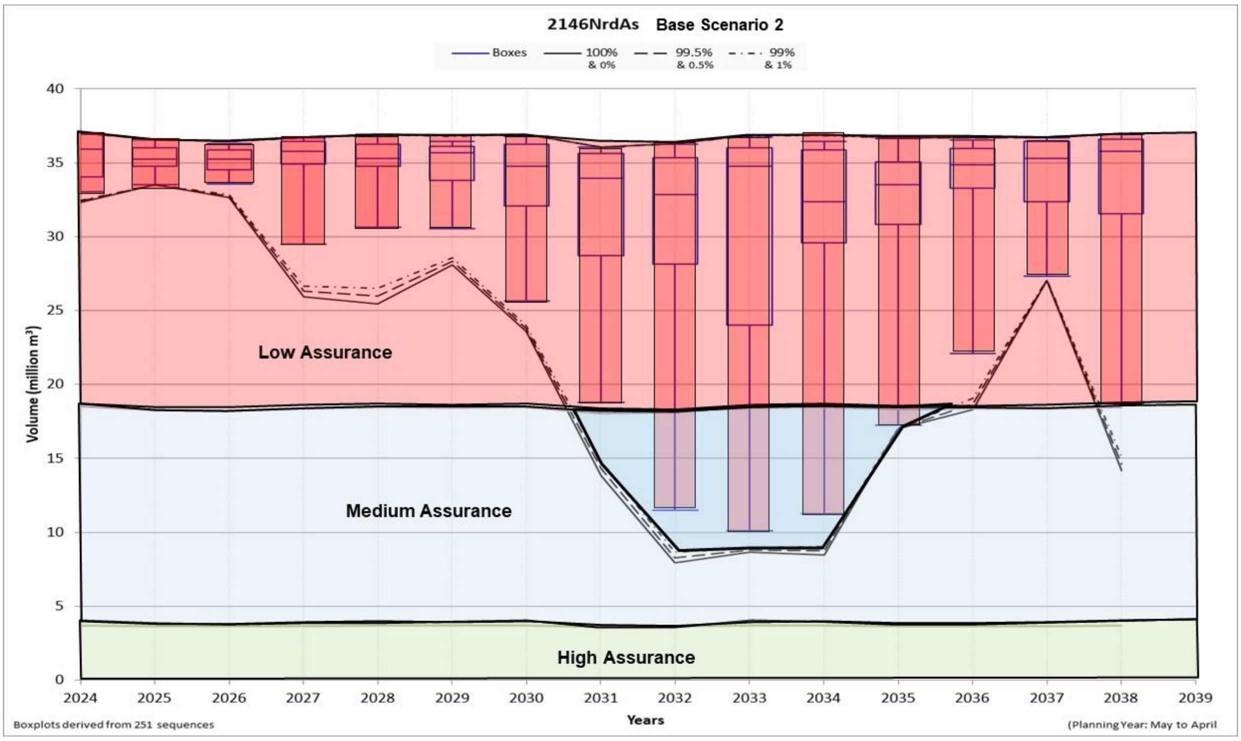


**Figure 5-27: Base Scenario 2 - Water supply to Noordoewer and Aussenkehr**

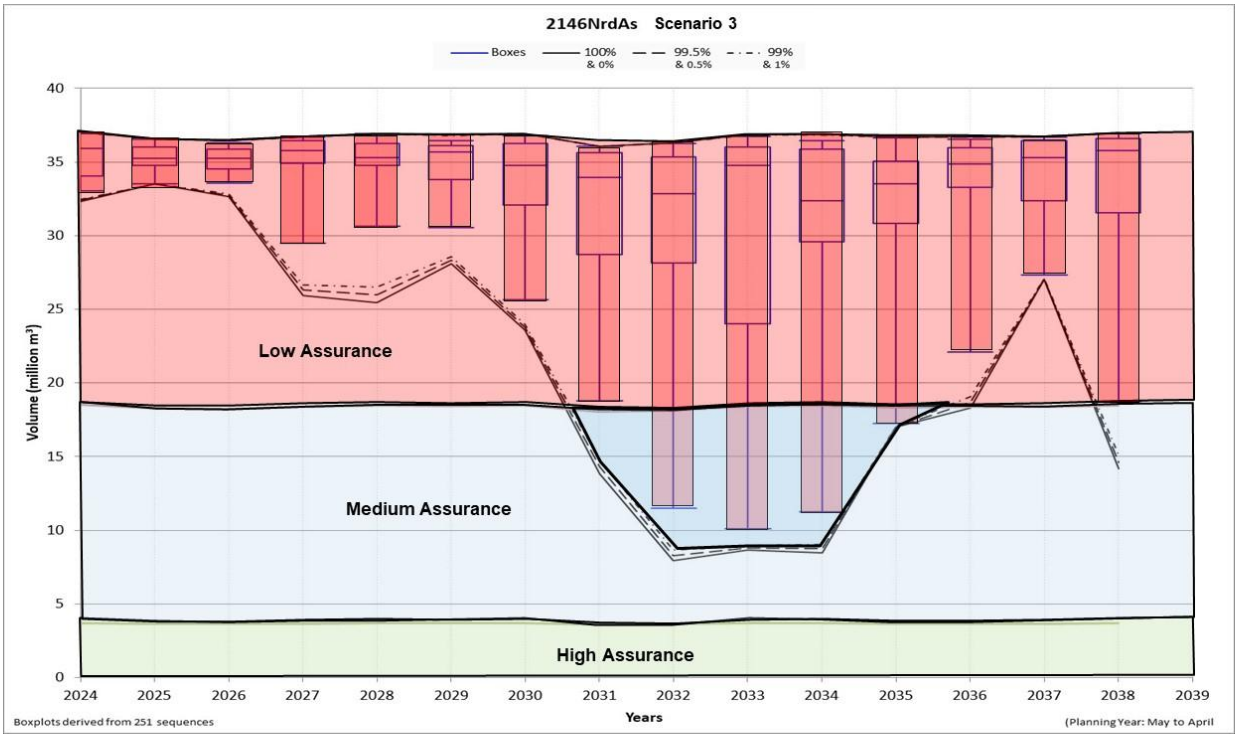


**Figure 5-28: Scenario 3 - Water supply to Noordoewer and Aussenkehr**

Similar to the curtailment plots, the red zone in these water supply graphs represents the low assurance supply, the blue zone the median assurance supply and the green zone the high assurance supply. When the 95% whisker of the boxplot enters the low assurance supply zone, it means that the supply did not adhere to the supply criteria (Red highlighted whiskers). The low assurance use was restricted more often than 1 in 20 years. This occurred over the entire simulation period, with the highest exceedance between 2031 and 2035. The median assurance supply was violated from 2031 to 2035 (See area highlighted in blue). The High assurance supply was not violated in any of the three scenarios.

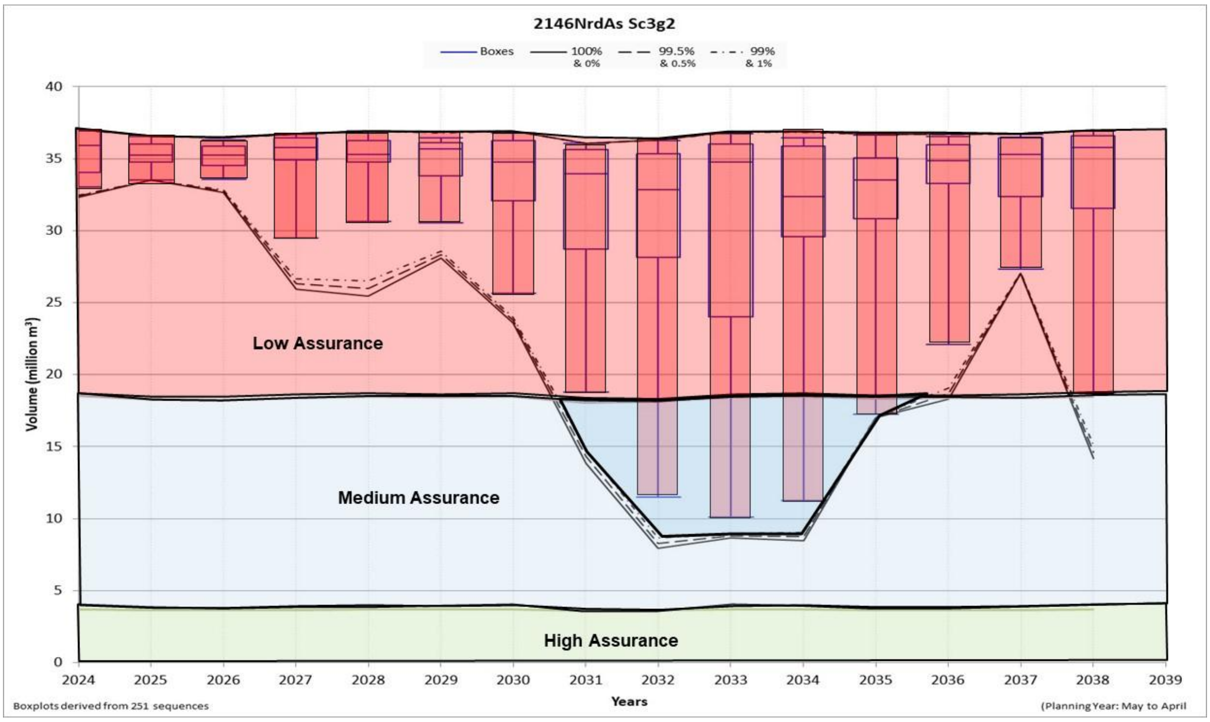


**Figure 5-29: Scenario 3g2 - Water supply to Noordoewer and Aussenkehr**

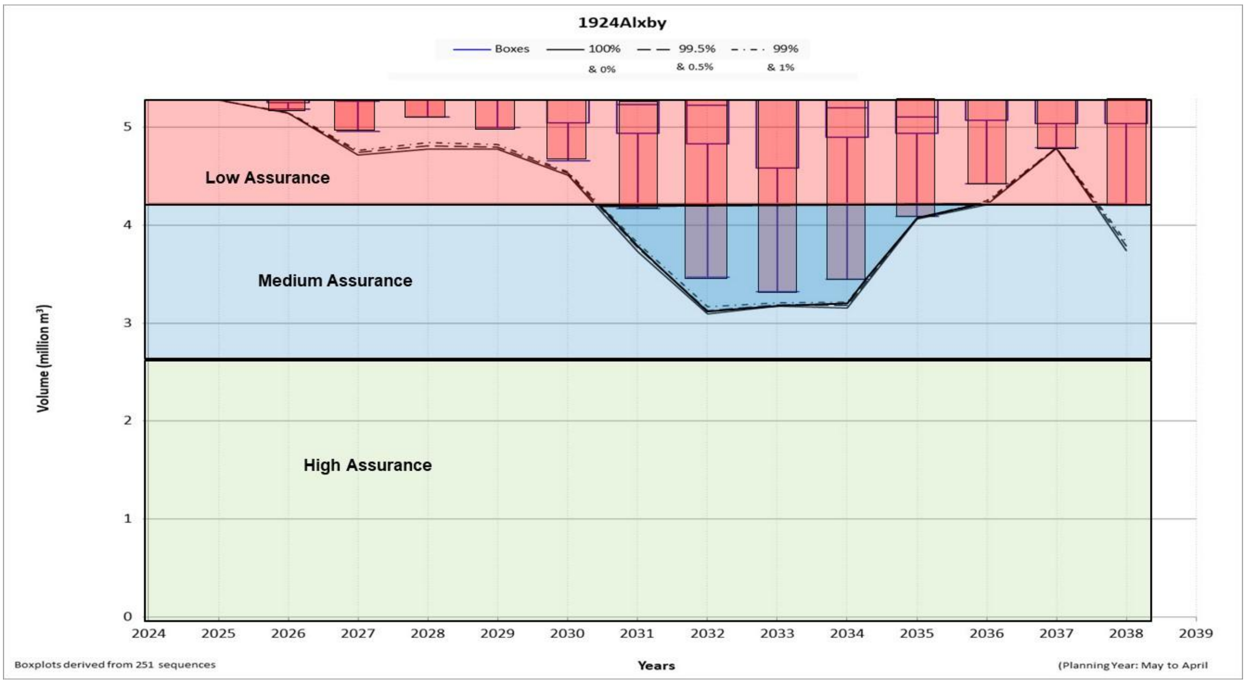


**Figure 5-30: Base Scenario 2 – Water supply to Alexander Bay**

Similar to the Noordoewer – Aussenkehr supply, Figures 5-31, 5-32 & 5-33 are identical for all three scenarios (Base Scenario 2, Scenario 3 and Scenario 3g2), showing the water supply to Alexander

Bay. The abstractions from the Orange River to fill the Haib off-channel storage dam had thus no impact on the water supply to Alexander Bay.

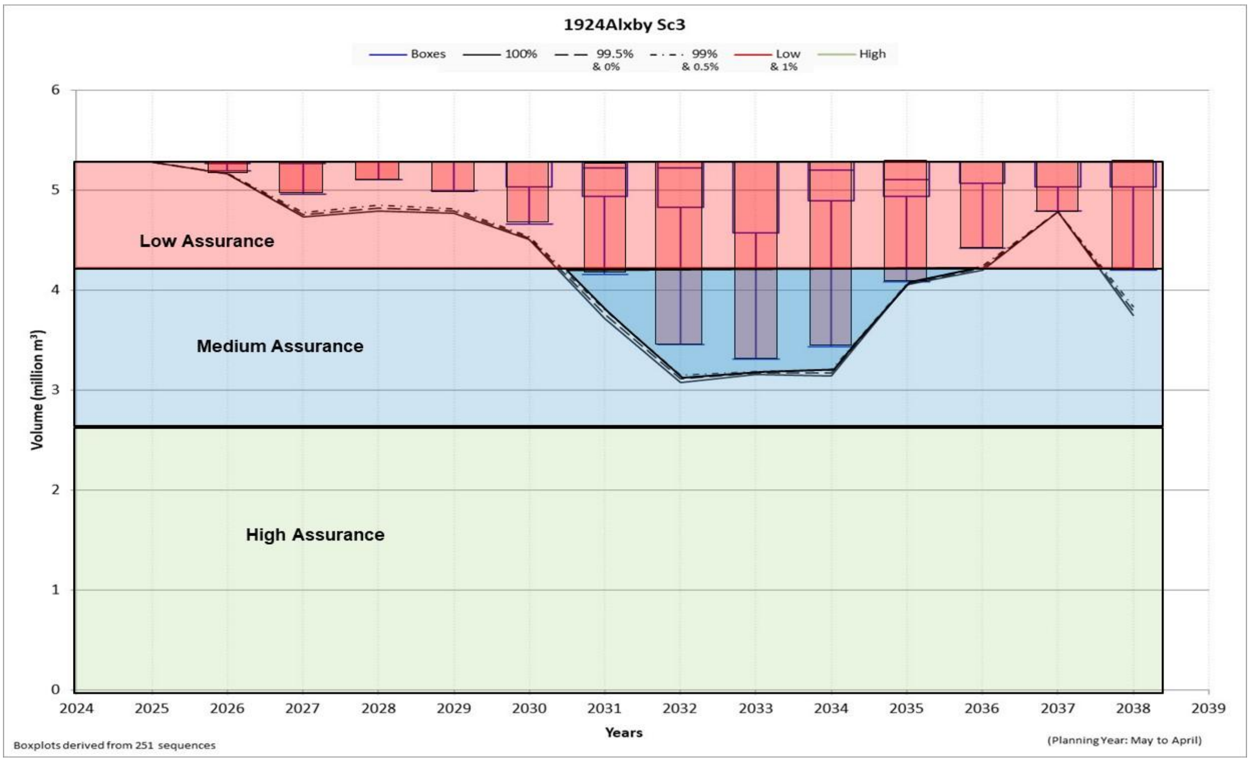


**Figure 5-31: Scenario 3 – Water supply to Alexander Bay**

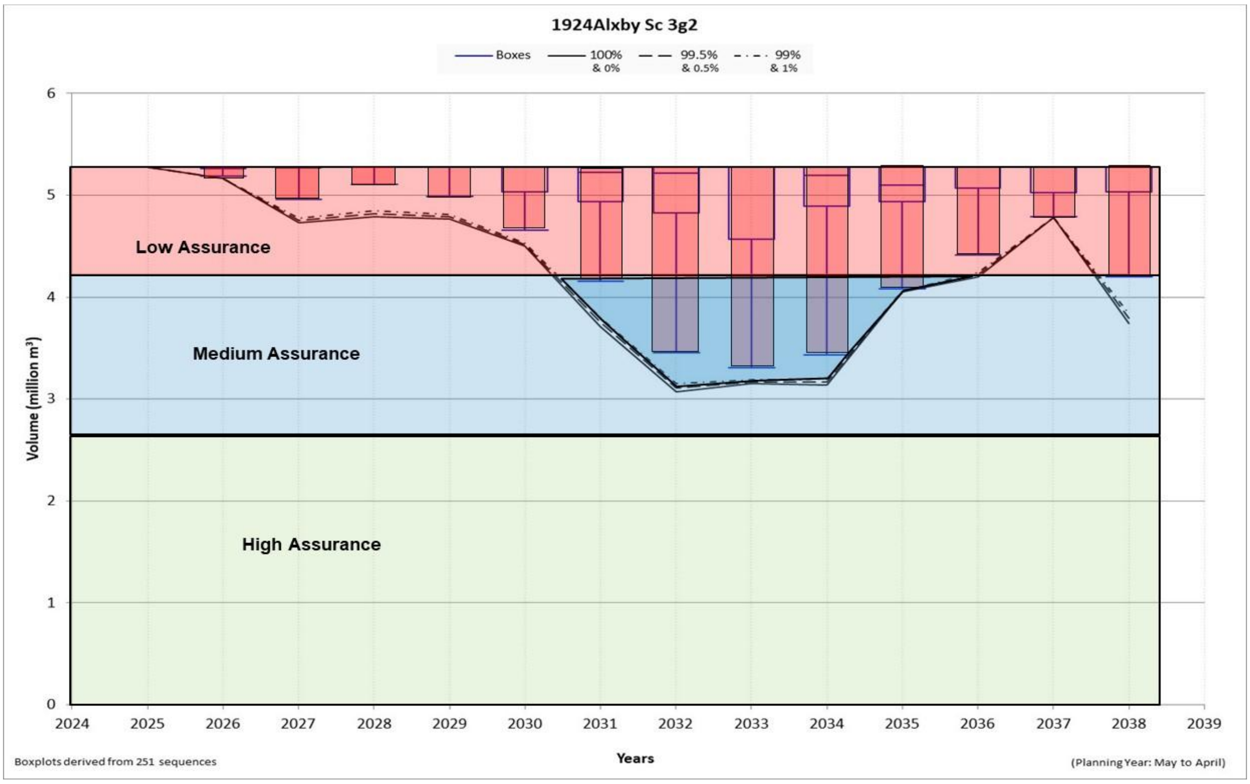


**Figure 5-32: Scenario 3g2 - Water supply to Alexander Bay**

When comparing the Noordoewer - Aussenkehr Alexander Bay water supply plots, it is evident that the lower assurance component for the irrigation is much larger than that used for Alexander Bay, which is for domestic and mining purposes. This directly relates back to the priority classification given in Table 5-1, showing the percentage of the total demand allocated to each of the three assurance levels. Although the percentage curtailment in each assurance class is similar for both users, the total volume curtailed for the irrigation use is more than the volume curtailed for an urban/Industrial/Mining user due to the higher percentage of the irrigation requirement allocated to the low and medium assurance classes.

## 5.2 Base Scenario 3, Scenario 4 & Scenario 5

As described in Section 4.3.2.2, all the scenarios already analysed thus far made use of the option in the WRPM to restrict or curtail water requirements to protect the resources or storage dams from running empty. To be able to use this option, the short-term stochastic yield characteristics as determined for the combination of storage dams used to supply a specific system are required. Short-term stochastic yield characteristics for the OPR system were available for all the scenarios carried out up to Scenario 3g2.

Base Scenario 3 is the first scenario which includes the use of the proposed Verbeeldingskraal and Noordoewer-Vioolsdrift Dams and the Lower-Level Storage in Vanderkloof Dam. When the new combined ORP system that includes these components is analysed, it means that a new set or sets of short-term stochastic yield characteristics will be required.

As the final storage capacities of both the Verbeeldingskraal and the Noordoewer-Vioolsdrift Dams are still to be determined and agreed upon, no short-term stochastic yield characteristics have yet been determined for these development options.

To be able to determine the impact of Haib Mine water use on existing users for Base Scenario 3 and related Scenarios 4 and 5, without these short-term stochastic yield characteristics, a different approach therefore needs to be followed by necessity. This approach will exclude the option to restrict or curtail water users during dry periods. This means that the users will then always be supplied at their full allocation or requirement, and only once the dams reach their minimum operating levels will less water be supplied, based on what is available in the system at the time. The water requirements will thus not be supplied at different assurance levels as explained in Section 5.1.

Base Scenario 3 represents all the existing 2024 water resource development infrastructure plus the expected near-future developments (See Section 4.1.2 for more detail). This scenario includes additional near-future developments to those from Base Scenario 2 to be able to rebalance the ORP system. Results from Base Scenario 2 already showed that the ORP system under those conditions was experiencing significant deficits. The additional infrastructure will be used to increase the ORP yield and to reduce the deficits within the system to acceptable levels. The near future developments include the following:

- Polihali Dam and the tunnel to Katse Dam. The related increased volume to be transferred to the Vaal River System will form part of the analysis (from Base Scenario 2).
- Transfer water from the Gariep Dam to the Greater Bloemfontein area, including the improvements in the Greater Bloemfontein water supply system (from Base Scenario 2).
- Neckartal Dam irrigation and hydro-power generation are in place (from Base Scenario 2).
- Haib mine abstraction is not active.
- Water requirements at the 2035 development level (from Base Scenario 2).
- Verbeeldingskraal Dam in the Orange River just upstream of Aliwal North (New Base Scenario 3)

- Noordoewer-Vioolsdrift Dam on the Lower Orange just upstream of the Vioolsdrift Weir (New Base Scenario 3).
- Utilising the Lower-Level Storage in Vanderkloof Dam (New Base Scenario 3).

Results from Base Scenario 3 will be compared against the results from Scenario 4 and Scenario 5.

**Scenario 4** is as Base Scenario 3 but includes an abstraction from Noordoewer-Vioolsdrift Dam to supply water to the Haib Mine water with a water requirement of 6 million m$^3$/a.

**Scenario 5** is as Base Scenario 3 but with a 20 million m$^3$/a continuous abstraction by Haib Mine supported from the Noordoewer-Vioolsdrift Dam.

The purpose of these three scenarios is to determine the impact of the two possible Haib Mine demand scenarios of 6 and 20 million m$^3$/a on the ORP system and its users when using the Noordoewer-Vioolsdrift Dam as the resource.

The results from the stochastic analysis were derived by using the WRPM and analysing 251 possible flow sequences (possible future natural rainfall runoff from each sub-catchment) with record lengths of 15 years each. This means that the model will produce 251 different answers for each monthly storage volume, water supply, river flow, etc. To be able to put meaning to these vast numbers of results, box plots are used to describe the results in terms of exceedance probability (See Section 5.1 and Figure 5-1).

### 5.2.1 Results from the Stochastic Analysis

The Bloemhof Dam storage projection plots are slightly different from those derived from Base Scenario 2, Scenario 3 and Scenario 3g2. The reason for these differences is that the option in the WRPM to restrict or curtail water requirements to protect the resources or storage dams from running empty was not used for Base Scenario 3, Scenario 4 and Scenario 5 (See Section 4.3.2.2). The users will, in this case, always be supplied at their full allocation or requirement, and only once the dams reach their minimum operating levels will less water be supplied, based on what is available in the system at the time. This is the reason why the Bloemhof Dam is dropping to lower levels than before. The Bloemhof dam storage projection plots for all three scenarios (Base 3, Scenario 4 & Scenario 5) are identical (See Figures 5-33, 5-34 & 5-35) as the changes made did not impact the Vaal System.

Bloemhof Dam is the most downstream dam on the Vaal River, and spills from this dam will also reach the Orange River just downstream of Douglas. No releases are, however, made from Bloemhof Dam in support of the users along the Orange River.

Two new major storage dams were added to Base Scenario 3, Scenario 4 and Scenario 5. These include the Verbeeldingskraal Dam in the Upper Orange just upstream of Aliwal North. The second dam is the Noordoewer-Vioolsdrift Dam just upstream of the existing Vioolsdrift Weir. The reader is referred to Section 4.3.2.2, as important background is given there regarding Base Scenario 3, Scenario 4 and Scenario 5.

Due to its importance, the operating rule followed between the four dams; Verbeeldingskraal, Gariep, Vanderkloof and Noordoewer-Vioolsdrift is repeated before the first results from the stochastic analysis are discussed.

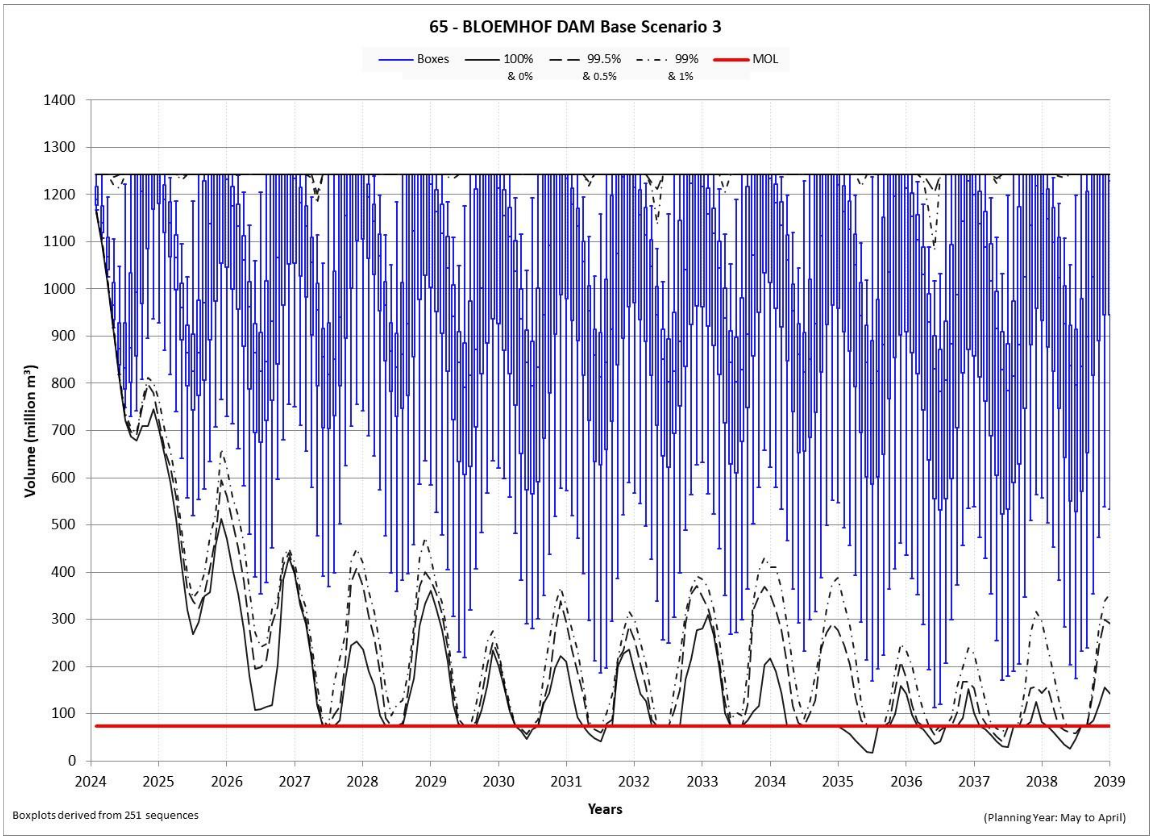


**Figure 5-33: Base Scenario 3 Bloemhof Dam Storage projection**

These operating rules between the four dams, Verbeeldingskraal, Gariep, Vanderkloof and Noordoewer-Vioolsdrift Dams are very important to obtain the maximum yield and hydro-power generation from the dams. These operating rules will be refined once the proposed Verbeeldingskraal and Noordoewer-Vioolsdrift Dams are in place. For the analysis, the following basic operating rules were followed:

- Keep the water in Verbeeldingskraal Dam for as long as possible and only release water from Verbeeldingskraal Dam once the water levels in the downstream dams are very low.
- Support the Gariep Dam with releases from Verbeeldingskraal Dam to keep the Gariep Dam just above the minimum level required for hydro-power generation purposes.
- Support Vanderkloof Dam from Gariep Dam to keep Vanderkloof Dam above the minimum level required for hydro-power generation purposes.
- Only when there is not sufficient water in Gariep and Verbeeldingskraal dams, start to utilise the lower-level storage in Vanderkloof Dam.
- Vanderkloof Dam is used to supply all downstream water requirements between Vanderkloof Dam and the Noordoewer-Vioolsdrift Dam. Only when the water level in the Noordoewer-Vioolsdrift Dam drops below MOL 1 will additional releases be made from Vanderkloof Dam to support the Noordoewer-Vioolsdrift Dam, only if Vanderkloof Dam is above the minimum level for hydro-power generation.
- All the demands downstream of the Noordoewer-Vioolsdrift Dam are to be supplied from the dam. This will include all the downstream users, the river mouth environmental requirements, as well as the river requirements.

- Only when the Noordoewer-Vioolsdrift Dam drops below MOL 2 can water from Vanderkloof and Gariep Dams below their MOL for hydro-power generation be released in support of Noordoewer-Vioolsdrift Dam.

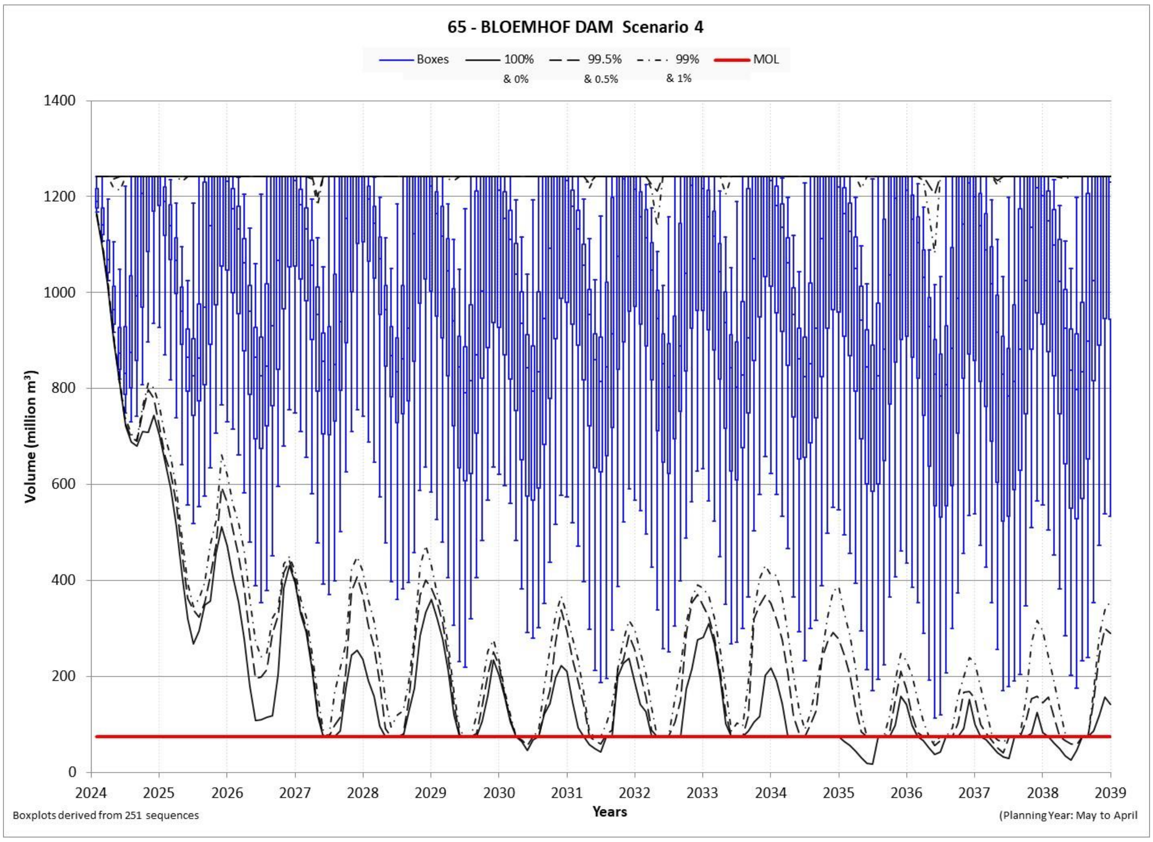


**Figure 5-34: Scenario 4 Bloemhof Dam Storage projection plot**

The storage projection plots for all four of the dams and for all three scenarios analysed are given in the pages to follow, as well as the discussion and comparisons of the results between the three scenarios.

From Figure 5-36, 5.37 and Figure 5.38, it is evident that Verbeeldingskraal Dam is fairly full most of the time, with the median storage always at full supply storage except for the initial years when the dam was filling. This is a result of the operating rule requiring keeping the water in Verbeeldingskraal Dam for as long as possible before releases are made to support the downstream dams.

It is important to note that the four dams are working together as a system. Therefore, an increase in demand anywhere in the system will have some impact on each of the dams, but not necessarily the same impact on each dam due to the location of the increased demand and the operating rule that is followed. The only difference between the three scenarios considered is the demand imposed on the Noordoewer-Vioolsdrift Dam.

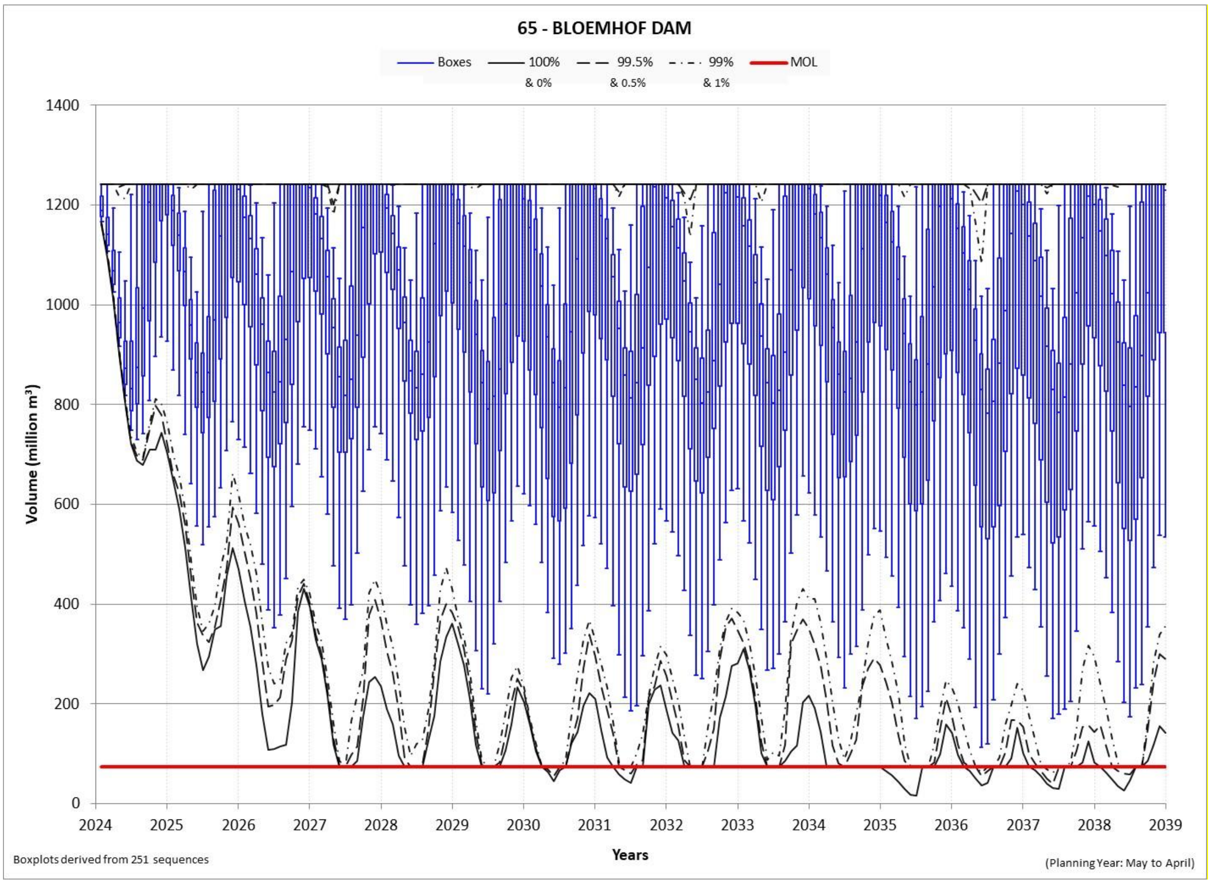


**Figure 5-35: Scenario 5 Bloemhof Dam Storage Projection plot**

For Base Scenario 3, the expected 2035 downstream demands, including the increased irrigation due to the Noordoewer-Vioolsdrift Dam, were imposed on the dam, but excluding the Haib Mine water requirement.

Scenario 4 is the same as Base Scenario 3, but a 6 million $m^3/a$ Haib Mine requirement was also imposed on the Noordoewer-Vioolsdrift Dam. For Scenario 5, the 6 million $m^3/a$ Haib Mine requirement was increased to 20 million $m^3/a$.

The storage projection plots for Verbeeldingskraal Dam for all three scenarios are very similar, although a very small difference can be noticed on close inspection (See Figures 5-36,5-37 & 5-38). This is to be expected as the four dams are operated as an integrated water supply system, with the total system demand increasing by 6 million $m^3/a$ for Scenario 4 and by a further 14 million $m^3/a$ for Scenario 5.

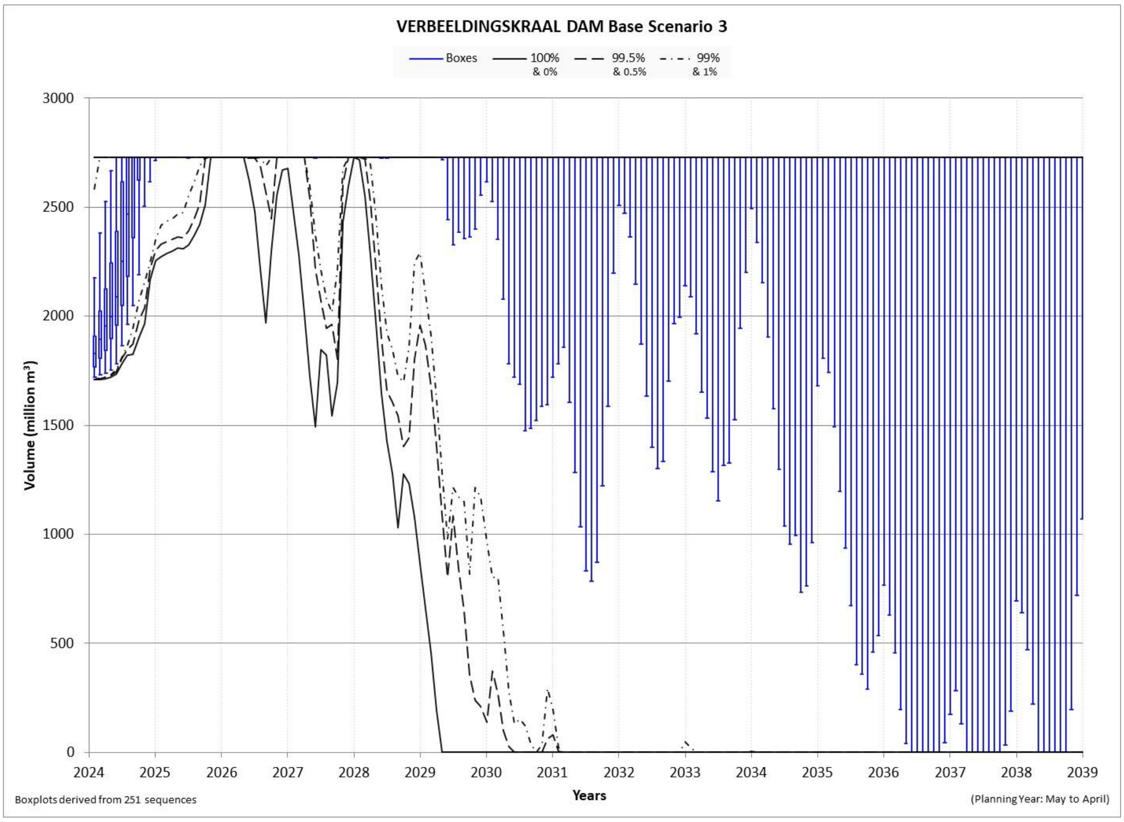


**Figure 5-36: Base Scenario 3 – Verbeeldingskraal Dam**

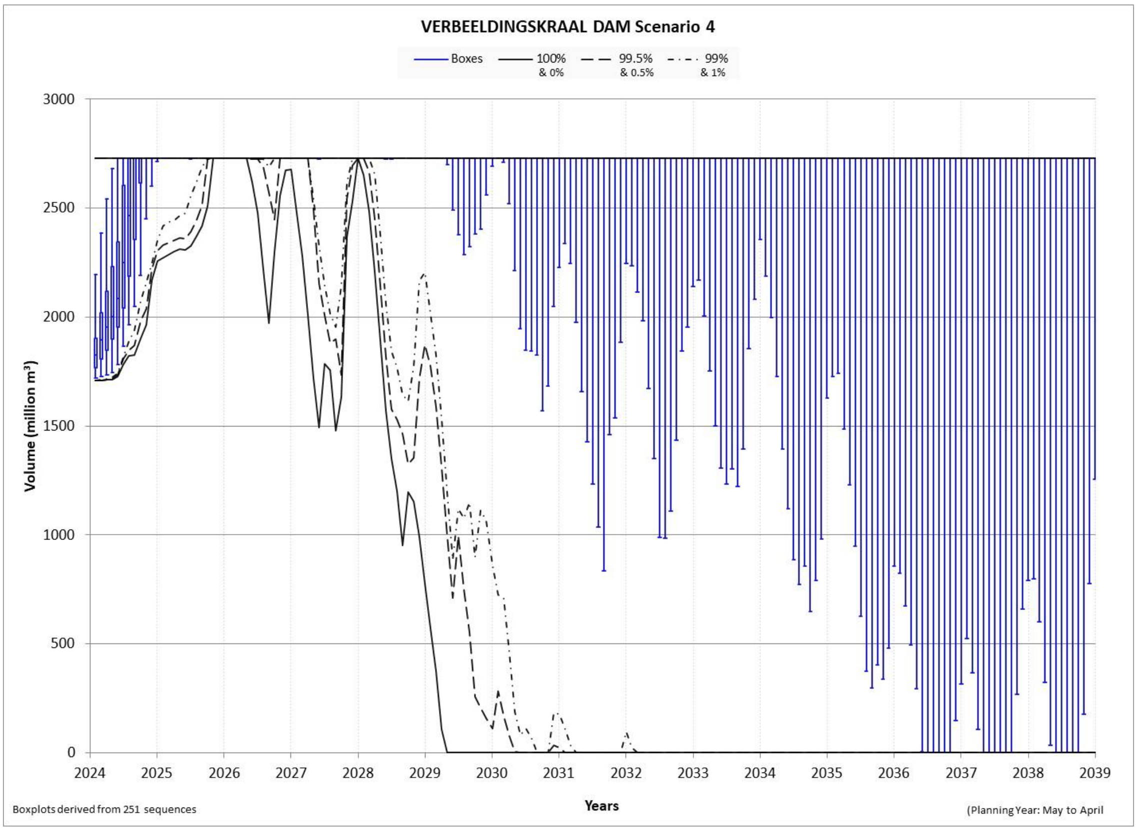


**Figure 5-37: Scenario 4- Verbeeldingskraal Dam**

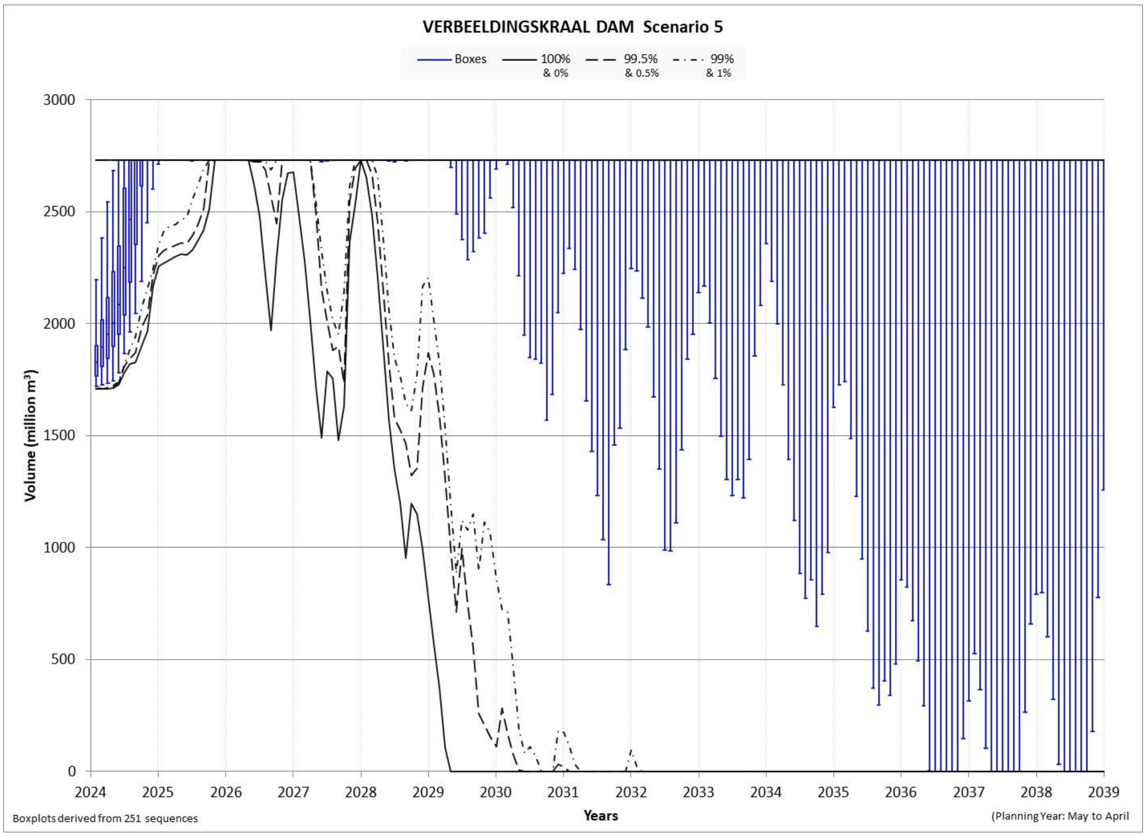


**Figure 5-38: Scenario 5- Verbeeldingskraal Dam**

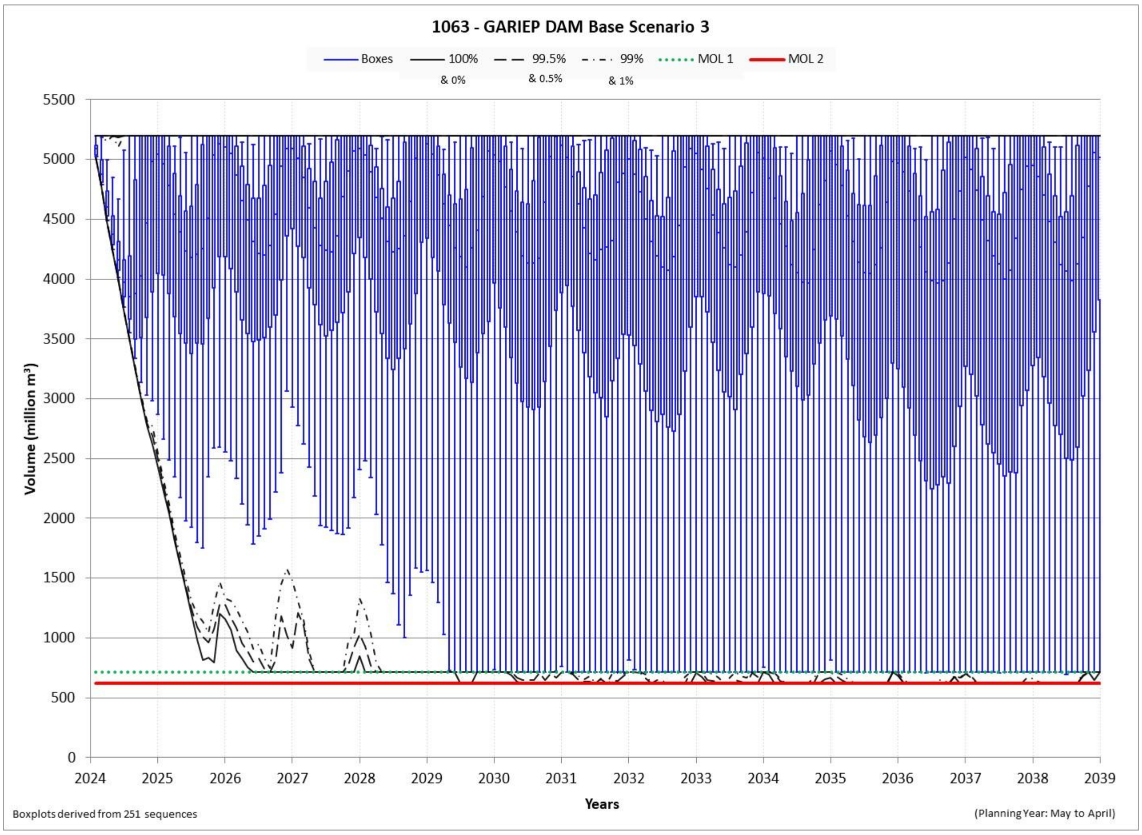


**Figure 5-39: Base Scenario 3 – Gariep Dam storage projection**

The Gariep Dam storage projection plots for all three scenarios are almost identical, with very few differences between them. This is partly due to the large storage capacity of Gariep Dam, which totally dwarfs the small additional demand imposed on the integrated system.

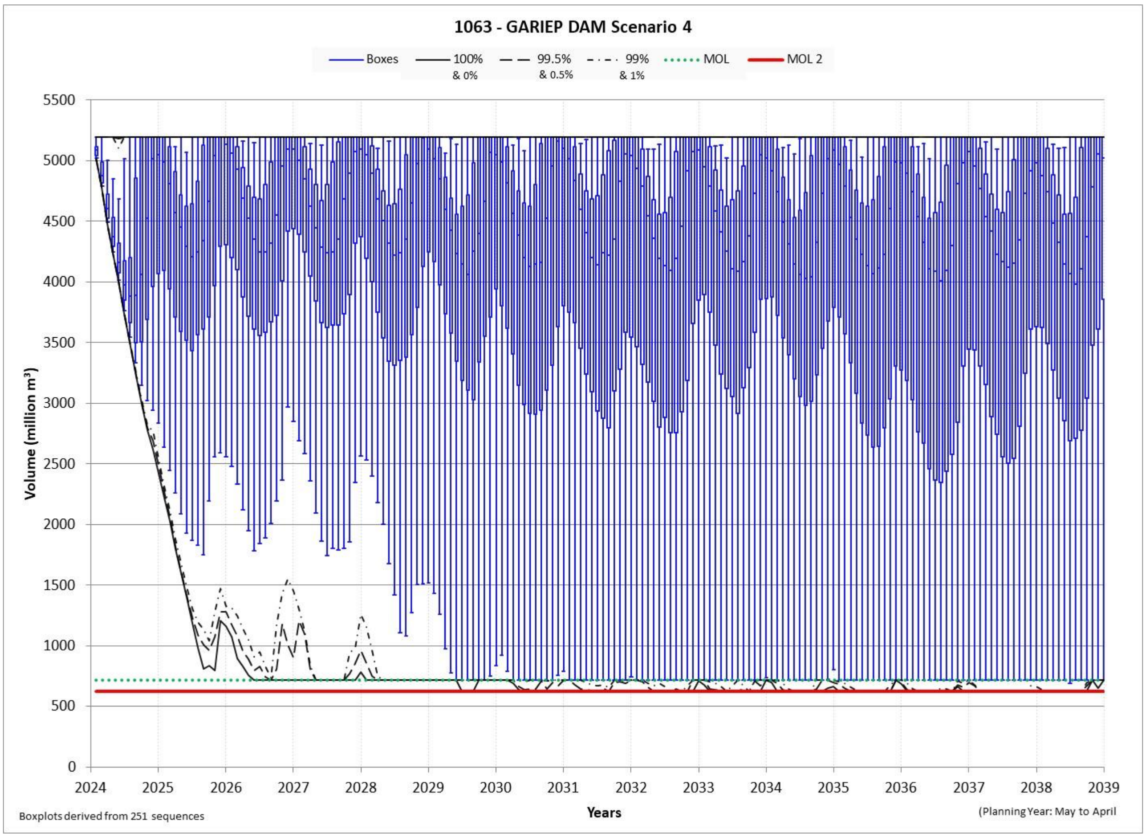


**Figure 5-40: Scenario 4 - Gariep Dam storage projection**

It is only during the extreme 1 in 100 and 1 in 200-year droughts that the Gariep Dam drops below MOL 2, which refers to the MOL for hydro-power generation. This is a result of the operating rule built into the system.

The significant difference in the storage between MOLs 1 and 2 in Vanderkloof Dam is referred to as the Lower-level Storage in Vanderkloof Dam, which is currently not used. DWS RSA is planning to use this storage when Polihali Dam starts to store water to add yield to the existing system and mitigate part of the negative yield impact of Polihali Dam on the ORP. When the storage in Vanderkloof drops below MOL 1, no hydropower can be generated from the dam. The operating rule dictates that storage must be kept at or above MOL 1 for as long as possible. This is evident from the Vanderkloof storage projection plots for all three scenarios analysed (see Figures 5-42, 5-43 & 5-44) showing that initially Vanderkloof storage only drops below MOL 1 for the extreme dry years of 1 in 100 and 1 in 200-years. Towards the end of the simulation, this also starts occurring at the 1 in 20-year droughts.

The Vanderkloof Dam storage projection plots for the three scenarios are almost identical, with only small differences visible. This is to be expected as the four dams are operated as an integrated water supply system, and Vanderkloof Dam will be used to support the Noordoewer-Vioolsdrift Dam when required.

The combined storage projection plots for the ORP and the Verbeeldingskraal Dam are almost identical, with very few differences between them. This is partly due to the very large storage capacity of the three dams combined, which totally dwarfs the small additional demand imposed on the integrated system.

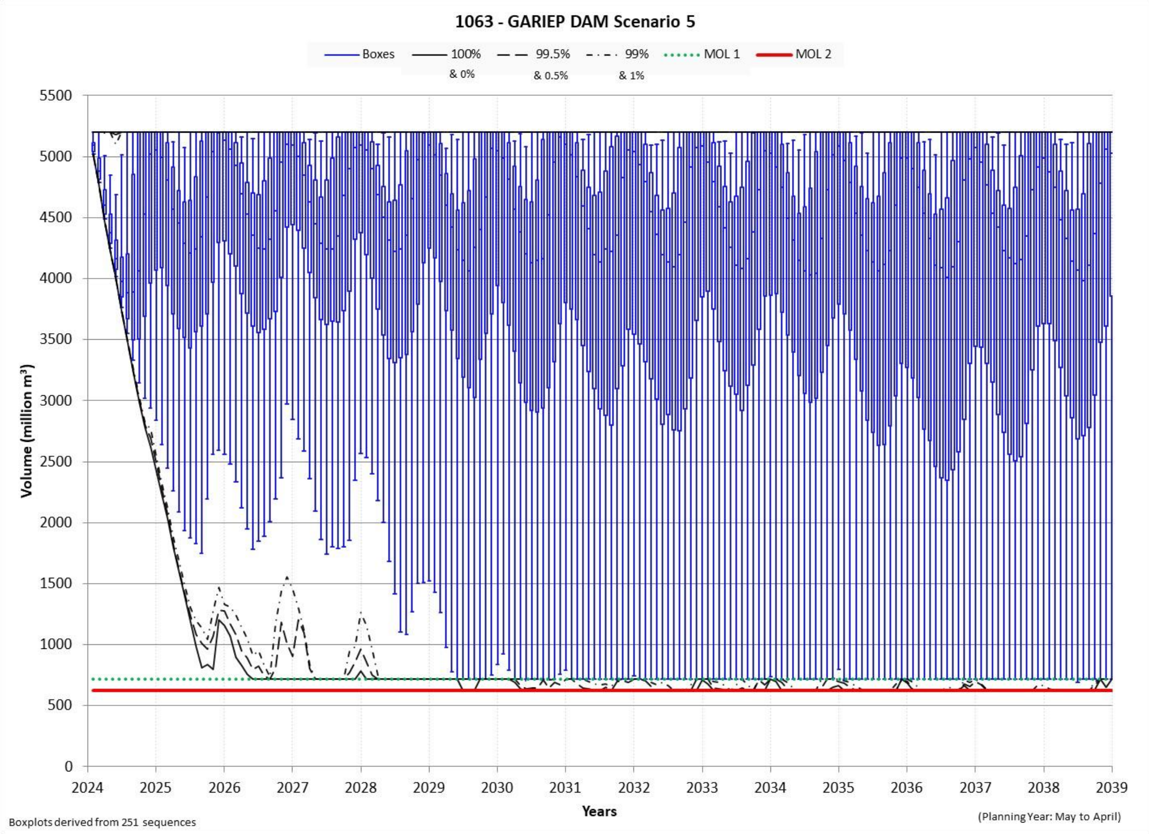


**Figure 5-41: Scenario 5 - Gariep Dam storage projection**

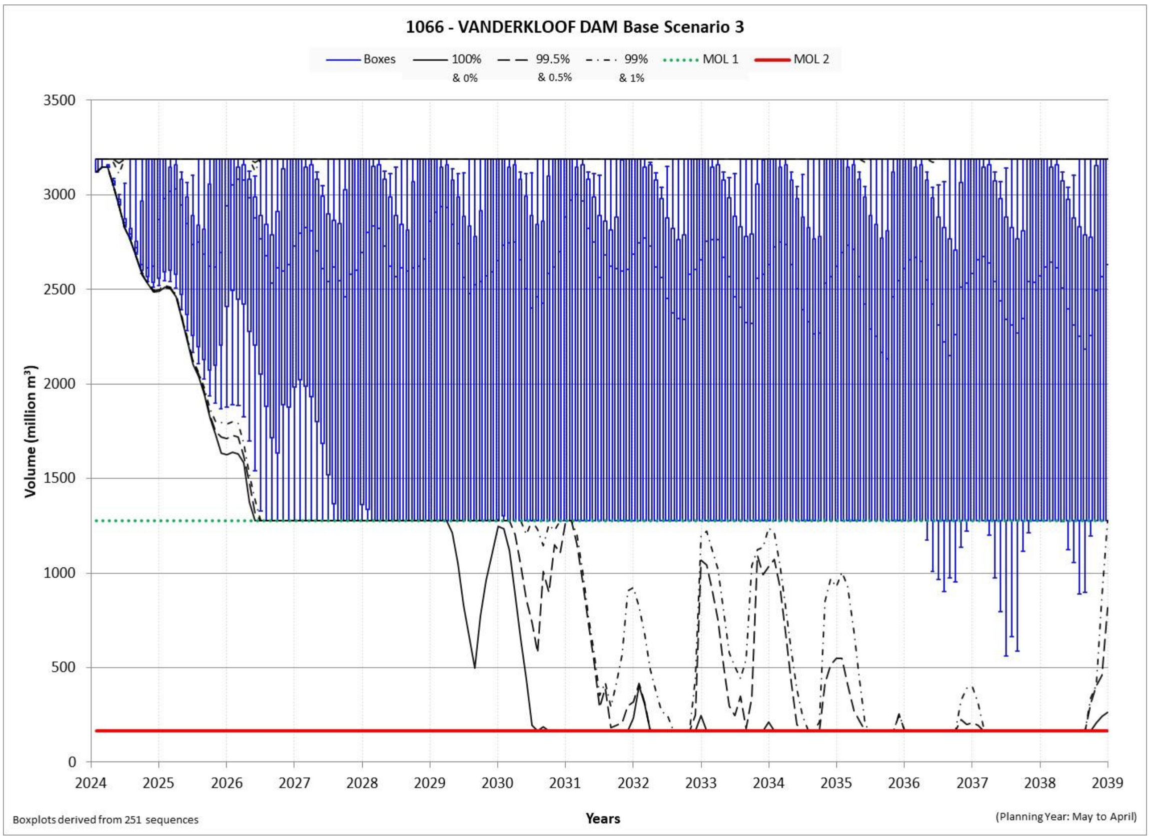


**Figure 5-42: Base Scenario 3 – Vanderkloof Dam storage projection**

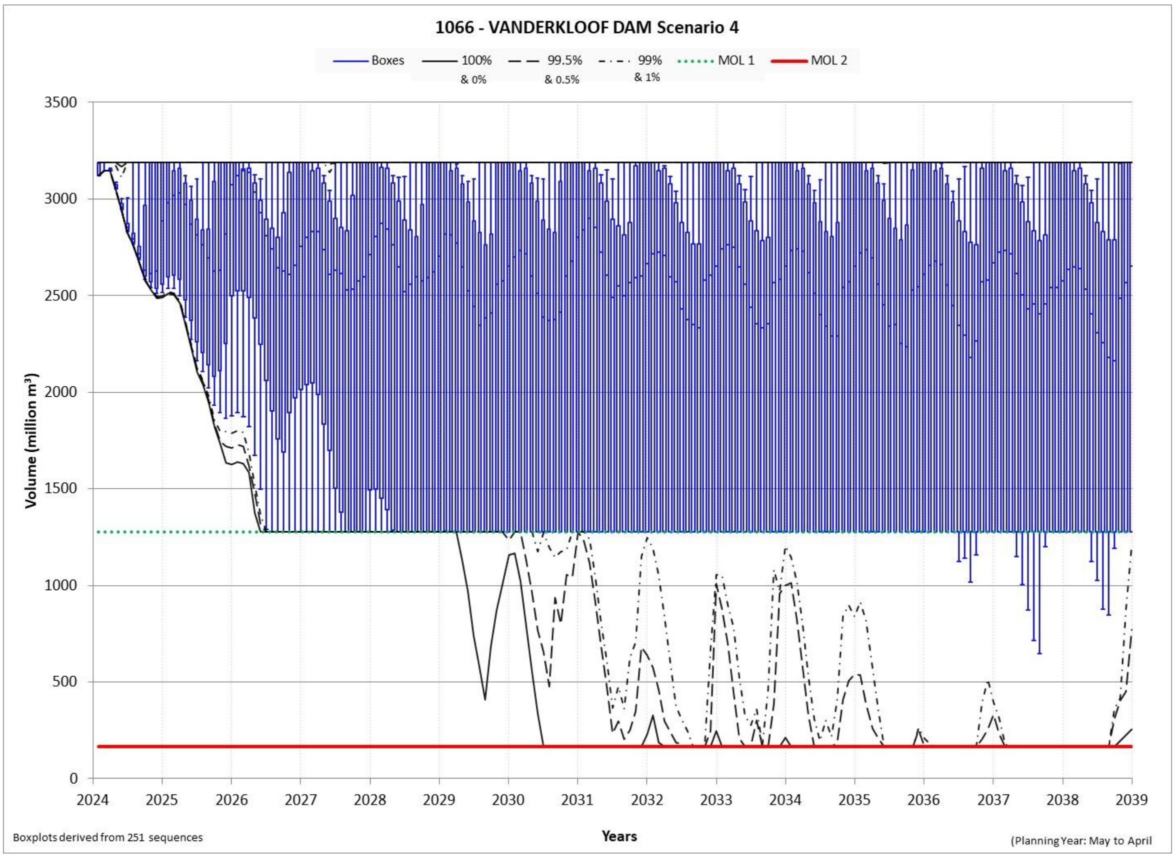


**Figure 5-43: Scenario 4 - Vanderkloof Dam storage projection plot**

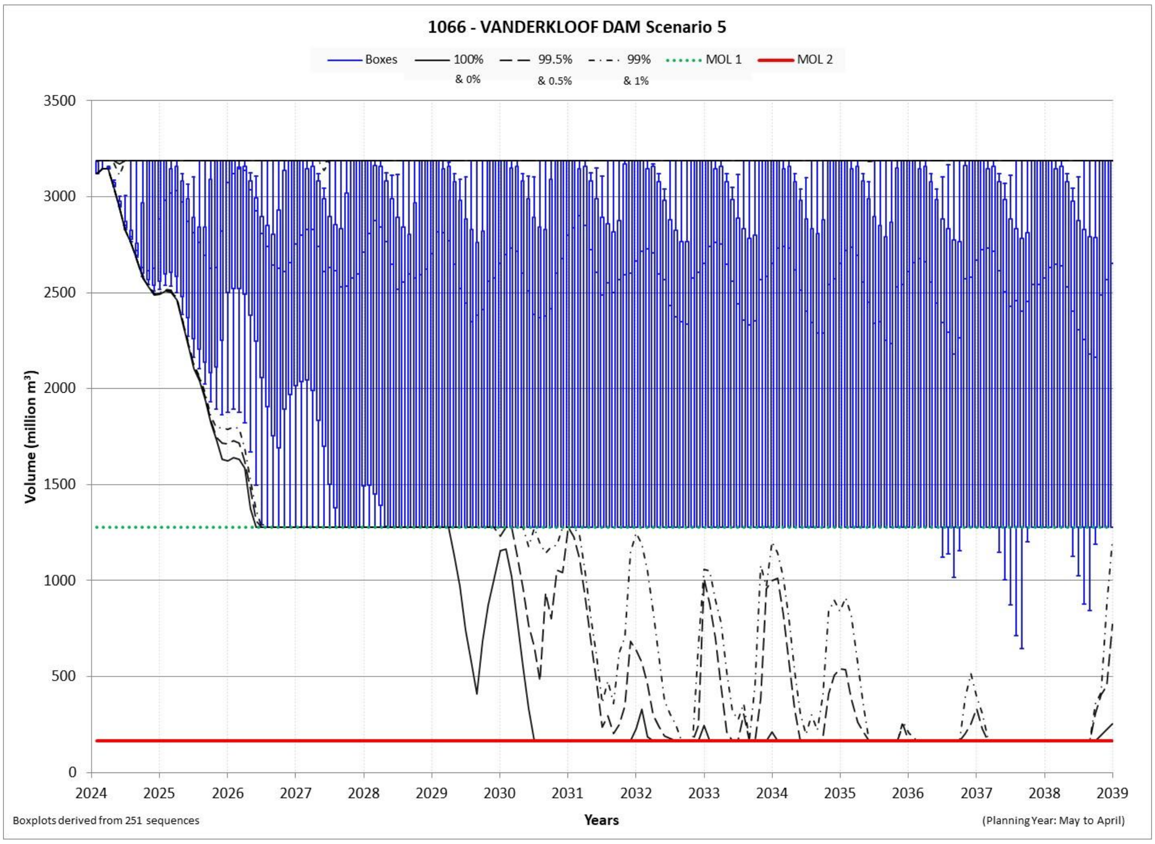


**Figure 5-44: Scenario 5 - Vanderkloof Dam storage projection plot**

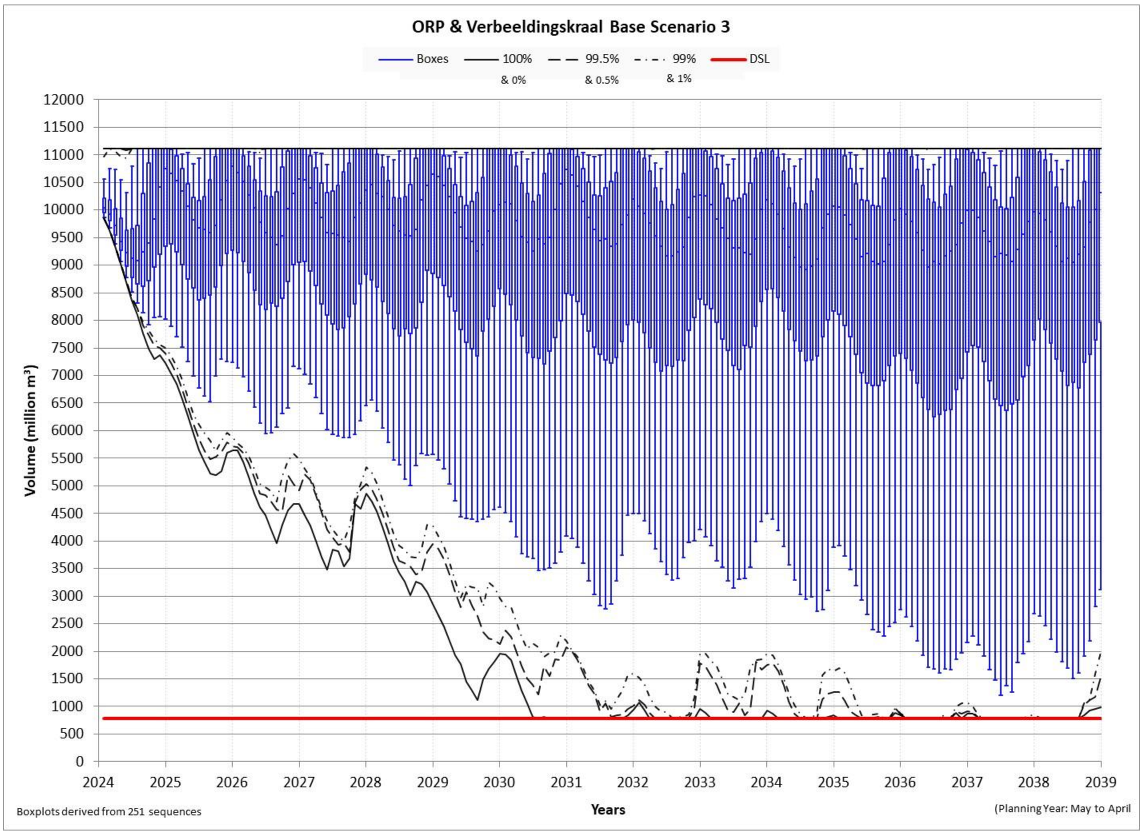


**Figure 5-45: Base Scenario 3 – ORP & Verbeeldingskraal Dam combined storage projection**

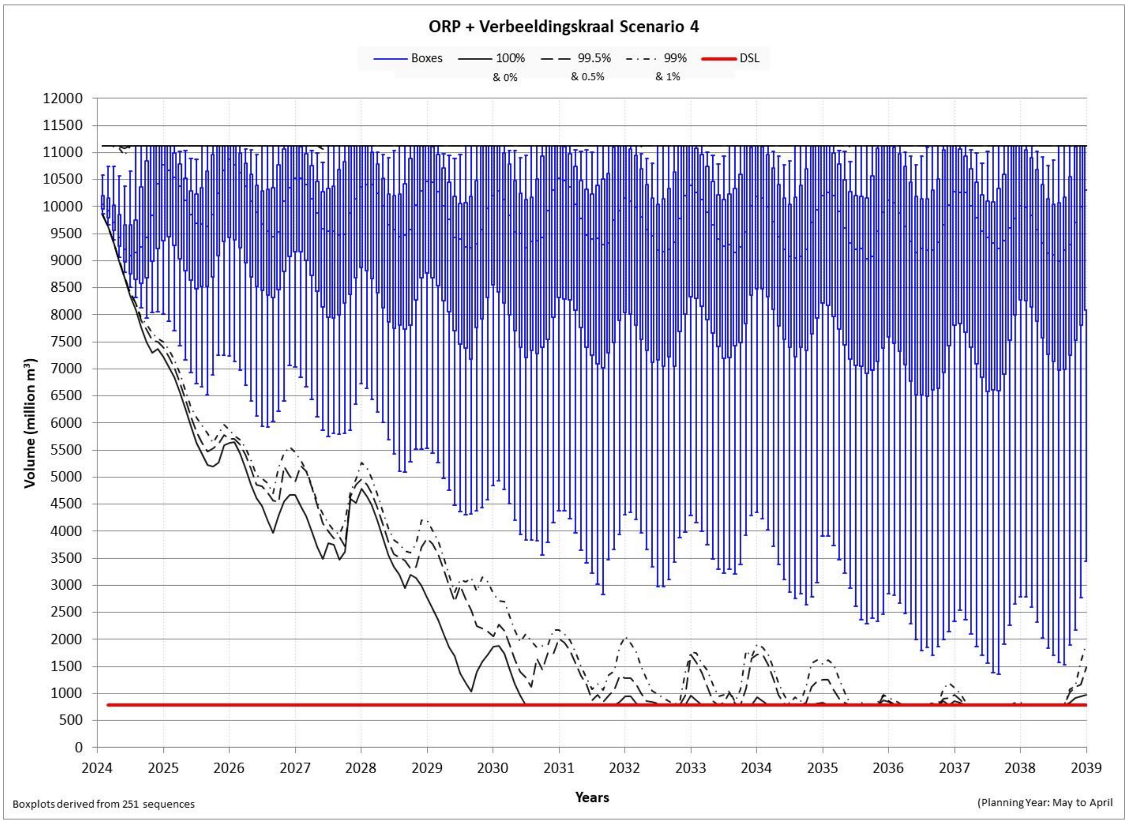


**Figure 5-46: Scenario 4 - ORP & Verbeeldingskraal Dam combined storage projection**

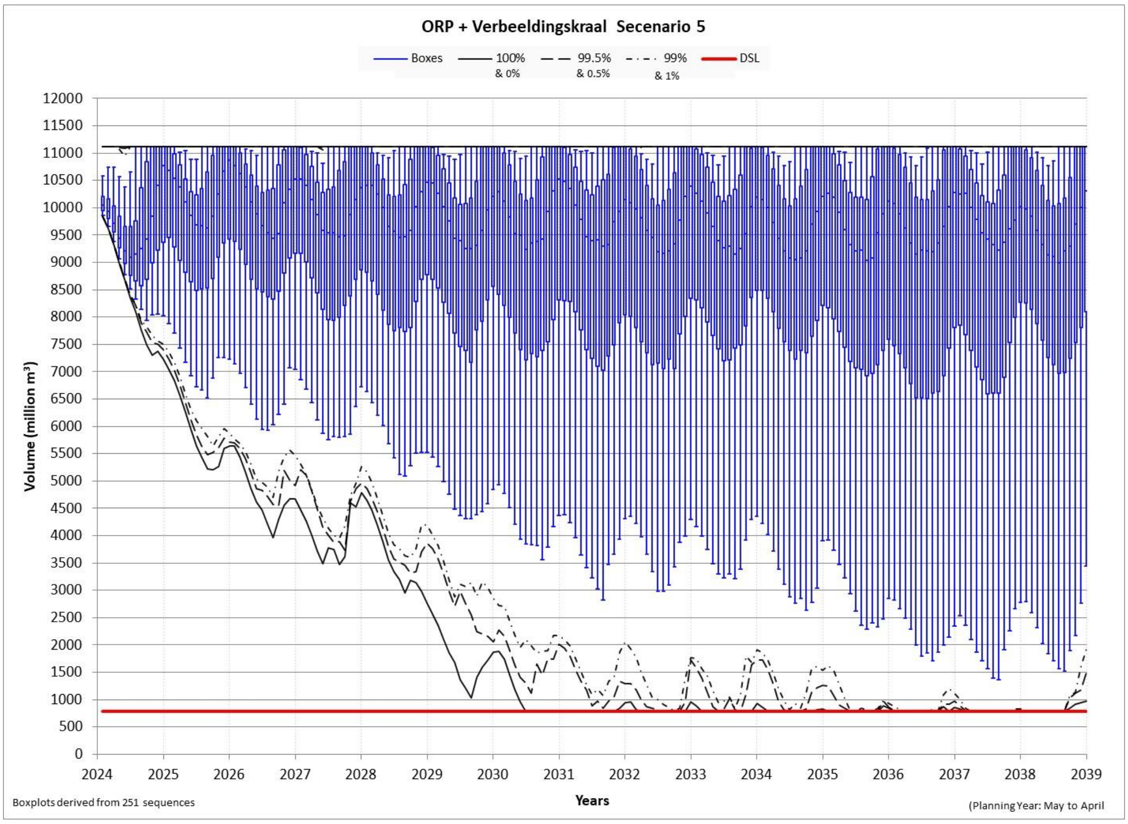


**Figure 5-47: Scenario 5 - ORP & Verbeeldingskraal Dam combined storage projection**

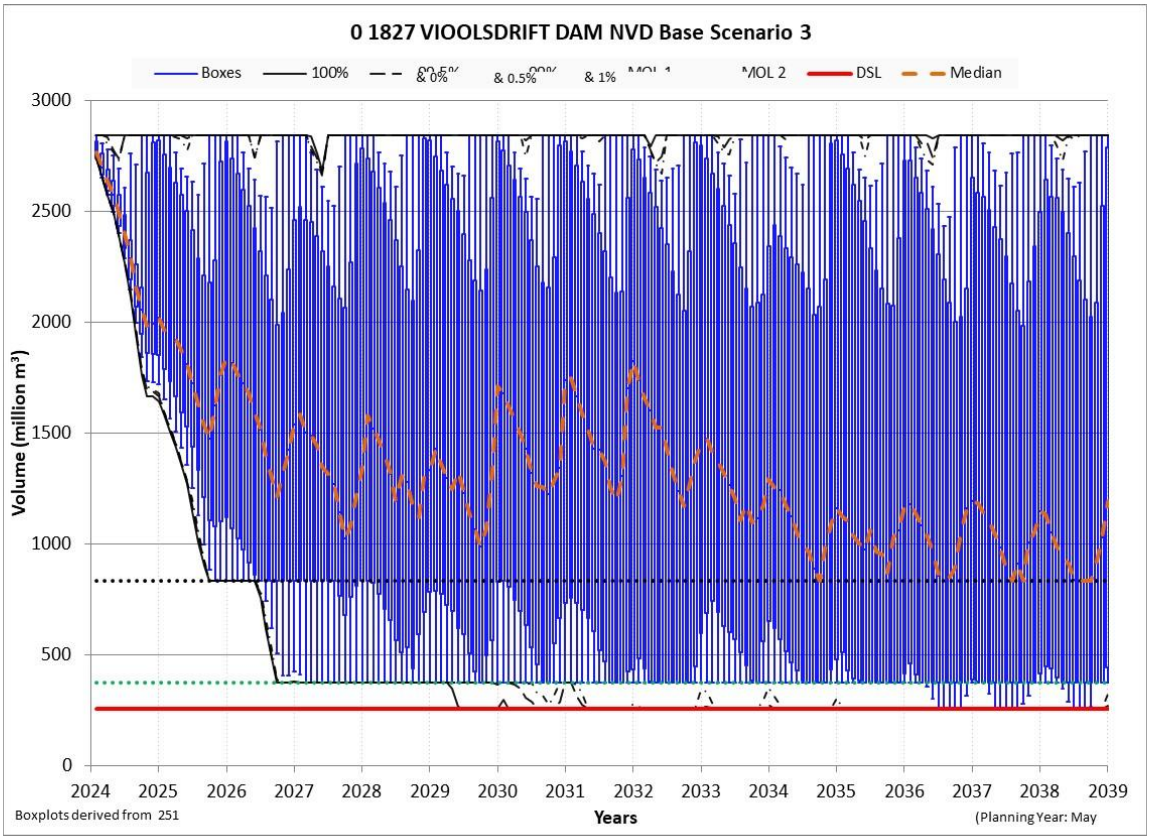


**Figure 5-48: Base Scenario 3 – Noordoewer-Vioolsdrift Dam storage projection plot**

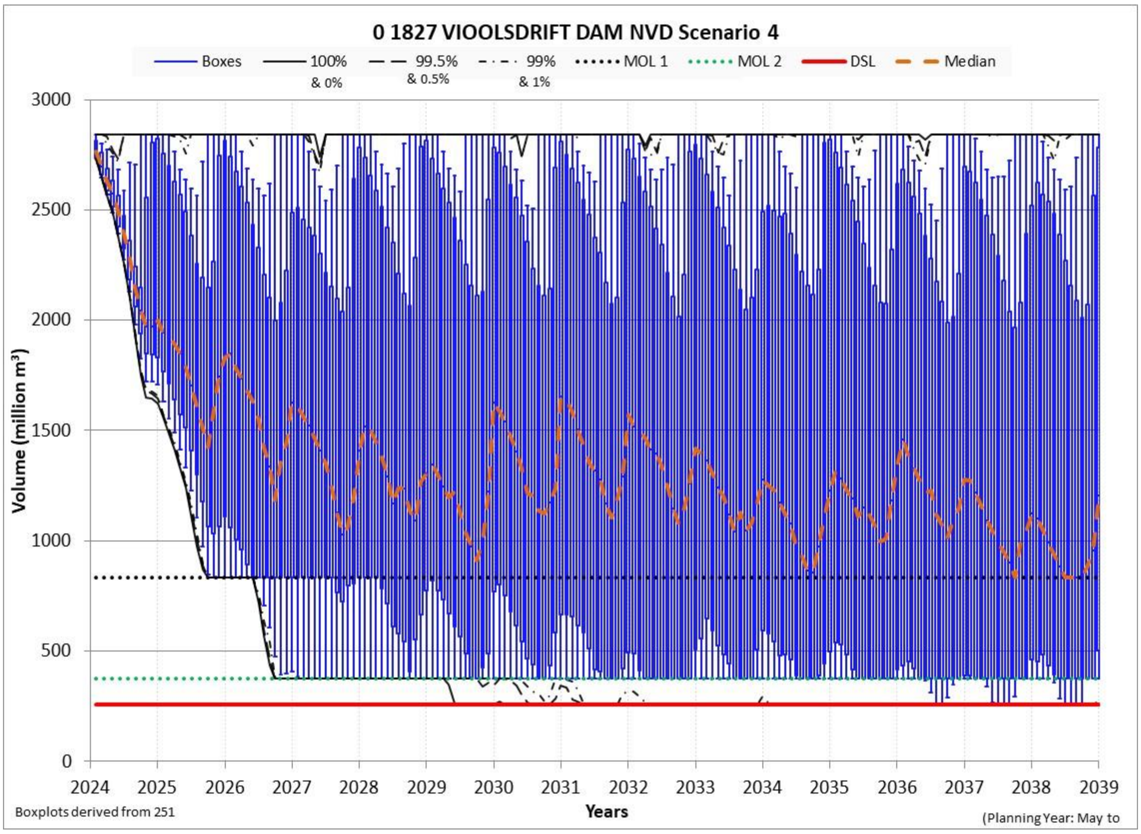


**Figure 5-49: Scenario 4 - Noordoewer-Vioolsdrift Dam storage projection plot**

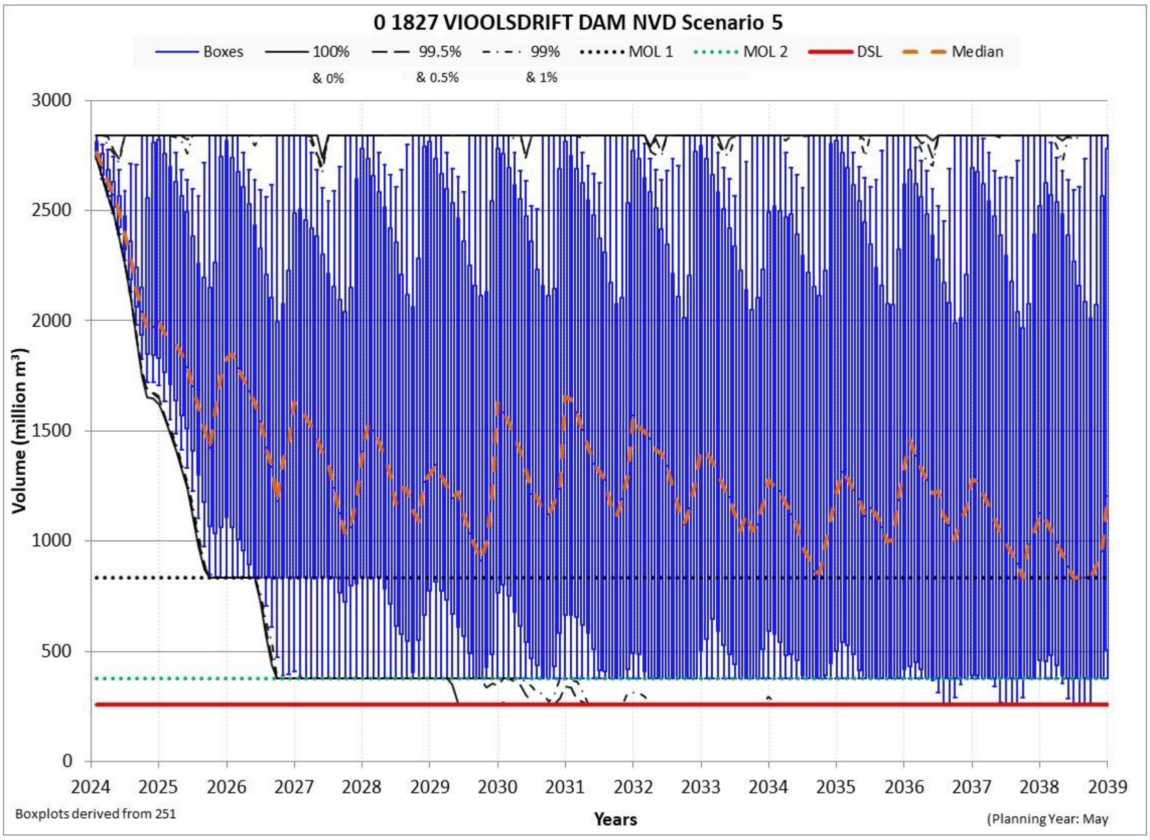


**Figure 5-50: Scenario 5 - Noordoewer-Vioolsdrift Dam storage projection plot**

The storage projection plots for the Noordoewer-Vioolsdrift Dam are given in Figures 5-48, 5-49 & 5-50 for all three scenarios analysed. Similar to Vanderkloof Dam, the plots are almost identical with very small differences, as explained before.

The operating rule, however, dictates that support from Vanderkloof to Noordoewer-Vioolsdrift Dam only takes place when the storage in the Noordoewer-Vioolsdrift Dam is at 29% or lower. See the details below:

- When the Noordoewer-Vioolsdrift Dam is between 29% and 13%, it will be supported from Vanderkloof Dam only when Vanderkloof Dam is above MOL 1, thus above the MOL for hydro-power generation.
- When the Noordoewer-Vioolsdrift Dam is between 13% and 9%, it will be supported from Vanderkloof Dam, even when Vanderkloof Dam is below its MOL 1.

The impact of these operating rules is evident on all three of the projection plots prepared for the Noordoewer-Vioolsdrift Dam (Figures 5-48, 5-49 & 5-50).

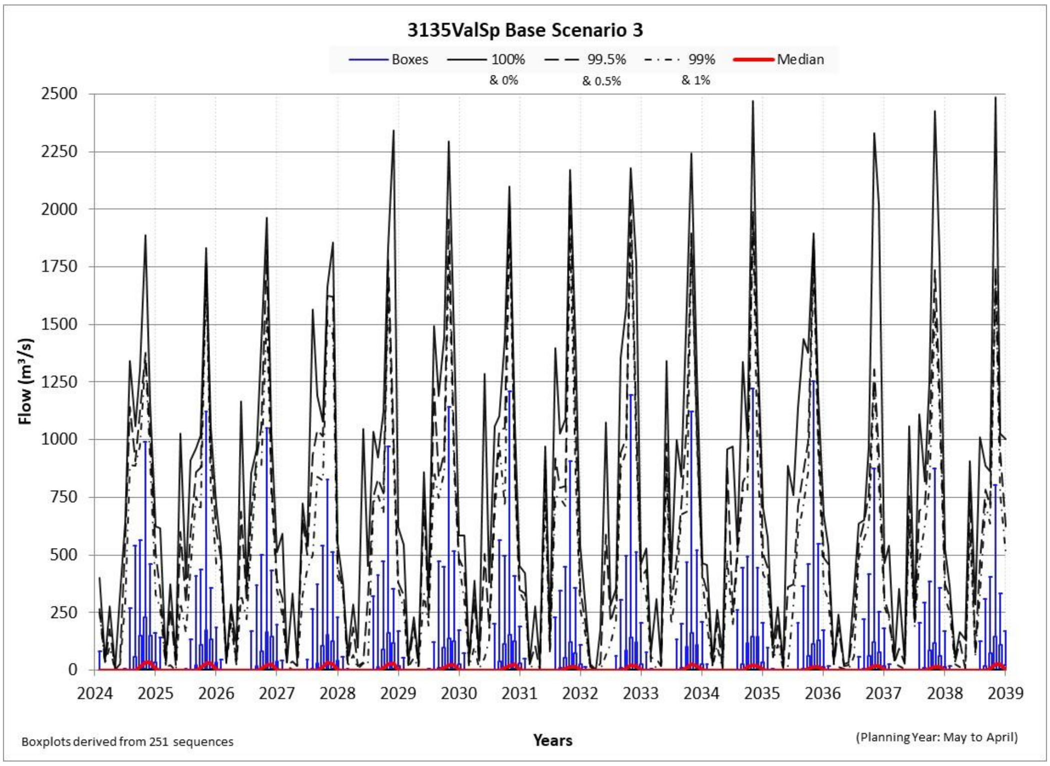


**Figure 5-51: Base Scenario 3 – Spills from the Vaal River**

The median spills from the Vaal River system (Figure 5-51) are clearly less than those observed from Base Scenario 2. This is a result of the exclusion of restrictions from the operating rules, allowing Bloemhof Dam to drop to lower levels and thus resulting in reduced spills from Bloemhof Dam. This is also evident from Figure 5-52 when zooming in on the low flows of the Vaal system spills.

The 95% exceedance level (1 in 20 years) Vaal spills for Base Scenario 2 and Base Scenario 3 are, however, very similar, indicating that the base flows from the Vaal River into the Orange is for practical purposes, the same for the two scenarios.

The Vaal River spills for Base Scenario 3 and Scenarios 4 and 5 are identical as expected, as the changes between those scenarios are not impacting the Vaal System.

The flow to supply water to the users along the Orange River downstream of Vanderkloof Dam to the Orange River estuary is all released from Vanderkloof Dam. This includes the support required by the Noordoewer-Vioolsdrift Dam. From Figures 5-55 and 5-56, it is evident that a much stronger base flow is observed downstream of Vanderkloof Dam than from the Vaal Spills (Figure 5-51), which is due to the releases from Vanderkloof Dam in support of the downstream users. Figure 5-56 zooms in on the base flows just downstream of Vanderkloof Dam.

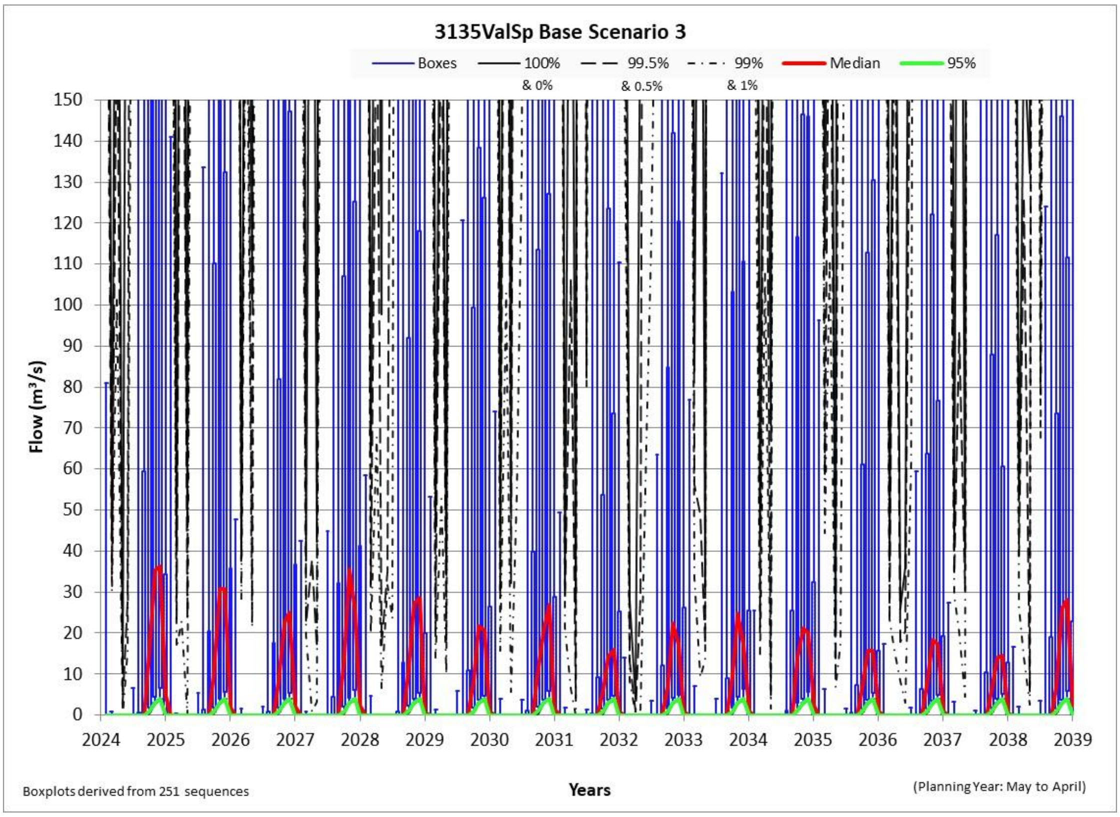


**Figure 5-52: Base Scenario 3 – Spills from the Vaal System entering the Orange River**

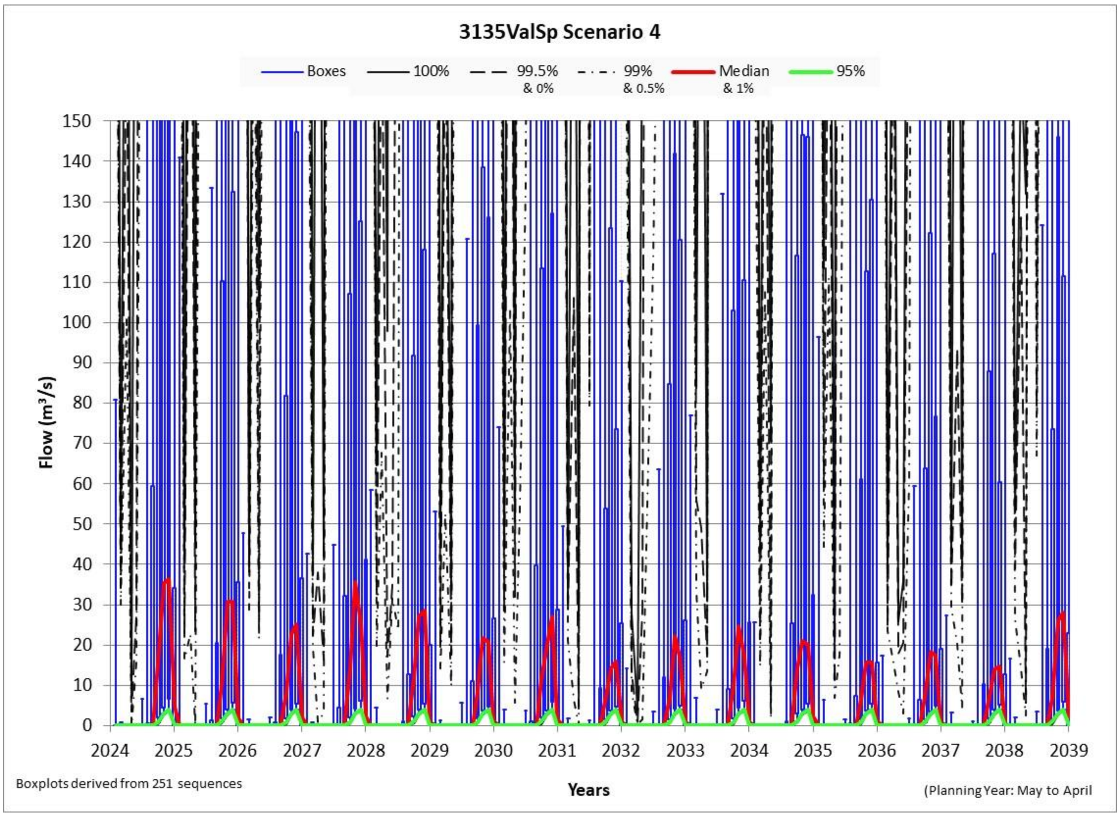


**Figure 5-53: Scenario 4 - Vaal River spills low flows**

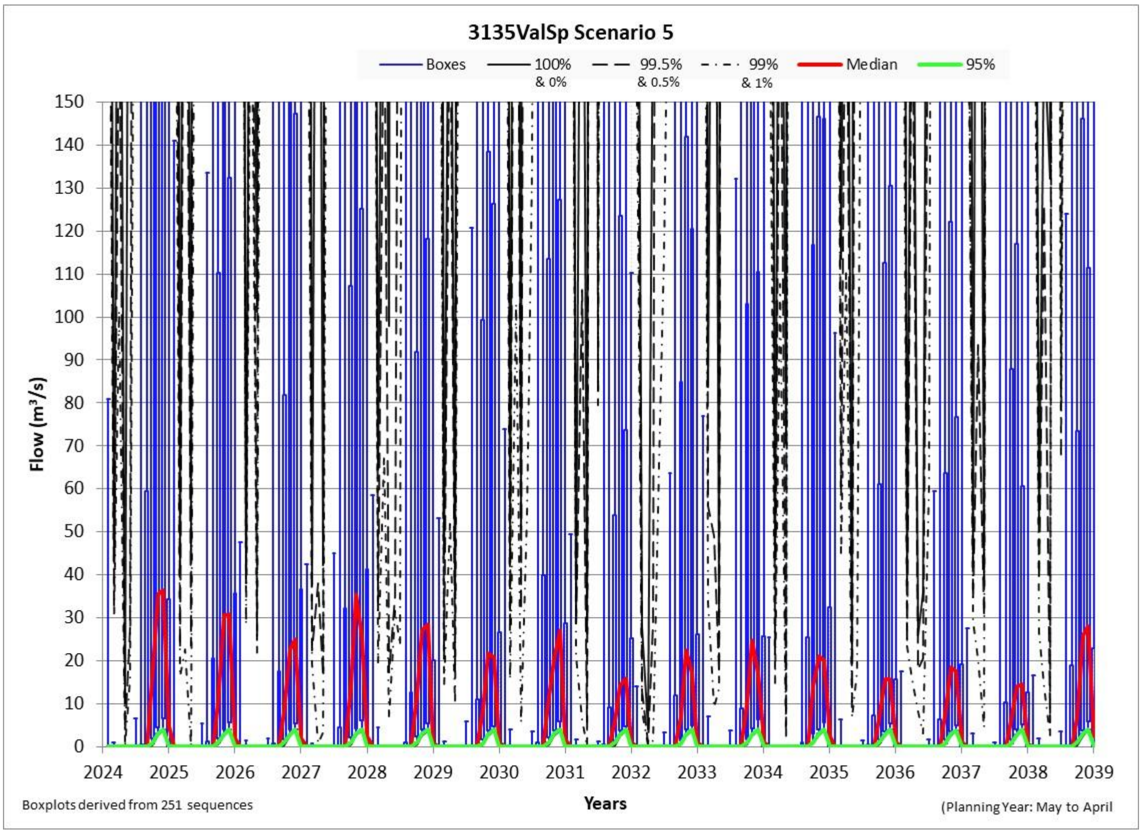


**Figure 5-54: Scenario 5- Vaal River spills low flows**

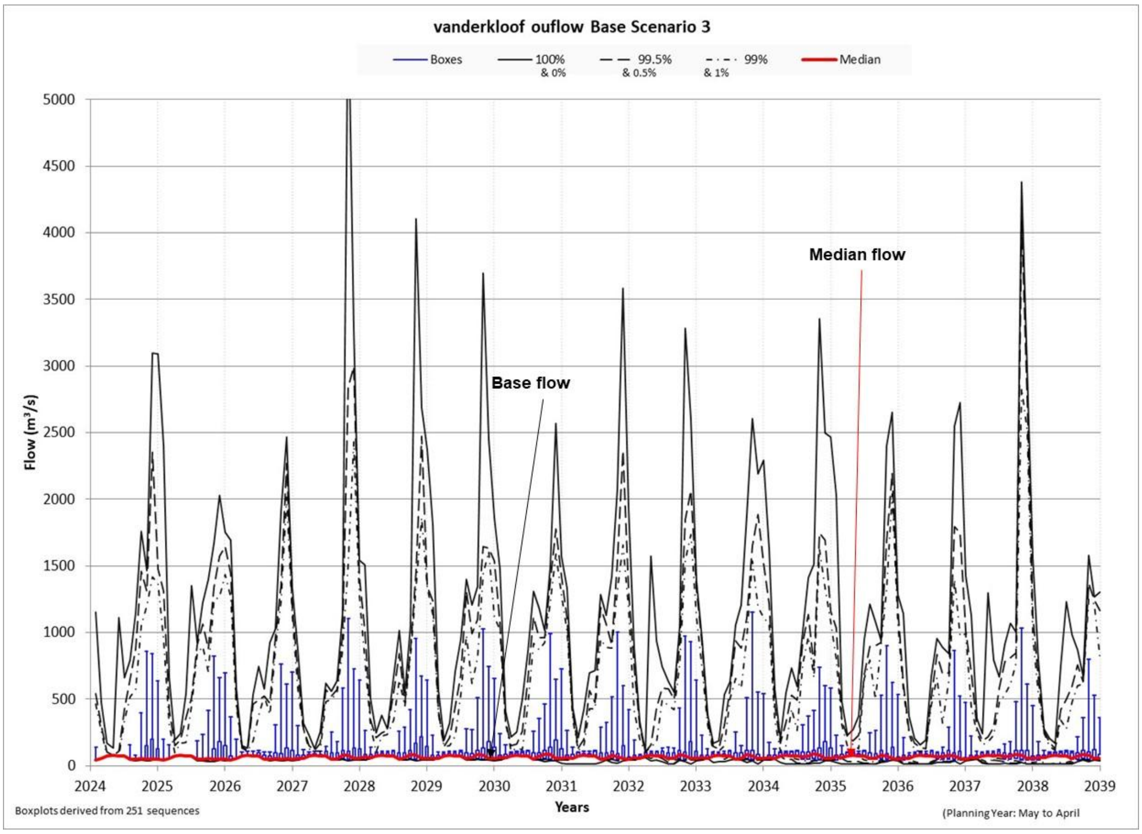


**Figure 5-55: Base Scenario 3 – Releases and spills from Vanderkloof Dam**

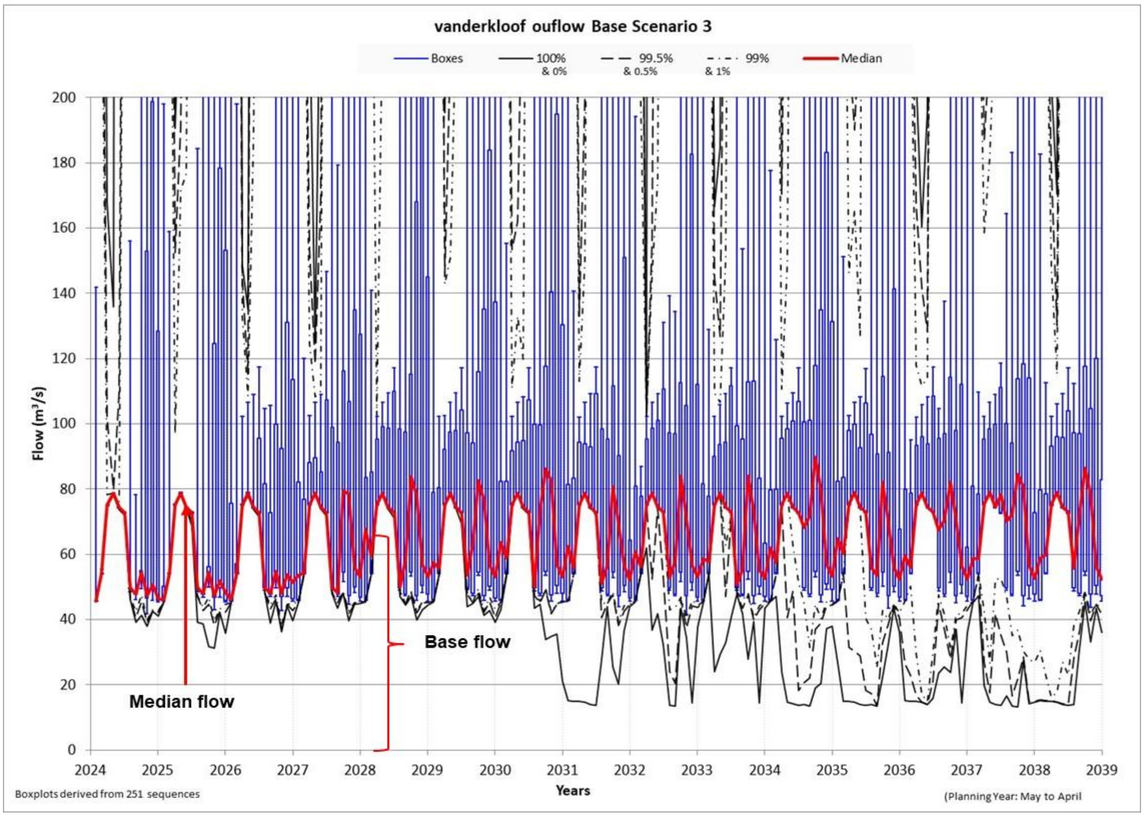


**Figure 5-56: Base Scenario 3 - Vanderkloof Dam monthly releases and spills focussing on lower flows**

The Vanderkloof base flows for Base Scenario 3 (Figure 5-57) are slightly less than those evident from Base Scenario 2 (Figure 5-25) and are due to the Noordoewer-Vioolsdrift Dam, which is taking some of the load previously imposed on Vanderkloof Dam. The other major difference between the base flows of Base Scenario 2 and Base Scenario 3 is that the impact of restrictions is clearly evident from the base flows for Base Scenario 2 in particular over the period 2031 to 2039 (Figure5-25). For Base Scenario 3, it is only during the very severe drought years of 1 in 200 and 1 in 100-years that one sees a drop in the base flows, showing that it only occurs during those severe dry years over the winter period when the dams reach empty or almost empty with less water then being supplied to users.

Comparing the Vanderkloof Base Flows for Scenarios 4, 5 and Base Scenario 3, it is evident that the base flows are almost identical. The differences are so small that they are not observable from the box plots. This shows that the increase in demand imposed on the Noordoewer-Vioolsdrift Dam due to the Haib Mine demand required almost no additional support from Vanderkloof Dam to (support) the Noordoewer-Vioolsdrift Dam.

The base flows at Blouputs for Base Scenario 3, Scenario 4 and Scenario 5 are given in Figures 5-60, 5-61 and 5-62, respectively. The low flows for all three scenarios are almost identical, with differences so small that they can hardly be observed on the flow plots. This further confirms that almost no additional support was required from Vanderkloof Dam when the Haib Mine demand was added.

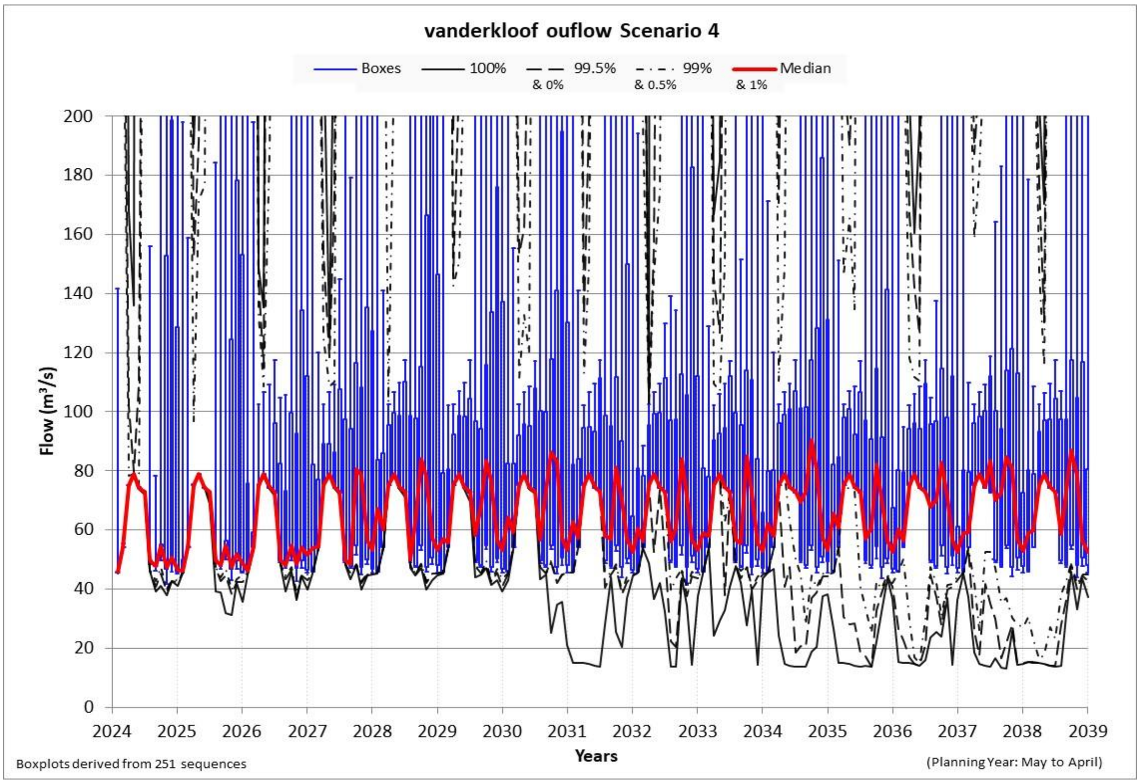


**Figure 5-57: Scenario 4: Vanderkloof Dam monthly releases and spills focussing on lower flows**

The minimum flows at Blouputs as required for Base Scenario 2 were included in the flow projection at Blouputs for Base Scenario 3 (See green dashed line Figure 5-60.). This shows the simulated low flow is now significantly lower than the minimum flow as required for Base Scenario 2. This is a result of the inclusion of the Noordoewer-Vioolsdrift Dam, which is taking some load off Vanderkloof Dam, as it now supplies all the water requirements downstream of its location (the Noordoewer-Vioolsdrift Dam). A new minimum flow requirement therefore needs to be determined once the Noordoewer-Vioolsdrift Dam is in place.

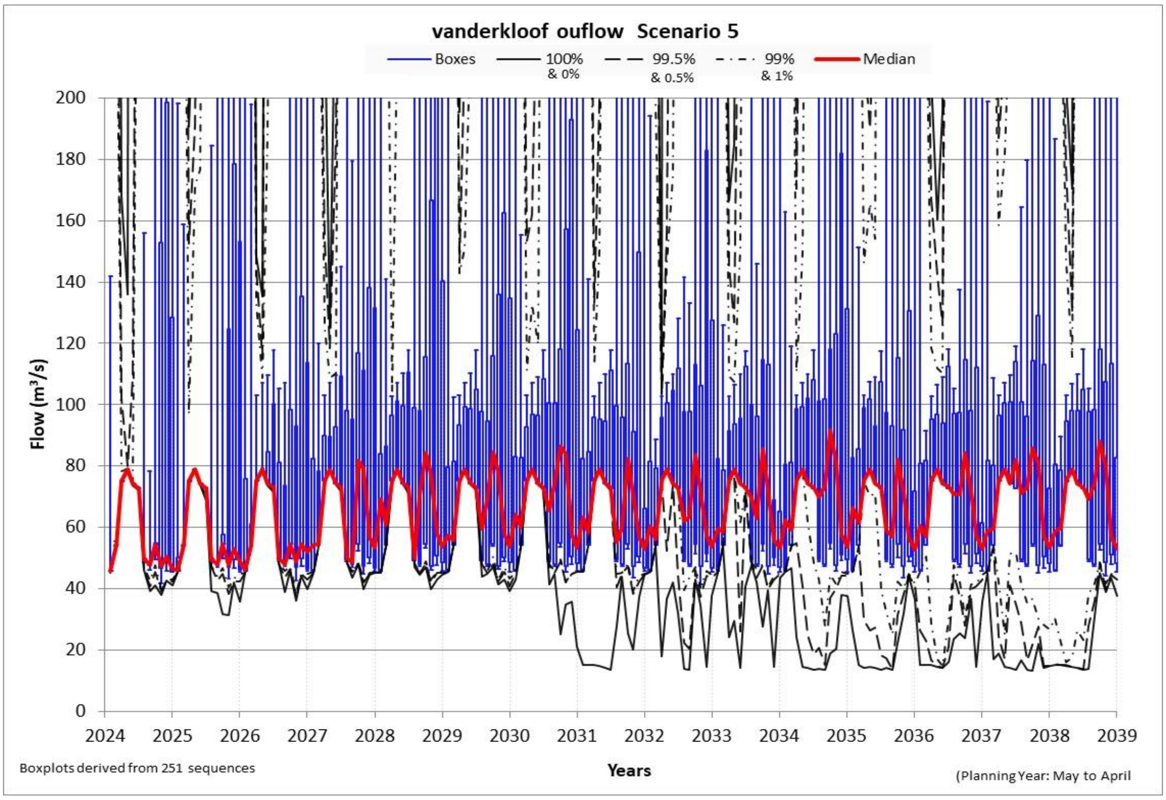


**Figure 5-58: Scenario 5 - Vanderkloof Dam monthly releases and spills focussing on lower flows**

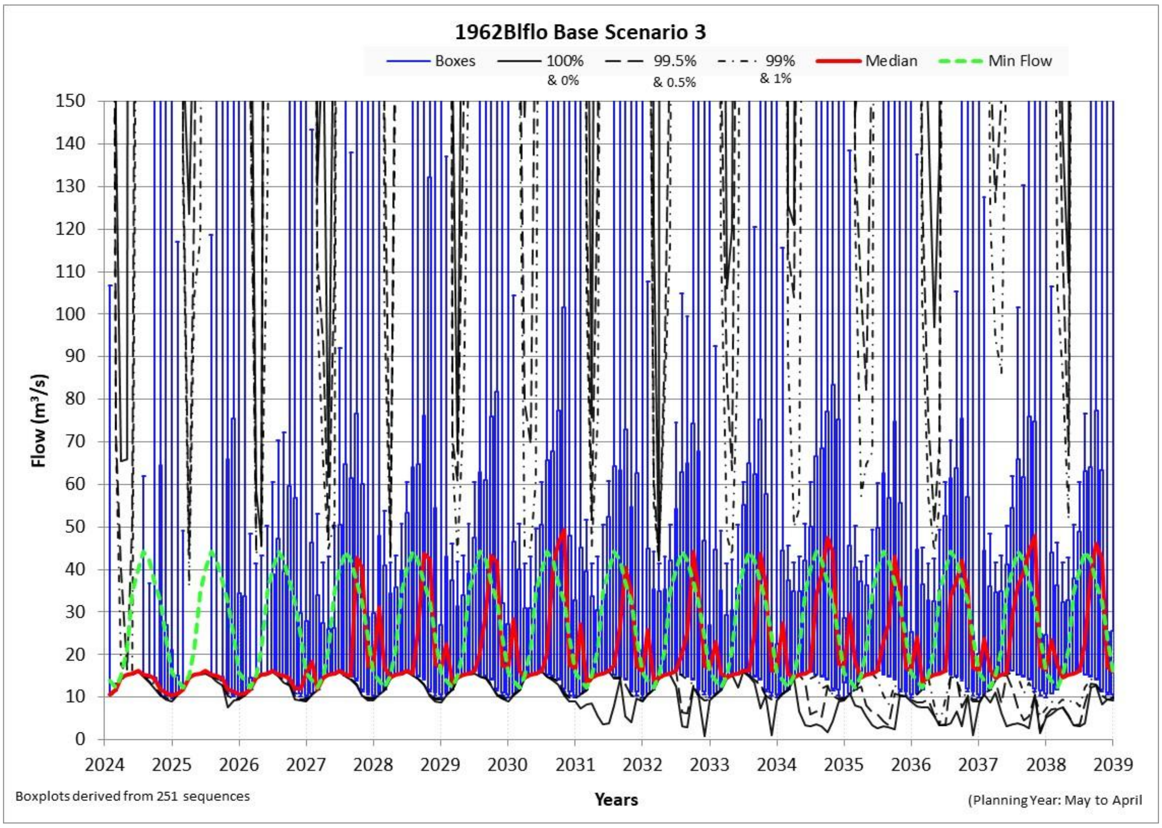


**Figure 5-59: Base Scenario 3 – Simulated low flows at Blouputs**

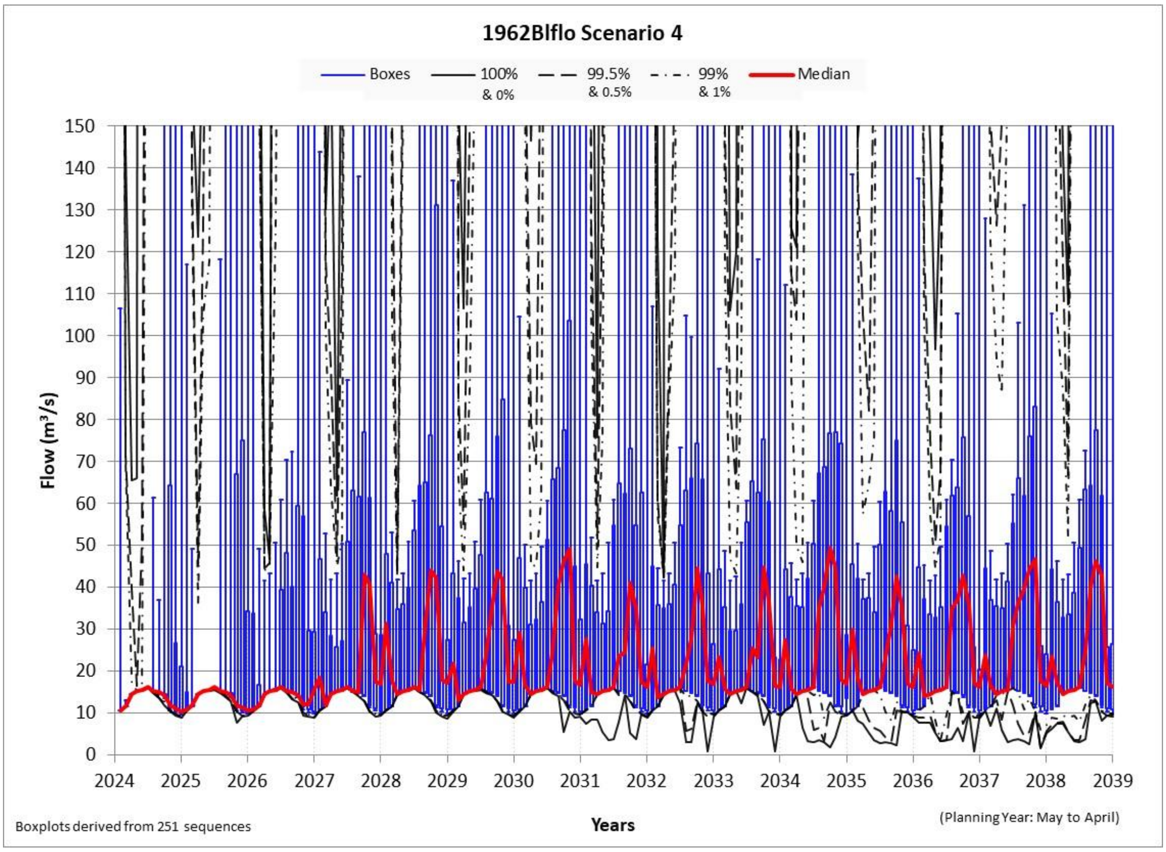


**Figure 5-60: Scenario 4 – Simulated low flows at Blouputs**

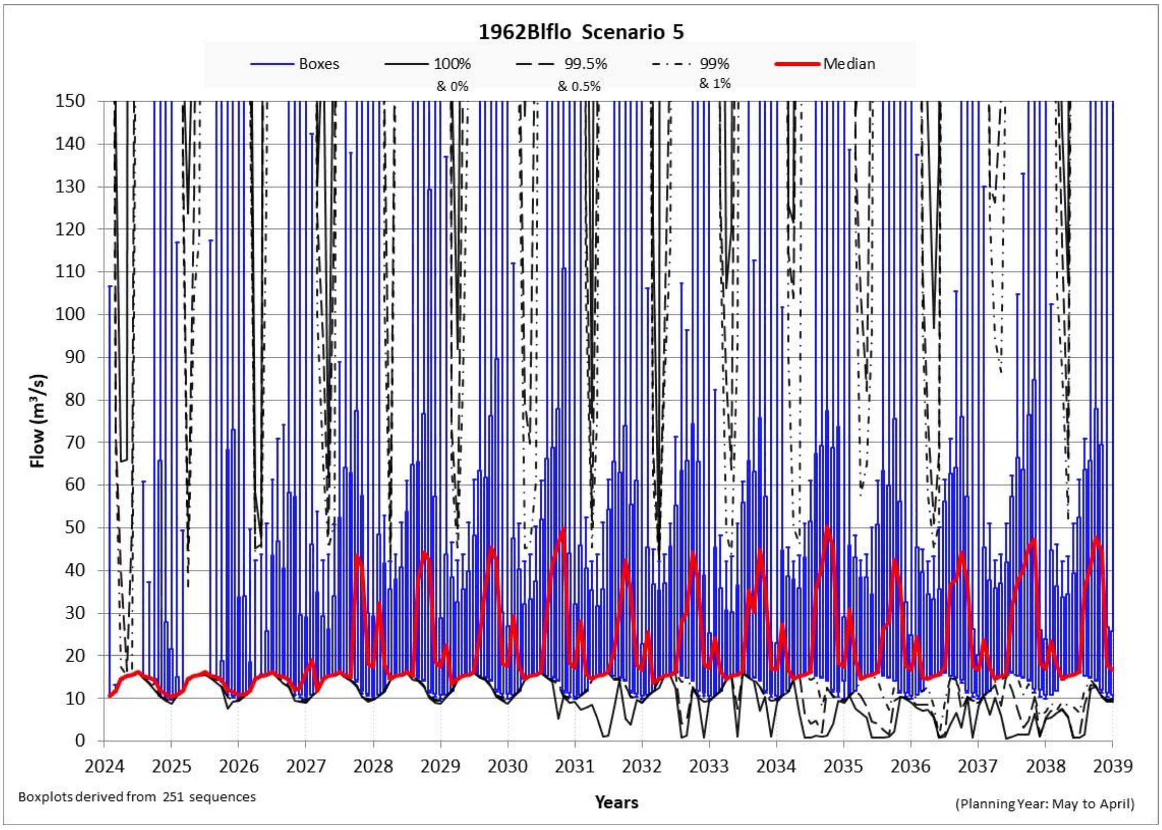


**Figure 5-61: Scenario 5 – Simulated low flows at Blouputs**

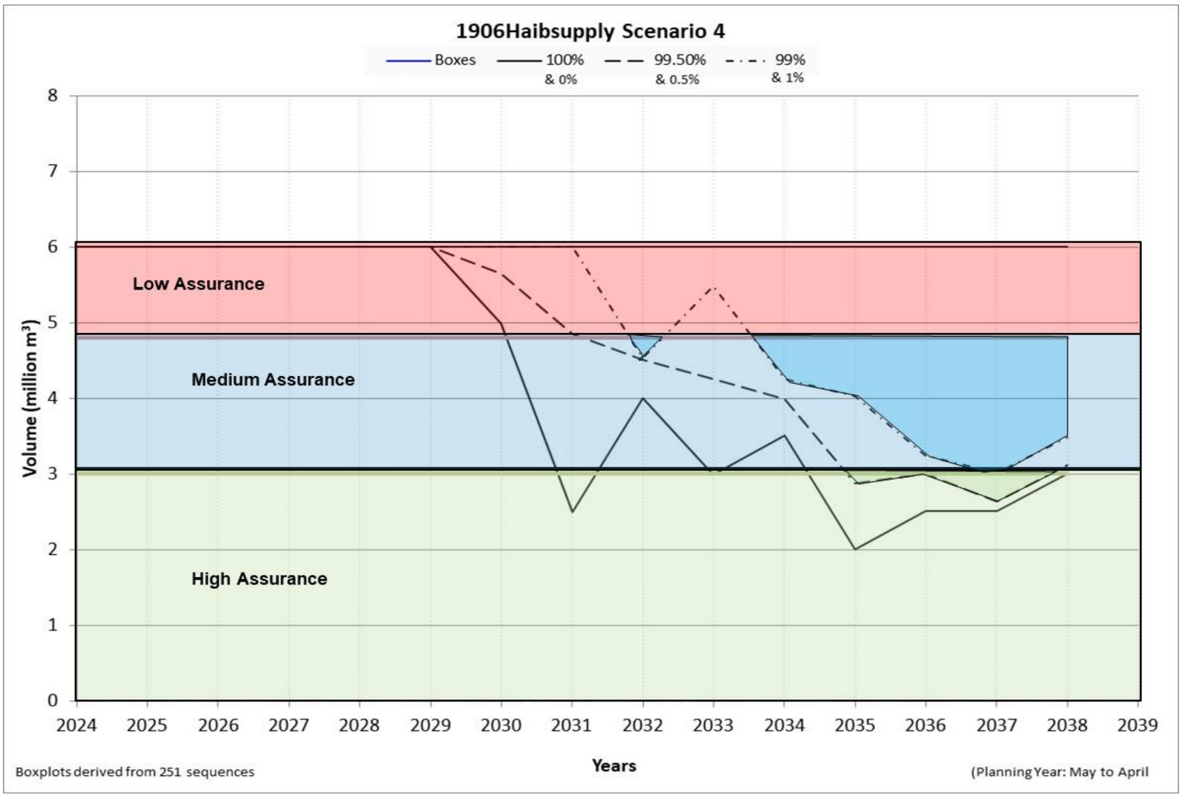


**Figure 5-62: Scenario 4 - Water supply to Haib Mine from Noordoewer-Vioolsdrift Dam**

The water supply to Haib Mine from the Noordoewer-Vioolsdrift Dam is given in Figures 5.63 and 5.64 for Scenarios 4 and 5, respectively.

As mentioned before, the WRPM analysis for Base Scenario 3, Scenario 4 and Scenario 5 did not use the curtailment option within the WRPM and thus also did not allocate the demands into different assurance of supply classes. The portion of the water requirement, as normally subdivided into the different assurance classes were however, included in the water supply graphs to obtain a better understanding of how well the water demand was supplied. It should be understood that the model did not try to achieve the correct supply at the required assurance level, as that option was not used in the analysis for these three scenarios.

The low and high assurance components of the Haib demand could be supplied almost fully over the entire simulation period, with a small deficit on the high assurance towards the end of the simulation. The medium assurance supply started to exceed the assurance of supply criteria from about 2034 onwards.

The difference in supply to Haib Mine between Scenario 4 and Scenario 5 is relatively small, with the supply to Haib from Scenario 5 slightly worse.

The results from the analyses can also be expressed as follows. When assuming the total demand needs to be supplied at a given assurance, for example, a 95% assurance, it is evident that for both scenarios 4 and 5, the Haib demand could be 100% supplied over the total simulation period. When considering the 99% assurance, both scenarios will, on average, over the simulation period, be supplied at 85%.

**Table 5-2: Average Haib supply at given assurance for Scenarios 4 and 5**

| Scenario | Average Haib Mine supply at the given assurance | | | |
|---|---|---|---|---|
| | **50% (median)** | **95%** | **99%** | **99.5%** |
| Scenario 4 | 100% supply | 100% supply | 85% supply | 79% supply |
| Scenario 5 | 100% supply | 100% supply | 85% supply | 78% supply |

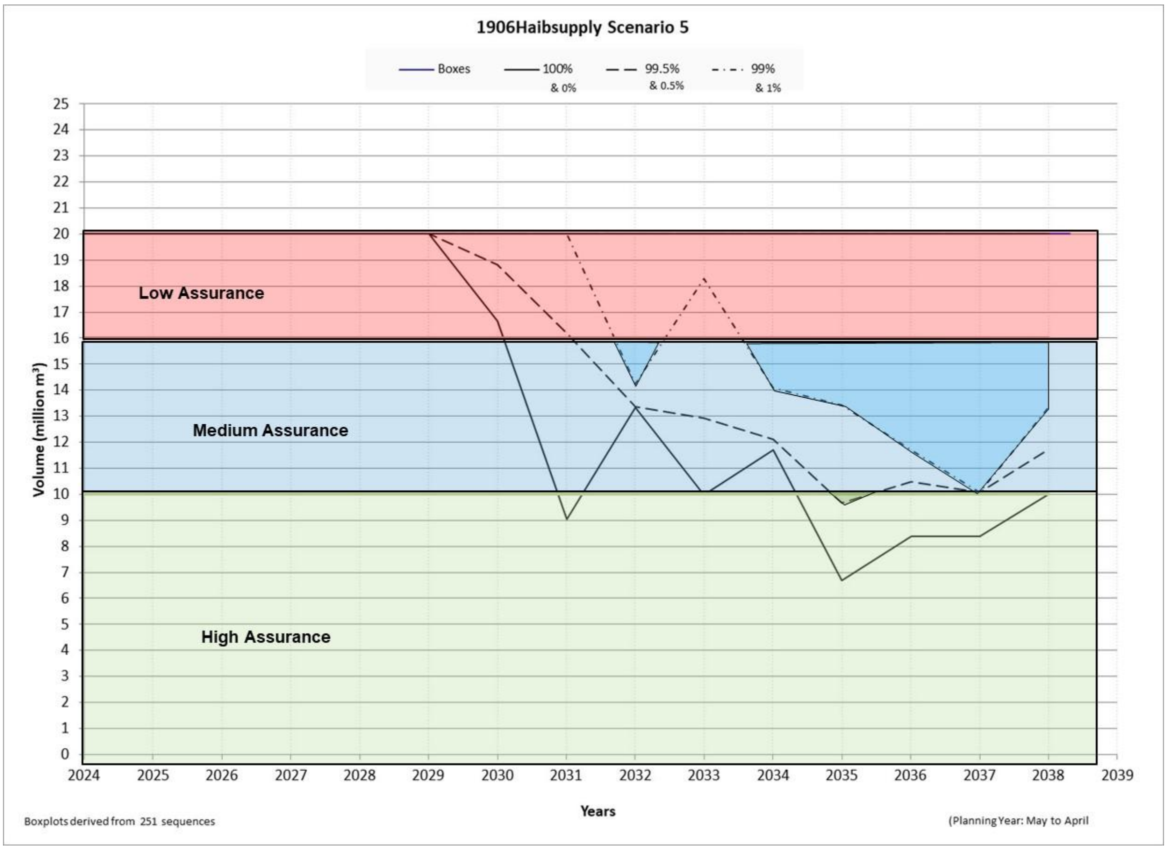


**Figure 5-63: Scenario 5 - Water supply to Haib Mine from Noordoewer-Vioolsdrift Dam**

The water supply to Alexander Bay, as given in Figure 5-64, is significantly better than that obtained for Base Scenario 2, where Alexander Bay could only be fully supplied for 2 out of the 15 years analysed. This is a result of the inclusion of Verbeeldingskraal Dam, utilising the Lower-Level Storage in Vanderkloof Dam and adding the Noordoewer-Vioolsdrift Dam. Including these intervention options almost fully balances the ORP system. The purpose of the analysis was not to find the optimum combination of intervention options to fully balance the ORP system, but rather to show that future intervention options should be able to rebalance the ORP system, including supplying the Haib Mine demand. Information from previous studies was used to decide on the applicable dam sizes and demands imposed on the system as used in this analysis. The results showed that there is still a small deficit in the system. This will be addressed by future studies to ensure proper water balances in the system to cater for the future requirements.

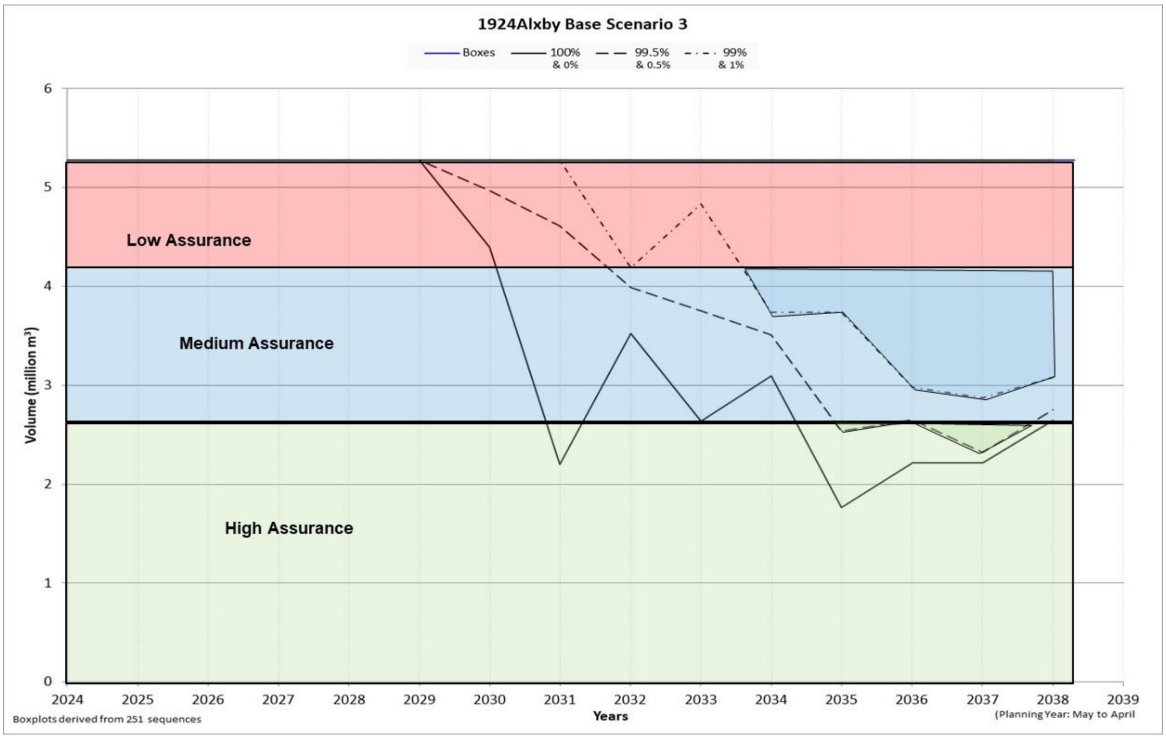


**Figure 5-64: Base Scenario 3 – Water supply to Alexander Bay**

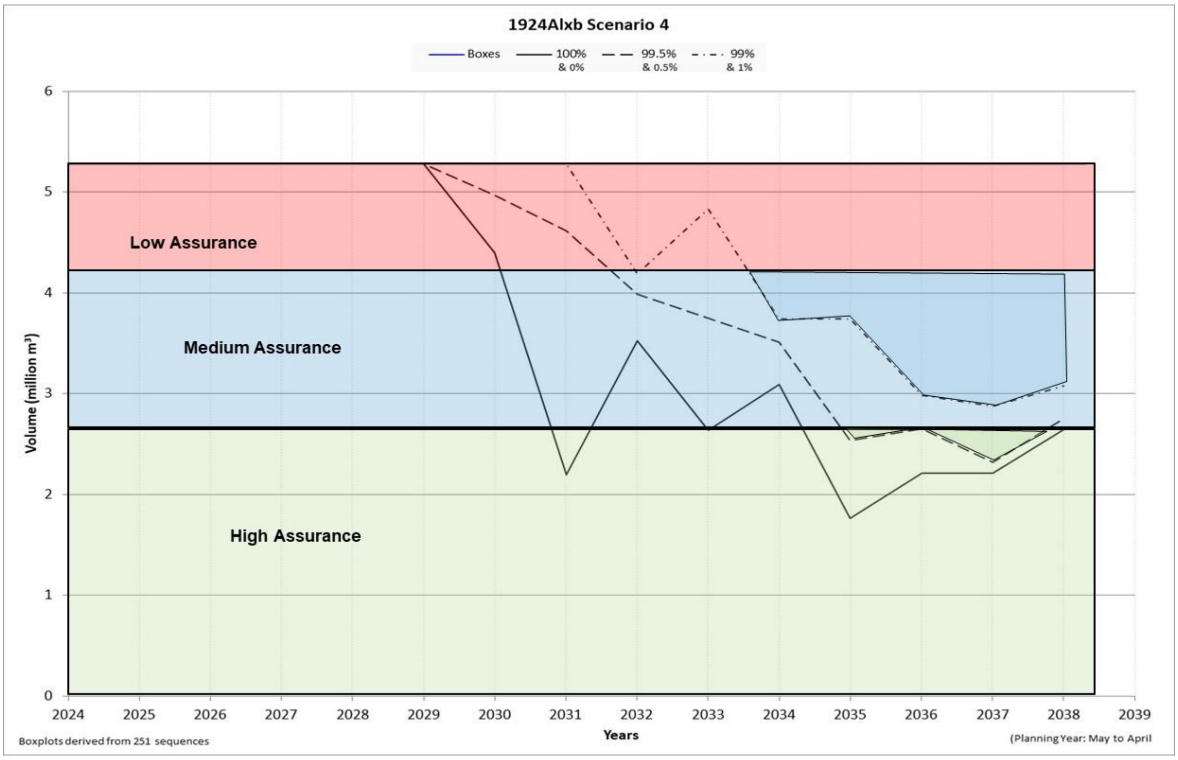


**Figure 5-65: Scenario 4 - Water supply to Alexander Bay**

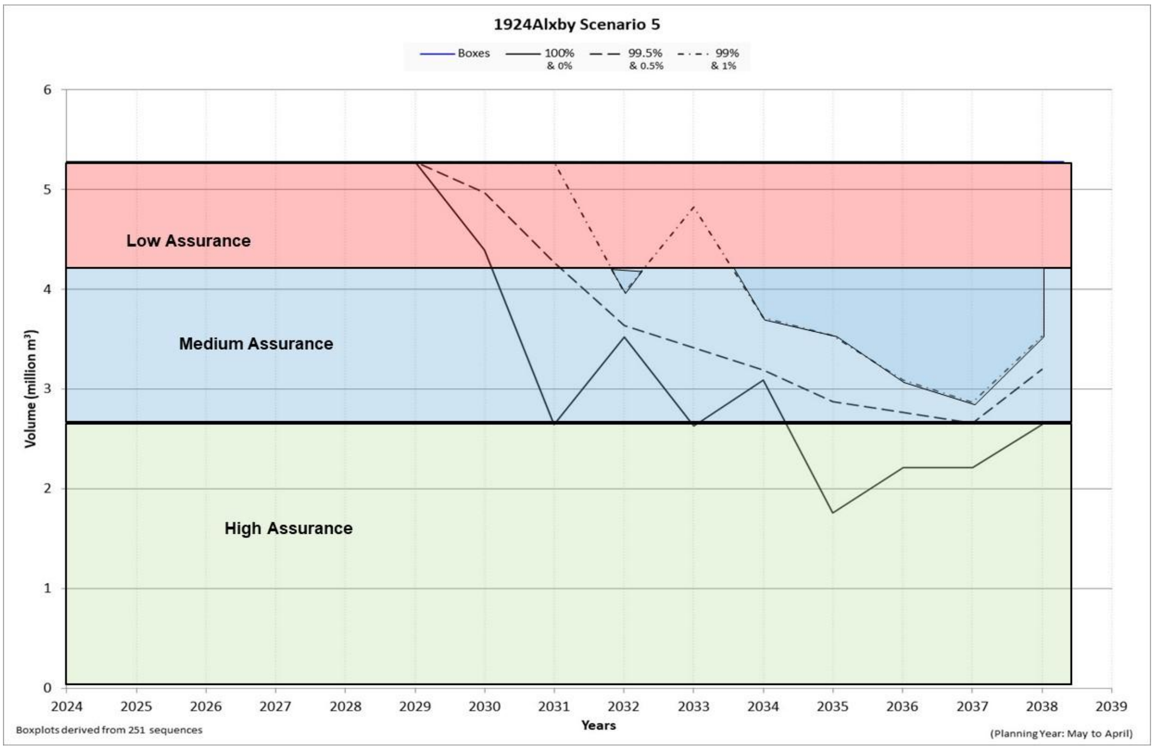


**Figure 5-66: Scenario 5 - Water supply to Alexander Bay**

Irrigation requirements in the WRPM are not considered as a fixed annual demand that is imposed on the system. Irrigation water requirements in the WRPM are most of the time determined by an irrigation block, which uses crop factors, rainfall and evaporation data to calculate the irrigation requirements. During high rainfall years, one would then typically obtain a lower irrigation requirement and in dry years, a higher irrigation requirement. This is illustrated in Figure 5-68 for Base Scenario 3, where the irrigation supply to Aussenkehr and Noordoewer combined was fully supplied over the entire simulation period. The irrigation requirement, however, varied between the green line (wet years) and the upper purple line for the dry years. The variance in the irrigation requirement between these two lines does not indicate a deficit in the irrigation supply, but only that the irrigation requirement varies due to rainfall.

Similar to the water supply plot for Alexander Bay, the portion of the water requirement, as normally subdivided into the different assurance classes was included in the irrigation water supply graphs to obtain a better understanding of how well the water demand was supplied, although the WRPM model did not try to achieve the correct supply at the required assurance level.

From Figures 5-68 and 5.69, it is evident that the water supply to Aussenkehr and Noordoewer remained the same for Base Scenario 3 and Scenario 4. The Aussenkehr and Noordoewer irrigation water supply for Scenario 5 did show some deficits at the medium assurance level from 2036 onwards. This corresponds to that found for Scenario 5 relating to the water supply to Alexander Bay.

These results further confirm that the intervention options included in Scenarios 4 and 5 did not fully balance the ORP system but significantly improved the water supply to the users in comparison with the results from Base Scenario 2.

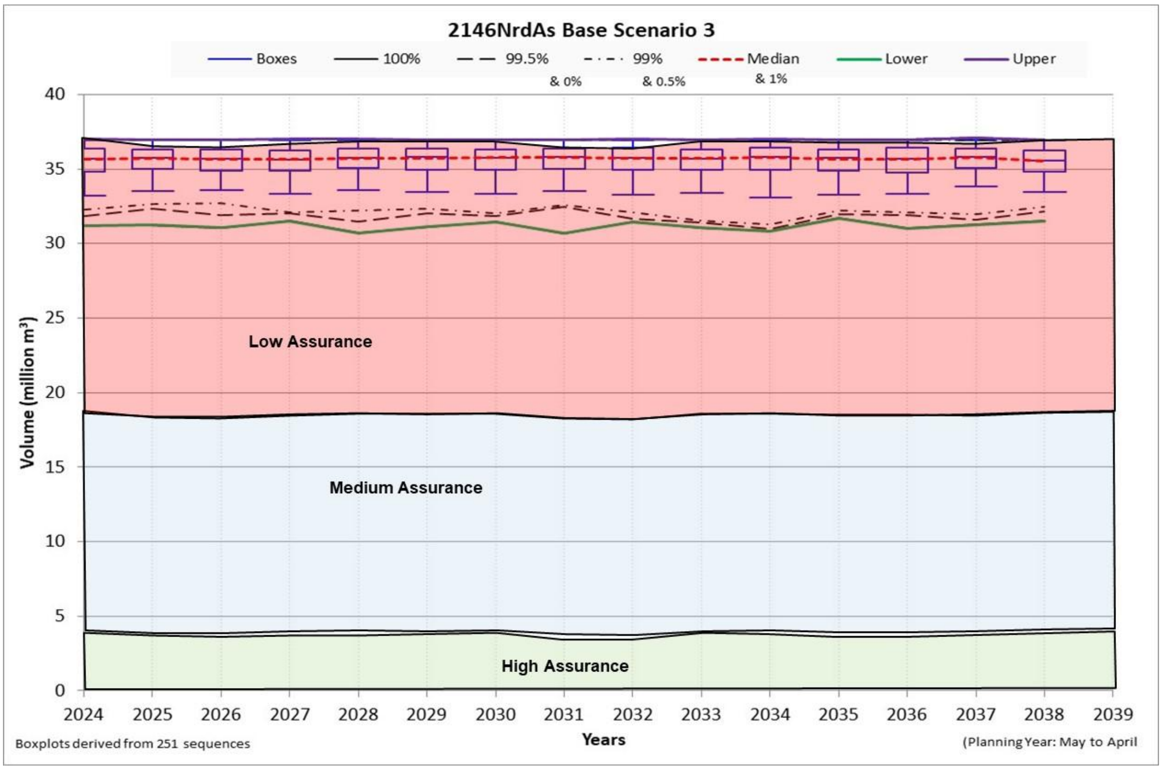


**Figure 5-67: Base Scenario 3 – Water supply to Aussenkehr & Noordoewer**

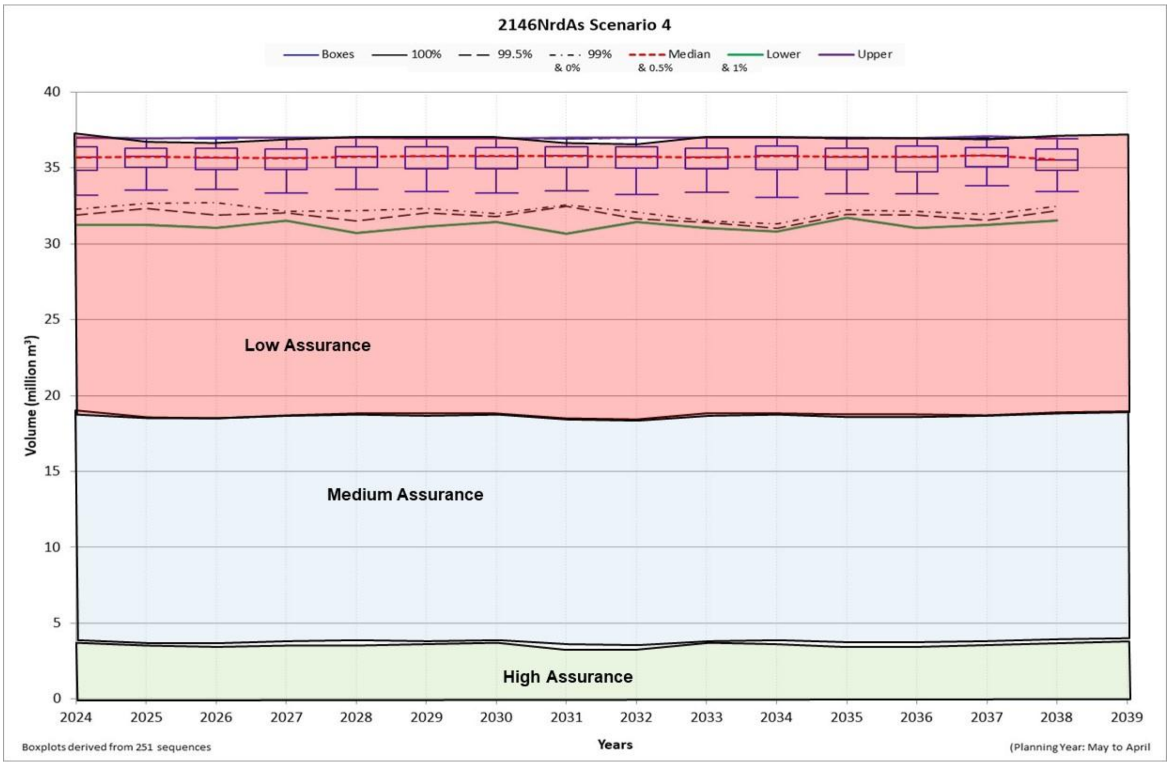


**Figure 5-68: Scenario 4– Water supply to Aussenkehr & Noordoewer**

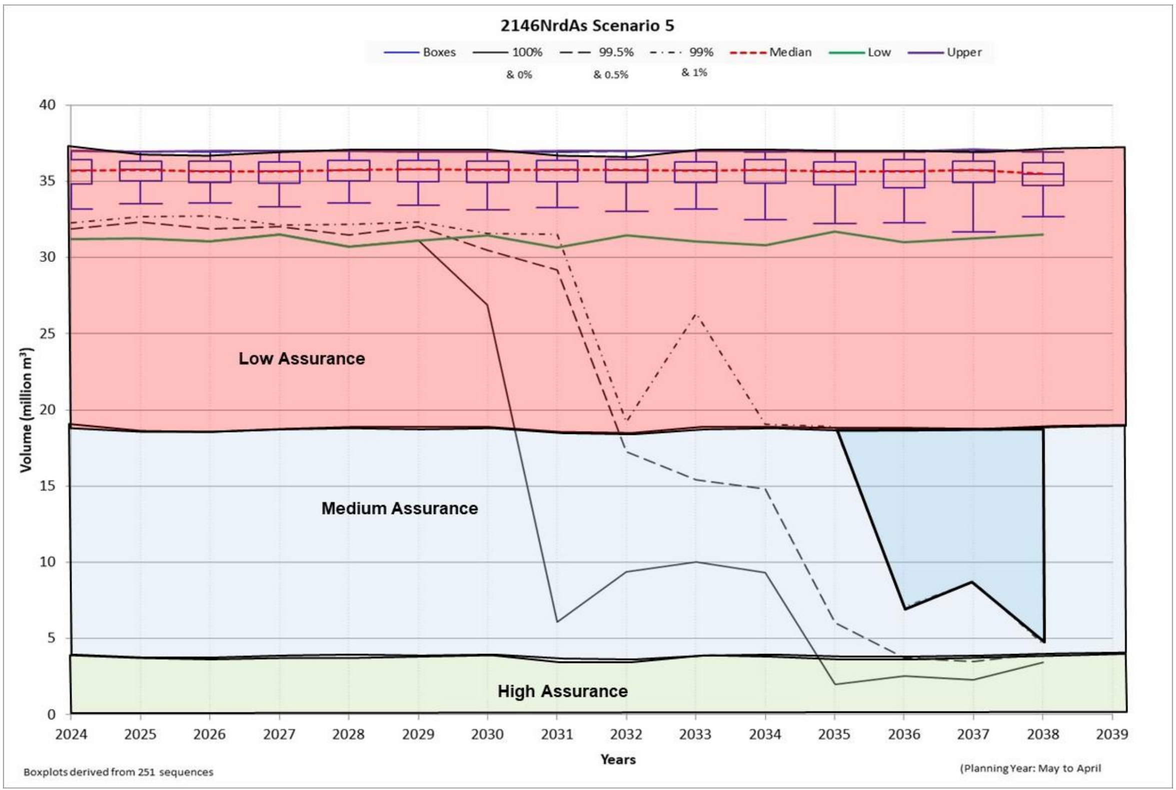


**Figure 5-69: Scenario 5 – Water supply to Aussenkehr & Noordoewer**

The current study (Noordoewer-Vioolsdrift Dam Bridging Feasibility Study) by ORASECOM on behalf of Namibia and the RSA on the Noordoewer-Vioolsdrift Dam development will ensure that there is a balance between the future demand imposed on the dam and the yield available from the proposed Noordoewer-Vioolsdrift Dam. It is, however, important that the latest Haib Mine water requirements are supplied to the study team of that Bridging Feasibility Study to ensure that the Noordoewer-Vioolsdrift Dam development includes the correct Haib Mine water requirement for future development.

# 6.0 ORANGE RIVER PROJECT WATER BALANCE

The Orange River Project water balance was obtained from the 2024 Annual Operating Analysis Report and slightly adjusted for the purposes of this study. At the 2024 development, the ORP is already in a small deficit, as very little water conservation savings from irrigation have been realised.

It is currently expected that the Polihali Dam currently under construction, will start to inundate water in the second half of 2026. This will reduce the ORP system yield as indicated from 2027 onwards. The Orange Reconciliation Strategy study by DWS RSA identified several intervention options to rebalance the ORP after the completion of the Polihali Dam. The first two intervention options to include are the real-time monitoring and modelling option, as well as the utilisation of the lower-level storage in Vanderkloof Dam. Both these options are relatively cheap and can be implemented within a year or two (Figure 5-1).

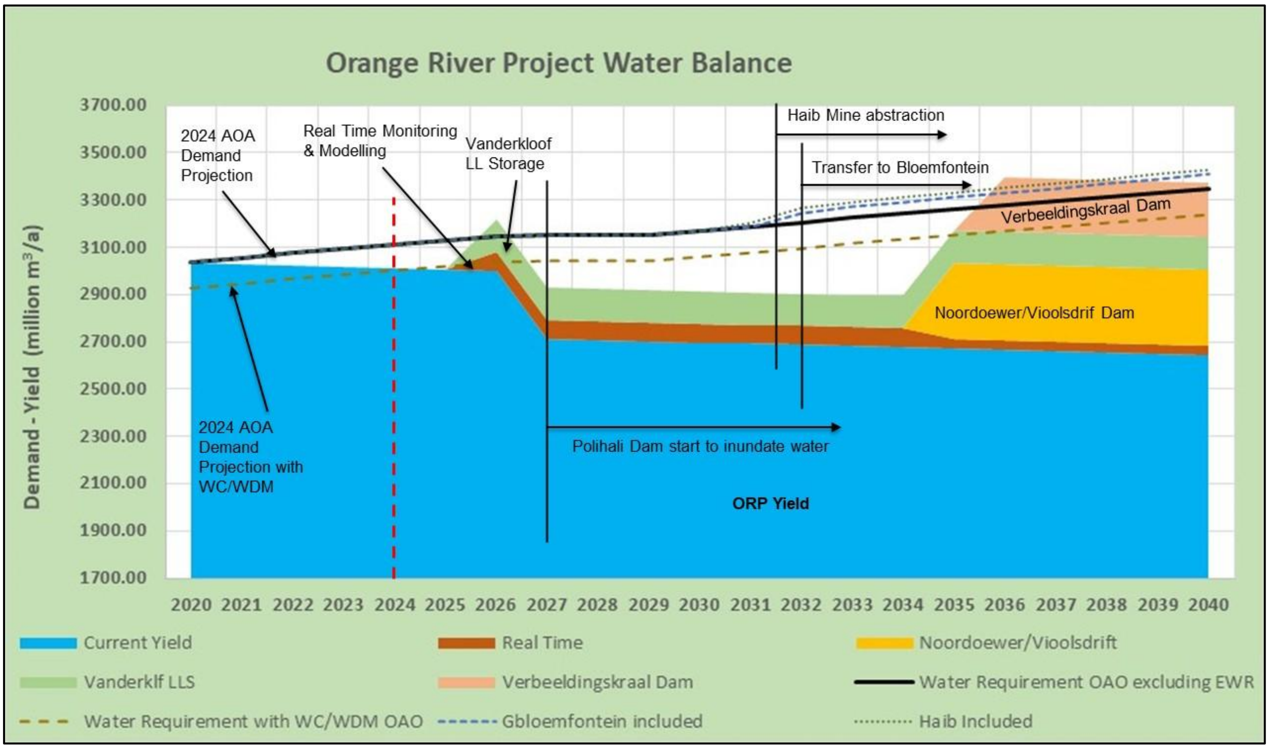


**Figure 6-1: Water balance for the Orange River Project**

These two interventions are not sufficient to rebalance the ORP, and two large storage reservoirs were identified in the Reconciliation Strategy study to further increase the system yield. This includes the possible future, Noordoewer-Vioolsdrift Dam. For the purpose of this water balance, it was assumed that this dam would be in place by 2035 and the Verbeeldingskraal Dam by 2036.

The transfer from Gariep to the Greater Bloemfontein is expected to be in place by 2032 and will eventually transfer a total volume of 101 million m$^3$/a to Mangaung. It is expected that the Haib Mine might start using water by 2031, increasing the total demand imposed on the ORP system by 20 million m$^3$/a.

From the water resource analysis carried out as described in Section 4 of this report, it is evident that there are options where Haib Mine will only abstract from the surplus water available in the Lower Orange River. By storing that in an off-channel storage dam, the Haib Mine requirements can be supplied without using releases from Vanderkloof Dam and thus have no impact on the total demand imposed on the ORP. From the ORP water balance, it is evident that the ORP system will experience deficits in water supply for several years (9 years) until the recommended additional two storage dams are completed.

# 7.0 CLIMATE CHANGE

Detailed work was carried out on climate change as part of the study by ORASECOM referred to as the "Preparation of climate resilient water resources investment strategy & plan and Lesotho-Botswana water transfer multipurpose transboundary project". This work is documented in the Climate Change Report Document no. 007/2019 dated August 2021. A brief description of the work done and related results and conclusions are given below.

The impact of climate change on the Orange-Senqu Basin was determined by using six global climate change models. The climate change models were downscaled and bias corrected to obtain acceptable regional meteorological trends, correlating with historic data within the accepted Southern African Hydrology.

The six Global Climate Models that were downscaled are:

- Australian Community Climate and Earth System Simulator (ACCESS1-0), hereafter referred to as ACC
- Geophysical Fluid Dynamics Laboratory Coupled Model (GFDL-CM3), hereafter referred to as GFD.
- National Centre for Meteorological Research Coupled Global Climate Model, version 5 (CNRM-CM5), hereafter referred to as CNR.
- Max Planck Institute Coupled Earth System Model (MPI-ESM-LR), hereafter referred to as MPI.
- Norwegian Earth System Model (NorESM1-M), hereafter referred to as NOR.
- Community Climate System Model (CCSM4), hereafter referred to as CCS.

The bias-corrected climate change rainfall and evaporation data were used to determine their impacts on the natural runoff. This was done for two scenarios, including bias-corrected climate change rainfall for scenario 1 and bias-corrected rainfall and evaporation for scenario 2. The Pitman Model was programmatically re-run for the 11 sub-systems containing 119 runoff units for the 6 climate change models and two scenarios. These natural runoff, rainfall and evaporation datasets were compiled as inputs for the Water Resources Yield Model (WRYM). The WRYM was used to determine the yields for the four separate sub-systems, consisting of the Lesotho Highlands Water Project (LHWP), Greater Bloemfontein Water Supply Scheme (GBWSS), Makhaleng Dam and the Orange River Project (ORP). A constant development level of 2030 was used for the analysis. The changes in yield for the six climate change models and two scenarios were then compared to the firm yield determined for each of the four systems based on the historic hydrology before climate change impacts.

The historic firm yield for the Orange River project using the historic flows without any climate change impacts is 3 339 million $m^3$/a.

The Firm Yield results based on the climate change-impacted hydrology are presented in **Table 7-1** along with the respective percentage difference compared to the Historical Firm yield.

The changes in runoff and subsequent changes in yield for the ORP are relatively small, with five of the six CCMs producing consistent decreases in runoff with an average decrease in yield of 4% for scenario 1 and an 8% decrease in yield for scenario 2.

**Table 7-1: Firm yield as obtained for different climate change models and scenarios**

| Description | | Firm Yield for 85year simulation period (million m$^3$/annum) | | Percentage difference of the Firm Yield results for the climate change scenarios compared to the Historical Firm Yield | |
|---|---|---|---|---|---|
| Sub-system | CCM | Scenario 1 (Adjusted rainfall) | Scenario 2: (Adjusted rainfall and evaporation) | Scenario 1 vs. Historical Firm Yield | Scenario 2 vs. Historical Firm Yield |
| Orange River Project | ACC | 3194 | 3011 | -4% | -10% |
| | CCS | 3116 | 2927 | -7% | -12% |
| | CNR | 3060 | 2974 | -8% | -11% |
| | GFD | 3702 | 3665 | 11% | 10% |
| | MPI | 3037 | 2853 | -9% | -15% |
| | NOR | 3175 | 3011 | -5% | -10% |
| | **Average** | **3214** | **3074** | **-4%** | **-8%** |

The importance of using a stochastic simulation method is apparent as they encapsulate the potential impacts of climate change. The lowest stochastically generated sequences are lower than those from the climate change models. This means that if the hydrology is updated and stochastically analysed consistently after the occurrence and recovery of severe droughts, the results will be able to guide managers to plan for potential shortfalls and to engage restrictions sooner, use more efficient operating rules or to implement interventions timely.

# 8.0 CONCLUSIONS AND RECOMMENDATIONS

From the water resource analysis results carried out for different scenarios, the following conclusions were drawn, and recommendations were made as given below: These conclusions and recommendations were subdivided into two sections; Section 7-1 and 7-2. Section 7-1 will include the conclusions and recommendations carried out for the initial work and related scenarios analysed.

## 8.1 Initial Scenarios

1. Results showed that the Orange River Project (ORP) at the 2024 development level is already slightly over-utilised. There is thus no more surplus yield available from the ORP to supply increasing water requirements.
2. When Haib Mine, with a 20 million $m^3$/a water requirement, is supplied from the ORP (Gariep and Vanderkloof dams), the average restriction over the restricted years increases from 12% to 14%. Years with restrictions increased from 7 to 9 out of the 85 years. When Haib Mine is using water supplied from the ORP at the 2024 development level, it will thus impact the assurance of supply to other users. This impact is, however, relatively small.
3. When only 6 million $m^3$/a water requirement is supplied (Scenario 1b) from the ORP (Gariep and Vanderkloof dams) to Haib Mine, which represents the water requirements during the Haib Mine construction period, the impact on the other users is minimal, and the Haib requirement could be supplied 100% of the time.
4. At the 2024 development level for the option (Scenario 2), when off-channel storage is used to supply Haib Mine with water, the results showed that 35 million $m^3$ storage is required in combination with a 1.8 $m^3$/s diversion pump capacity. Pumping from the Orange River into the off-channel storage can only take place when there is surplus water available in the Orange River.
5. When the diversion pump capacity for Scenario 2 is increased to 2 $m^3$/s, the required storage capacity for the Haib off-channel storage will reduce to 25 million $m^3$ at the 2024 development level (using the initially defined “dummy” dam).
6. When 6 million $m^3$/a is supplied from Vanderkloof Dam and the remaining 14 million from the Hiab off-channel storage Dam (Scenario 2b 2024 development level), the diversion pump capacity could be reduced from 1.8 $m^3$/s to only 1.07 $m^3$/s, with the storage capacity of the off-channel storage Dam remaining at 35 million $m^3$ (using the initially defined “dummy” dam). The average supply to Haib mine for this scenario is still high at 99.82%.
7. At the 2035 development level with Polihali Dam included (Base 2 Scenario), the restrictions on the ORP system increased significantly from only 7 years out of the 85 years analysed to 31 years out of the 85 years. The average restriction over the years with restrictions then increases from 12% to 18.1%. The worst restriction over this simulated period was high at 54% in 1933.
8. The bulk of the surplus water available in the Lower Orange River is due to water coming from the Vaal River. This applied to the 2024 and the 2035 development levels.
9. Results from the 2035 development level analysis (Scenario 3) showed that the Haib off-channel storage remains a good option to consider. An off-channel storage dam with 35 million $m^3$ storage (using the initially defined “dummy” dam) in combination with a 1.8 $m^3$/s diversion pump capacity was still sufficient to supply the 20 million $m^3$/a requirement of Haib Mine over the complete analysis period of 85 years.
10. Scenario 3e at 2035 developments level with 6 million $m^3$/a supplied from Vanderkloof Dam and the remaining 14 million $m^3$/a from the off-channel storage dam had the advantage of a

much lower diversion maximum pump capacity of 1.03 $m^3/s$ versus the 1.8 $m^3/s$ for Scenario 3 as well as a reduced off-channel storage of 23.6 million $m^3$ versus the 35 million $m^3$ for Scenario 3 (using the initially defined "dummy" dam). The average water supply to Haib Mine, however, reduced slightly to 98.9% for Scenario 3e in comparison with the 100% for Scenario 3.

11. The option with an off-channel storage dam in place and only pumping the surplus flows in the Lower Orange River is recommended for both the 2024 and 2035 development levels.
12. Some sensitivity analyses were carried out around Scenario 3 (off-channel storage dam in place). These sensitivity analyses showed that the required storage capacity of the Haib Mine proposed off-channel storage dam is quite sensitive to diversion pump capacity, the required water demand of Haib Mine, as well as the assurance of supply required for Haib Mine. It is thus recommended that more sensitivity analyses be carried out once improved information is available regarding the Haib Mine water requirement, the storage depth and area characteristics of the off-channel storage dam and the required assurance of supply.
13. When using the actual surveyed dam characteristics that only become available late(r) in the study, the required off-channel dam storage and total volume to be pumped on an annual basis were reduced significantly (Scenario 3e versus Scenario 3f). This will have a similar impact on all the scenarios analysed in which the off-channel storage at Haib was used as an option. If any of these options is used as a future option, it should be analysed again using the surveyed dam characteristics.

## 8.2 Scenarios in Support of Design Work

### 8.2.1 Historic Analysis

1. Scenarios 2 and 3 were repeated using the actual surveyed dam characteristics for the Haib off-channel storage dam. Results showed that a smaller dam storage is required for both scenarios. For Scenario 2 with a maximum pumping capacity of 1.8 $m^3s$, the required storage capacity was reduced from 35 million $m^3$ to 17.7 million $m^3$. The optimum dam size, however, seems to be a 13.7 million $m^3$ storage dam in combination with a 2 $m^3/s$ maximum pumping capacity.

   For Scenario 3, a 14.31 million $m^3$ storage was required in combination with a maximum pumping capacity of 2 $m^3/s$ in comparison with the initial storage of 25 million $m^3$ for the same pumping capacity. From the updated results, the 2 $m^3/s$ pumping capacity seems to represent an optimum combination of abstraction capacity and dam volume for Scenario 3.

2. The simulated flows at Blouputs for Scenario 3 were compared (Figure 4-21) against the observed flows at Blouputs, the minimum flow required at Blouputs, as well as the pumping from the Orange River to fill the Haib off-channel storage Dam. From this comparison, the following were evident:

   i. The simulated flow compared very well with the observed flows at Blouputs when bearing in mind that the simulated flows represent demands at 2035 development imposed on the system and the inclusion of Polihali Dam upstream in Lesotho. This is, for example, why the peak simulated flows occur a month later than the observed peak flows.

   ii. The critical months in which insufficient surplus water is available for pumping into the Haib off-channel storage are typically from July to October.

   iii. The simulated pumping required to fill the Haib off-channel storage is significantly less than the minimum flow requirement at Blouputs and much lower than the simulated and observed flows at Blouputs.

3. Scenario 3g2 represents a Haib Mine water requirement of 6 million $m^3/a$ with an off-channel Storage Dam at 2035 development level, and with Haib not supported from Vanderkloof Dam. Results showed an optimum pumping rate of 1 $m^3/s$ in combination with an off-channel storage capacity of 3.64 million $m^3$. As only surplus water is pumped into the off-channel storage dam at Haib Mine, the river abstraction to fill the off-channel storage dam had no impact on the downstream users. The long-term average restriction difference between the Base 2 Scenario and Scenario 3g2 is only 0.1%, thus showing a negligible impact on all the other users.
4. Base Scenario 3 is the first scenario which includes the use of the proposed Verbeeldingskraal and Noordoewer-Vioolsdrift Dams and the use of the Lower-Level Storage in Vanderkloof Dam to rebalance the ORP. These are among the longer-term and more expensive interventions proposed by the DWS' 2015 Development of Reconciliation Strategies for Large Bulk Water Supply System: Orange River assessment in which several intervention options were identified to rebalance the Orange River due to the increased upstream developments and growth in demand imposed on the ORP. A successful rebalance of the ORP system was confirmed by the results from the analysis, as all the users were 100% supplied over the analysis period.
5. From the results obtained for Base Scenario 3, Scenario 4 and Scenario 5, it is clear that the Haib Mine requirement of 6 or 20 million $m^3/a$ could be fully supplied at the 2035 development level without impacting the water use of all the other water users. It is, however, important to bear in mind that the final sizes of the Verbeeldingskraal and Noordoewer-Vioolsdrift Dams are not yet agreed upon, and the final agreed storage capacities might thus be different, which will impact the results obtained from the analyses given in this report.

### 8.2.2 Stochastic Analysis

1. Stochastic analyses were recommended to be carried out later in this study once the water supply option and related characteristics of the proposed water supply system were available and almost finalised. The client requested that a stochastic analysis be carried out for the following scenarios:
   a. Base Scenario 2 (Existing 2024 infrastructure plus Polihali Dam and 2035 demands)
   b. Scenario 3 (As Base Scenario 2, but including an off-channel storage dam at Haib Mine and a pump station with a maximum capacity of 2 $m^3/s$ with a Haib demand of 20 million $m^3/a$)
   c. Scenario 3g2 (As Base Scenario 2 but includes an off-channel storage dam at Haib Mine and a pumpstation with a maximum capacity of 0.8 $m^3/s$ with a Haib demand of 6 million $m^3/a$).
   d. Base Scenario 3 (As Base Scenario 2, but with the Noordoewer-Vioolsdrift and Verbeeldingskraal Dams in place and utilising the Lower-Level storage in Vanderkloof Dam as recommended by the DWS),
   e. Scenario 4 (As Base Scenario 3 but with a 6 million $m^3/a$ continuous abstraction by Haib Mine supported from the Noordoewer-Vioolsdrift Dam)
   f. Scenario 5 (As Scenario 4, with the only difference that a 20 million $m^3/a$ continuous abstraction by Haib Mine from the Noordoewer-Vioolsdrift Dam will take place).

2. Base Scenario 2, Scenario 3 and Scenario 3g2:
   a. The storage projection plots for both the Gariep and Vanderkloof Dams for all three scenarios analysed were identical. This proves that the inclusion of the Haib off-channel storage dam and related pumping from the Orange River did not impact the existing ORP and therefore also not existing/other users.
   b. The operating rule for the ORP system makes use of the short-term yield characteristics to impose restrictions on the users during droughts to protect the resource from running empty. From the ORP storage projection plots for all three scenarios, it is evident that even at a very severe drought of 1 in 200 years (99.5% exceedance probability), the combined 99.5% storage of the two dams only touched the minimum operating level towards the end of the simulation. Although the ORP system is totally overloaded for these scenarios, the operating rule was still able to protect the resource from running empty.
   c. When supplying a demand of 20 million $m^3/a$ from Haib off-channel storage to Haib Mine, a storage capacity of just over 14 million $m^3/a$ is required. Only during very severe droughts, such as a 1 in 200-year drought, did the storage in the Haib Dam reach the minimum operating level of the dam. This shows that the 20 million $m^3/a$ to Haib Mine can be supplied at a high assurance. This also applies to the small Haib off-channel storage dam with a storage capacity of almost 4 million $m^3$ and a demand of 6 million $m^3/a$ imposed on the dam.
   d. The curtailment plots for all three scenarios are identical, which also proves that the inclusion of the Haib off-channel storage dam and related pumping from the Orange River did not impact the existing ORP system supply.
   e. The curtailment plots for all three scenarios confirmed that the ORP system is totally overloaded and deficits in water supply are expected to occur almost every year. This is however due to the upstream developments (Polihali Dam, transfers to the Greater Bloemfontein area, etc.) and not due to abstraction by Haib Mine.
   f. The minimum flow required at Blouputs to supply all the water users downstream of Blouputs Weir was always adhered to for all three scenarios analysed. The minimum flow was adjusted according to the restrictions imposed on the system on an annual basis.
   g. The preliminary EWR, as determined by DWS RSA, is one of the largest requirements (or “users”) downstream of Blouputs. The water supply plots showed that the water supply to the EWR for all three scenarios is identical, showing that the water abstractions to fill the Haib off-channel storage dam did not impact on the supply of the EWR.
   h. Although the water supply to Noordoewer, Aussenkehr and Alexander Bay showed significant deficits over the analysis period, these deficits are identical for all three scenarios analysed. This further confirms that the river abstractions to fill the Haib off-channel storage dam did not impact the water supply to Noordoewer, Aussenkehr and Alexander Bay.

3. Base Scenario 3, Scenario 4 and Scenario 5:

    a. The Bloemhof Dam storage projection plots for these three scenarios are slightly different from those derived from Base Scenario 2, Scenario 3 and Scenario 3g2. The reason for these differences is that the option in the WRPM to restrict or curtail water requirements to protect the resources or storage dams from running empty was not used for Base Scenario 3, Scenario 4 and Scenario 5, as insufficient short-term stochastic yield curves are available. This is the reason why the Bloemhof Dam is dropping to lower levels than indicated by previous scenarios. The Bloemhof Dam storage projection plots for all scenarios (Base 3, Scenario 4 & Scenario 5) are identical, as the changes made between the three scenarios did not impact the Vaal System. This also resulted in the spills from the Vaal System into the Orange River being less than those obtained for Base Scenario 2, where restrictions were imposed on the Vaal System. The main differences were found to be in the median and higher spills, with the lower spills forming the base flow, still very similar for all three scenarios.

    b. The two existing major dams; the Gariep and Vanderkloof Dams, as well as the two proposed new major dams included in the analysis (Verbeeldingskraal Dam & Noordoewer-Vioolsdrift Dam), work together as one system. Therefore, an increase in demand anywhere in the system will have some impact on each of the dams, but not necessarily the same impact on all the dams, due to the location of the increased demand and the operating rule that was followed. For Base Scenario 3, the expected 2035 demands downstream of Noordoewer-Viooldsdrift, including the increased irrigation due to the Noordoewer-Vioolsdrift Dam development, were imposed on the Noordoewer-Vioolsdrift Dam. On top of this, a 6 million $m^3/a$ Haib Mine requirement (Scenario 4) was imposed on the dam, and a 20 million $m^3/a$ Haib Mine demand for Scenario 5:

        i. It was found that the storage projection plots for all four major dams, when compared individually with the storage projection plots from all three scenarios, were almost identical. A very small difference was found, which is, in most cases, so small that it is scarcely visible on the projection plots. These differences are due to increases in the total system demand when the Haib Mine demands are imposed on the system.

        ii. It was clear that the dams were not protected by a short-term stochastic rule to prevent them from running empty, as all the dams reached their minimum operating levels at the severe drought sequences of 1 in 100 and 1 in 200-year recurrence intervals towards the end of the simulation period (this is due to insufficient short-term stochastic yield curves being available necessitating a different analysis approach).

        iii. The storage projection levels clearly showed that the given basic operating rules were followed in all the analyses.

    c. The base flows just downstream of Vanderkloof Dam for Base Scenario 3 are slightly lower than those evident from Base Scenario 2, which is due to the Noordoewer-Vioolsdrift Dam accommodating some of the load (demand) previously imposed on Vanderkloof Dam. The other major difference between the base flows of Base Scenario 2 and Base Scenario 3 is that the impact of restrictions is clearly evident from the base flows for Base Scenario 2, in particular over the period 2031 to 2039. For Base Scenario 3, it is only during the very severe drought years of 1 in 200 and 1 in 100-

years that a drop in the base flows is noticeable. This showed that it is only during those dry years over the winter periods that the dams reach empty or almost empty, resulting in less water being supplied to the downstream users.

d. The low flows for all three scenarios at Blouputs are almost identical, with differences so small that one can hardly see them on the flow projection plots. This further confirms that almost no additional support was required by Noordoewer-Vioolsdrift Dam from Vanderkloof Dam when the Haib Mine demand was added.

e. The minimum flows at Blouputs as required for Base Scenario 2 were compared with the flow projection at Blouputs for Base Scenario 3, showing that the simulated low flow for Base Scenario 3 is significantly lower than the minimum flow required for Base Scenario 2. This is due to the inclusion of the Noordoewer-Vioolsdrift Dam, which accommodates some of the load (demand) of Vanderkloof Dam, as it supplies all the water requirements downstream of its position. A new minimum flow requirement for Blouputs thus needs to be determined once the Noordoewer-Vioolsdrift Dam is in place.

f. The base flows at Blouputs for Base Scenario 3, Scenario 4, and Scenario 5 are for all three scenarios, almost identical, with differences so small they can hardly be identified on the flow plots. This further confirms that almost no additional support was required from Vanderkloof Dam to the Noordoewer-Vioolsdrift Dam when the Haib Mine demand was added.

g. Before evaluating the water supply to downstream users, it is important to note the following. The WRPM analysis for Base Scenario 3, Scenario 4 and Scenario 5 did not use the curtailment option within the WRPM and thus also did not allocate the demands into different assurance of supply classes. The portion of the water requirement, as normally would be subdivided into the different assurance classes were however, included in the water supply graphs to obtain a better understanding of how well the water demand was supplied. It should be understood that the model did not try to achieve the correct supply at the required assurance level, as that option was not used for these three scenarios (due to insufficient short-term stochastic yield curves being available necessitating a different analysis approach):

    i. The low and high assurance components of the Haib demand could be supplied almost fully over the entire simulation period, with a small deficit on the high assurance component towards the end of the simulation. The medium assurance supply started to exceed the assurance of supply criteria from about 2034 onwards. The difference in supply to Haib Mine between Scenario 4 and Scenario 5 is relatively small, with the supply to Haib from Scenario 5 slightly worse.

    ii. The water supply to Alexander Bay for Base Scenario 3 is significantly better than that obtained for Base Scenario 2, where Alexander Bay could only be fully supplied for 2 out of the 15 years analysed. This is a result of the inclusion of Verbeeldingskraal Dam, utilising the Lower-Level Storage in Vanderkloof Dam and adding the Noordoewer-Vioolsdrift Dam. Including these intervention options almost fully balanced the ORP system based on the stochastic analyses.

iii. The purpose of the stochastic analysis was not to find the optimum combination of intervention options to fully rebalance the ORP system, but rather to show that future intervention options should be able to rebalance the ORP system, including the impact of the Haib Mine demand. Information from previous studies was used to propose the applicable dam sizes and demands imposed on the system. The results showed that there is still a small deficit in the ORP system. This will be addressed by future studies to ensure proper water balances in the system to cater for the future requirements.

iv. Similar to the water supply plot for Alexander Bay, the portion of the water requirement as normally would be sub-divided into the different assurance classes were included in the water supply graphs to obtain a better understanding of how well the water demand was supplied, although the WRPM model did not try to achieve the correct supply at the required assurance level as that option was not used for these three scenarios.

v. From the results, it is evident that the water supply to Aussenkehr and Noordoewer remained the same for Base Scenario 3 and Scenario 4. The Aussenkehr and Noordoewer irrigation water supply for Scenario 5 did show some deficits at the medium assurance level from 2036 onwards. This corresponds to that found for Scenario 5 relating to the water supply to Alexander Bay.

vi. All these water supply results confirm that the intervention options included in Base Scenario 3, Scenario 4 and Scenario 5 did not fully rebalance the ORP system. These scenarios, however, significantly improved the water supply to the users in comparison with the results from Base Scenario 2.

vii. It is interesting to note that historic analysis showed no deficits in the water supply to downstream users, as well as the supply to Haib Mine. The stochastic analysis, however, did show some deficits at the 1 in 100 and 1 in 200-year assurance levels. The reason for this is that the stochastic analysis generates wetter and drier flow sequences than those obtained from the historical record. In this case, the historical record is only 85 years in length and will most probably not contain a 1 in 100-year or 1 in 200-year drought. From the stochastic analysis, it was evident that the deficits only occurred during the severe 1 in 100-year or 1 in 200-year droughts, which explains why deficits were only evident from the stochastic analysis. When using the curtailment option for the Vaal System, as for Base Scenario 2, higher spills from the Vaal River into the Orange River are observed. For Base Scenario 3, Scenario 4 and Scenario 5, the curtailment option was not used for the Vaal River System. If this option were to be used for the Vaal River System, more water from the Vaal River would enter the Orange River, resulting in a reduction in the deficits for all three scenarios, which would improve the stochastic analysis results.

viii. It is very important that the latest Haib Mine water requirements (demands) be supplied to the study team of the current Bridging Feasibility Study to ensure that the Noordoewer-Vioolsdrift Dam development and related demands represent the correct Haib Mine water requirements for future development purposes.

4. It needs to be noted that in the context of the ORP system yield and the flow available in the Lower Orange River, the water demand required by Haib Mine is quite small. Observed and simulated flows have an error margin of at least 10% or more. The accuracy of the observed and simulated small/low flows is thus of some concern. Using the WRPM setup and related modelling of scenarios is, however, the best that can currently be done to analyse the ORP system.
5. Once the location and size of the Verbeeldingskraal and Noordoewer-Viooldsdrift Dams have been finalised, updated short-term stochastic yield curves should be generated, and the stochastic analyses for Base Scenario 3, Scenario 4 and Scenario 5 should be re-analysed and compared with the results described in this report.

Overall, the analyses with both the historical and stochastic flow sequences show that abstraction from the Orange River by Haib Mine during periods of surplus flow, with storage in an off-channel storage dam, is required in lieu of direct run-of-river abstraction in order to ensure no adverse impacts to other users.

# 9.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

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# APPENDIX A1 – SCENARIO 2 MONTHLY PUMPING FROM THE RIVER TO THE HAIB OFF-CHANNEL STORAGE

## A-1: Scenario 2 Monthly pumping from the river to the Haib off-channel storage

| Year | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | AVE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.399 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.681 |
| 1921 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.196 | 1.800 | 1.800 | 1.800 | 1.800 | 1.293 | 1.152 | 1.570 |
| 1922 | 0.755 | 0.752 | 0.751 | 0.929 | 0.498 | 0.009 | 0.491 | 0.169 | 1.800 | 1.800 | 1.800 | 1.800 | 0.963 |
| 1923 | 0.895 | 0.807 | 0.774 | 0.900 | 0.063 | 0.033 | 0.466 | 1.800 | 1.800 | 1.800 | 1.800 | 1.091 | 1.019 |
| 1924 | 0.762 | 0.807 | 0.751 | 0.929 | 1.075 | 0.100 | 1.800 | 0.668 | 1.764 | 1.800 | 1.800 | 1.800 | 1.164 |
| 1925 | 0.084 | 0.023 | 0.061 | 0.024 | 0.005 | 0.032 | 0.469 | 0.242 | 1.800 | 1.800 | 1.800 | 1.800 | 0.671 |
| 1926 | 0.199 | 0.015 | 0.009 | 0.056 | 0.021 | 0.451 | 0.306 | 0.591 | 1.800 | 1.800 | 1.800 | 1.800 | 0.731 |
| 1927 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.310 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.674 |
| 1928 | 1.381 | 0.807 | 0.774 | 0.817 | 0.941 | 1.270 | 1.475 | 1.368 | 1.800 | 1.529 | 1.351 | 1.181 | 1.223 |
| 1929 | 0.895 | 0.137 | 0.030 | 0.502 | 0.185 | 0.017 | 0.396 | 0.141 | 1.800 | 1.800 | 1.800 | 1.800 | 0.786 |
| 1930 | 1.800 | 1.800 | 0.728 | 0.024 | 0.010 | 0.007 | 0.408 | 1.007 | 1.800 | 1.800 | 1.800 | 1.800 | 1.078 |
| 1931 | 0.742 | 0.215 | 0.051 | 0.016 | 0.098 | 0.032 | 0.025 | 0.013 | 1.800 | 1.800 | 1.800 | 0.041 | 0.548 |
| 1932 | 0.017 | 0.061 | 0.051 | 0.025 | 0.016 | 0.006 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.915 |
| 1933 | 1.712 | 0.807 | 0.774 | 0.929 | 1.075 | 1.147 | 1.454 | 1.505 | 1.740 | 1.485 | 1.355 | 1.100 | 1.257 |
| 1934 | 0.830 | 0.805 | 0.774 | 0.927 | 1.072 | 0.025 | 1.800 | 0.256 | 1.800 | 1.800 | 1.800 | 1.800 | 1.133 |
| 1935 | 1.152 | 0.807 | 0.608 | 0.047 | 0.157 | 0.055 | 1.800 | 1.800 | 1.800 | 1.667 | 1.375 | 1.162 | 1.036 |
| 1936 | 0.335 | 0.048 | 0.023 | 0.011 | 0.005 | 0.005 | 0.136 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.793 |
| 1937 | 1.800 | 1.371 | 0.855 | 0.310 | 0.034 | 0.067 | 0.578 | 0.467 | 1.800 | 1.800 | 1.800 | 1.800 | 1.057 |
| 1938 | 0.982 | 0.778 | 0.655 | 0.760 | 1.064 | 0.886 | 1.800 | 1.538 | 1.682 | 1.525 | 1.238 | 1.163 | 1.169 |
| 1939 | 0.891 | 0.804 | 0.760 | 0.915 | 0.372 | 0.108 | 1.466 | 0.479 | 1.800 | 1.800 | 1.403 | 1.143 | 0.995 |
| 1940 | 0.880 | 0.789 | 0.771 | 0.929 | 1.075 | 0.022 | 0.740 | 0.015 | 1.800 | 1.800 | 1.800 | 1.800 | 1.029 |
| 1941 | 0.473 | 0.261 | 0.089 | 0.009 | 0.008 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.120 |
| 1942 | 0.854 | 0.807 | 0.774 | 0.897 | 1.075 | 1.290 | 1.326 | 1.445 | 1.706 | 1.503 | 1.249 | 1.177 | 1.173 |
| 1943 | 0.887 | 0.801 | 0.772 | 0.461 | 0.179 | 0.108 | 0.049 | 0.019 | 1.800 | 1.800 | 1.800 | 1.800 | 0.868 |
| 1944 | 1.200 | 0.075 | 0.488 | 0.187 | 0.020 | 0.121 | 0.069 | 0.009 | 1.800 | 1.800 | 1.800 | 1.800 | 0.776 |
| 1945 | 1.800 | 1.800 | 1.800 | 0.458 | 0.142 | 0.081 | 0.061 | 0.031 | 1.800 | 1.800 | 1.800 | 1.800 | 1.111 |
| 1946 | 1.800 | 0.144 | 0.025 | 0.012 | 0.016 | 0.084 | 0.076 | 1.580 | 1.800 | 1.800 | 1.800 | 1.800 | 0.911 |
| 1947 | 1.800 | 1.800 | 1.243 | 0.916 | 0.600 | 0.039 | 0.049 | 0.075 | 1.800 | 1.800 | 1.800 | 1.800 | 1.143 |
| 1948 | 0.598 | 0.023 | 0.011 | 0.032 | 0.016 | 0.004 | 0.138 | 0.076 | 1.800 | 1.800 | 1.800 | 1.800 | 0.668 |
| 1949 | 1.800 | 1.800 | 1.309 | 0.879 | 0.983 | 1.220 | 1.415 | 1.508 | 1.730 | 1.519 | 1.367 | 1.179 | 1.392 |
| 1950 | 0.865 | 0.796 | 0.518 | 0.011 | 0.008 | 0.004 | 0.018 | 0.008 | 1.800 | 1.800 | 1.800 | 1.800 | 0.779 |
| 1951 | 1.602 | 0.059 | 1.800 | 1.800 | 1.800 | 0.037 | 1.800 | 0.940 | 1.800 | 1.800 | 1.800 | 1.800 | 1.418 |
| 1952 | 1.294 | 0.807 | 0.772 | 0.436 | 0.027 | 0.009 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.666 | 1.164 |
| 1953 | 0.873 | 0.806 | 0.773 | 0.928 | 1.067 | 0.370 | 1.800 | 1.800 | 1.800 | 1.621 | 1.348 | 1.138 | 1.190 |
| 1954 | 0.862 | 0.766 | 0.763 | 0.926 | 0.563 | 0.464 | 1.800 | 1.800 | 1.800 | 1.662 | 1.170 | 1.153 | 1.141 |
| 1955 | 0.868 | 0.804 | 0.774 | 0.929 | 1.075 | 0.026 | 0.819 | 1.800 | 1.734 | 1.546 | 1.308 | 1.180 | 1.072 |
| 1956 | 0.864 | 0.692 | 0.615 | 0.125 | 1.800 | 1.271 | 1.428 | 1.433 | 1.607 | 1.540 | 1.387 | 1.112 | 1.156 |
| 1957 | 0.786 | 0.807 | 0.774 | 0.929 | 0.549 | 0.010 | 0.358 | 1.800 | 1.800 | 1.800 | 1.800 | 0.980 | 1.031 |
| 1958 | 1.800 | 0.794 | 0.766 | 0.639 | 0.027 | 0.008 | 0.042 | 0.479 | 1.800 | 1.800 | 1.800 | 1.265 | 0.935 |
| 1959 | 0.870 | 0.677 | 0.017 | 0.054 | 0.019 | 0.014 | 0.017 | 0.076 | 1.800 | 1.800 | 1.800 | 1.800 | 0.745 |
| 1960 | 1.392 | 0.754 | 0.752 | 0.927 | 1.066 | 0.417 | 1.800 | 1.800 | 1.800 | 1.648 | 1.367 | 1.181 | 1.240 |
| 1961 | 0.895 | 0.797 | 0.774 | 0.882 | 1.051 | 0.161 | 1.800 | 1.800 | 1.800 | 1.537 | 1.294 | 1.024 | 1.151 |
| 1962 | 0.854 | 0.802 | 0.762 | 0.917 | 1.066 | 0.464 | 1.800 | 1.798 | 1.759 | 1.519 | 1.347 | 1.162 | 1.185 |
| 1963 | 0.890 | 0.446 | 0.066 | 0.013 | 1.056 | 0.038 | 0.623 | 0.754 | 1.800 | 1.800 | 1.800 | 1.800 | 0.917 |
| 1964 | 1.800 | 1.800 | 1.055 | 0.929 | 1.059 | 0.020 | 0.381 | 0.070 | 1.800 | 1.800 | 1.800 | 0.396 | 1.076 |
| 1965 | 0.028 | 0.017 | 0.012 | 0.006 | 0.007 | 0.238 | 0.091 | 0.080 | 1.800 | 1.800 | 1.800 | 1.800 | 0.640 |
| 1966 | 1.282 | 0.794 | 0.774 | 0.919 | 1.075 | 0.063 | 1.587 | 0.199 | 1.800 | 1.800 | 1.800 | 1.800 | 1.151 |
| 1967 | 1.197 | 0.805 | 0.774 | 0.929 | 1.071 | 0.022 | 0.625 | 0.135 | 1.800 | 1.800 | 1.800 | 1.800 | 1.058 |
| 1968 | 1.800 | 1.240 | 0.772 | 0.929 | 1.073 | 0.063 | 1.800 | 0.145 | 1.800 | 1.800 | 1.800 | 0.833 | 1.166 |
| 1969 | 0.830 | 0.508 | 0.098 | 0.573 | 0.234 | 0.373 | 1.169 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.061 |
| 1970 | 0.889 | 0.068 | 1.800 | 1.800 | 1.486 | 0.250 | 0.137 | 0.024 | 1.800 | 1.800 | 1.800 | 1.800 | 1.138 |
| 1971 | 0.895 | 0.798 | 0.772 | 0.929 | 1.072 | 0.018 | 0.612 | 0.012 | 1.800 | 1.800 | 1.800 | 1.800 | 1.019 |
| 1972 | 1.800 | 1.312 | 0.727 | 0.927 | 1.074 | 0.261 | 1.800 | 1.800 | 1.459 | 1.217 | 1.253 | 0.965 | 1.216 |
| 1973 | 0.882 | 0.787 | 0.774 | 0.917 | 1.074 | 0.483 | 1.800 | 1.479 | 1.656 | 1.506 | 1.092 | 1.149 | 1.133 |
| 1974 | 0.857 | 0.804 | 0.747 | 0.929 | 1.071 | 0.296 | 1.800 | 1.800 | 1.564 | 0.968 | 1.119 | 1.082 | 1.086 |
| 1975 | 0.819 | 0.779 | 0.772 | 0.920 | 1.064 | 1.211 | 1.475 | 1.517 | 1.736 | 1.422 | 1.272 | 0.909 | 1.157 |
| 1976 | 0.858 | 0.802 | 0.774 | 0.924 | 1.034 | 0.390 | 1.800 | 1.800 | 1.743 | 1.510 | 1.265 | 1.140 | 1.167 |
| 1977 | 0.895 | 0.805 | 0.758 | 0.901 | 1.028 | 0.014 | 1.527 | 0.047 | 1.800 | 1.800 | 1.800 | 1.097 | 1.033 |
| 1978 | 0.259 | 0.273 | 0.557 | 1.381 | 0.435 | 0.087 | 0.343 | 0.122 | 1.800 | 1.800 | 1.800 | 1.800 | 0.883 |
| 1979 | 1.800 | 0.407 | 0.099 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.755 | 1.181 | 1.486 |
| 1980 | 0.879 | 0.802 | 0.774 | 0.764 | 1.075 | 0.305 | 1.800 | 1.800 | 1.800 | 1.800 | 1.402 | 1.096 | 1.187 |
| 1981 | 0.895 | 0.785 | 0.768 | 0.928 | 0.783 | 0.432 | 0.592 | 0.499 | 1.800 | 1.800 | 1.800 | 0.091 | 0.929 |
| 1982 | 0.576 | 0.220 | 0.028 | 0.016 | 0.036 | 0.016 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.442 | 0.939 |
| 1983 | 0.177 | 0.069 | 0.023 | 0.069 | 0.042 | 1.021 | 0.482 | 0.025 | 1.800 | 1.800 | 1.800 | 1.619 | 0.738 |
| 1984 | 0.072 | 0.043 | 0.020 | 0.009 | 0.008 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.059 |
| 1985 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.201 | 0.353 | 0.938 | 1.800 | 1.800 | 1.800 | 0.405 | 1.358 |
| 1986 | 0.141 | 0.058 | 0.078 | 0.031 | 1.800 | 0.387 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.125 | 1.052 |
| 1987 | 0.891 | 0.806 | 0.774 | 0.898 | 1.017 | 1.286 | 1.431 | 1.415 | 1.587 | 1.276 | 1.380 | 1.090 | 1.154 |
| 1988 | 0.886 | 0.806 | 0.764 | 0.929 | 1.072 | 0.202 | 1.800 | 1.800 | 1.800 | 1.757 | 1.310 | 0.952 | 1.169 |
| 1989 | 0.895 | 0.718 | 0.772 | 0.929 | 1.044 | 0.008 | 0.025 | 1.114 | 1.800 | 1.800 | 1.279 | 1.168 | 0.963 |
| 1990 | 0.895 | 0.757 | 0.774 | 0.929 | 0.968 | 1.159 | 1.448 | 1.488 | 1.757 | 1.524 | 1.354 | 1.180 | 1.185 |
| 1991 | 0.752 | 0.066 | 0.036 | 0.552 | 0.199 | 0.092 | 0.050 | 0.012 | 1.800 | 1.800 | 1.800 | 1.800 | 0.741 |
| 1992 | 1.579 | 0.087 | 0.091 | 0.034 | 0.013 | 1.064 | 0.455 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.027 |
| 1993 | 1.800 | 0.787 | 0.763 | 0.929 | 1.074 | 0.013 | 0.231 | 0.012 | 1.800 | 1.800 | 1.800 | 1.800 | 1.067 |
| 1994 | 1.800 | 0.656 | 0.061 | 0.191 | 0.111 | 0.027 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.133 |
| 1995 | 1.800 | 1.399 | 0.638 | 0.922 | 1.068 | 0.240 | 1.800 | 1.800 | 1.702 | 1.553 | 1.214 | 1.178 | 1.276 |
| 1996 | 0.836 | 0.790 | 0.767 | 0.929 | 1.075 | 0.212 | 1.800 | 1.800 | 1.800 | 1.800 | 1.397 | 1.166 | 1.193 |
| 1997 | 0.894 | 0.807 | 0.773 | 0.927 | 0.336 | 0.018 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.621 | 1.112 |
| 1998 | 1.621 | 0.806 | 0.773 | 0.133 | 0.044 | 1.096 | 1.712 | 1.800 | 1.800 | 1.800 | 1.507 | 1.110 | 1.182 |
| 1999 | 0.895 | 0.802 | 0.774 | 0.929 | 0.987 | 0.499 | 1.800 | 1.800 | 1.800 | 1.610 | 1.225 | 1.038 | 1.177 |
| 2000 | 0.885 | 0.783 | 0.759 | 0.929 | 0.990 | 1.268 | 1.363 | 1.491 | 1.693 | 1.493 | 1.318 | 1.143 | 1.175 |
| 2001 | 0.851 | 0.782 | 0.774 | 0.888 | 1.071 | 0.026 | 1.800 | 1.800 | 1.800 | 1.800 | 1.501 | 1.164 | 1.183 |
| 2002 | 0.894 | 0.807 | 0.331 | 0.524 | 0.232 | 0.084 | 0.289 | 0.089 | 1.800 | 1.800 | 1.800 | 1.800 | 0.865 |
| 2003 | 1.800 | 1.800 | 0.866 | 0.044 | 0.347 | 0.280 | 0.081 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.182 |
| 2004 | 1.800 | 1.800 | 0.203 | 0.013 | 0.006 | 0.002 | 0.003 | 0.001 | 1.516 | 1.800 | 1.800 | 0.001 | 0.741 |
| **Average** | **1.066** | **0.769** | **0.665** | **0.691** | **0.709** | **0.359** | **1.068** | **1.068** | **1.773** | **1.717** | **1.622** | **1.376** | **1.071** |

# APPENDIX A2– SCENARIO 2B MONTHLY PUMPING FROM THE RIVER TO THE HAIB OFF-CHANNEL STORAGE

## A-2: Scenario 2b Monthly pumping from the river to the Haib off-channel storage

| Year | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | AVE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.504 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.022 |
| 1921 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.377 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.012 |
| 1922 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.009 | 0.974 | 0.169 | 1.070 | 1.070 | 1.070 | 1.070 | 0.899 |
| 1923 | 1.070 | 1.070 | 1.070 | 0.621 | 0.062 | 0.033 | 0.466 | 1.070 | 1.070 | 1.070 | 2.140 | 2.140 | 0.990 |
| 1924 | 1.070 | 0.633 | 0.584 | 0.747 | 0.901 | 0.100 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.871 |
| 1925 | 0.264 | 0.023 | 0.061 | 0.024 | 0.005 | 0.032 | 0.469 | 0.242 | 1.070 | 1.070 | 1.070 | 1.070 | 0.446 |
| 1926 | 0.199 | 0.015 | 0.009 | 0.056 | 0.021 | 0.451 | 0.306 | 0.591 | 1.070 | 1.070 | 1.070 | 1.070 | 0.491 |
| 1927 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.310 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.005 |
| 1928 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 |
| 1929 | 1.070 | 0.217 | 0.030 | 0.502 | 0.185 | 0.017 | 0.396 | 0.141 | 1.070 | 1.070 | 1.070 | 1.070 | 0.567 |
| 1930 | 1.070 | 1.070 | 1.070 | 0.968 | 0.010 | 0.007 | 0.408 | 1.007 | 1.070 | 1.070 | 1.070 | 1.070 | 0.824 |
| 1931 | 1.070 | 0.523 | 0.051 | 0.016 | 0.098 | 0.032 | 0.025 | 0.013 | 1.070 | 1.070 | 1.070 | 0.041 | 0.421 |
| 1932 | 0.017 | 0.061 | 0.051 | 0.025 | 0.016 | 0.006 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.550 |
| 1933 | 1.070 | 1.070 | 1.070 | 1.070 | 0.686 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.038 |
| 1934 | 1.070 | 0.631 | 0.607 | 0.745 | 0.898 | 0.025 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.866 |
| 1935 | 1.070 | 1.070 | 0.458 | 0.047 | 0.157 | 0.055 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.773 |
| 1936 | 0.410 | 0.048 | 0.023 | 0.011 | 0.005 | 0.005 | 0.136 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.497 |
| 1937 | 1.070 | 1.070 | 1.070 | 1.070 | 0.487 | 0.067 | 0.578 | 0.467 | 1.070 | 1.070 | 1.070 | 1.070 | 0.846 |
| 1938 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.886 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.055 |
| 1939 | 1.070 | 0.630 | 0.593 | 0.747 | 0.818 | 0.108 | 1.070 | 0.690 | 1.070 | 1.070 | 1.070 | 0.947 | 0.824 |
| 1940 | 0.708 | 0.615 | 0.604 | 0.747 | 0.901 | 0.022 | 1.070 | 0.168 | 1.070 | 1.070 | 1.070 | 1.070 | 0.756 |
| 1941 | 0.473 | 0.261 | 0.089 | 0.009 | 0.008 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.694 |
| 1942 | 1.070 | 1.070 | 1.070 | 0.714 | 0.901 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.052 | 0.981 | 1.017 |
| 1943 | 0.715 | 0.627 | 0.605 | 0.744 | 0.332 | 0.108 | 0.049 | 0.019 | 1.070 | 1.070 | 1.070 | 1.070 | 0.621 |
| 1944 | 1.070 | 0.199 | 0.488 | 0.187 | 0.020 | 0.121 | 0.069 | 0.009 | 1.070 | 1.070 | 1.070 | 1.070 | 0.535 |
| 1945 | 1.070 | 1.070 | 1.070 | 1.070 | 0.203 | 0.081 | 0.061 | 0.031 | 1.070 | 1.070 | 1.070 | 1.070 | 0.744 |
| 1946 | 1.070 | 0.841 | 0.025 | 0.012 | 0.016 | 0.084 | 0.076 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.623 |
| 1947 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.039 | 0.192 | 0.075 | 1.070 | 1.070 | 1.070 | 1.070 | 0.828 |
| 1948 | 0.898 | 0.023 | 0.011 | 0.032 | 0.016 | 0.004 | 0.138 | 0.076 | 1.070 | 1.070 | 1.070 | 1.070 | 0.453 |
| 1949 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 |
| 1950 | 0.830 | 0.622 | 0.604 | 0.488 | 0.008 | 0.004 | 0.018 | 0.008 | 1.070 | 1.070 | 1.070 | 1.070 | 0.570 |
| 1951 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.037 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.982 |
| 1952 | 1.070 | 1.070 | 1.070 | 0.240 | 0.027 | 0.009 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.826 |
| 1953 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.228 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.942 | 0.989 |
| 1954 | 0.690 | 0.592 | 0.596 | 0.744 | 0.901 | 0.464 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.980 | 0.859 |
| 1955 | 0.696 | 0.630 | 0.607 | 0.747 | 0.901 | 0.026 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.984 | 0.823 |
| 1956 | 0.692 | 0.518 | 0.606 | 0.458 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.916 | 0.890 |
| 1957 | 0.614 | 0.633 | 0.607 | 0.747 | 0.865 | 0.010 | 0.358 | 1.070 | 1.070 | 1.070 | 1.070 | 0.980 | 0.756 |
| 1958 | 1.070 | 1.070 | 0.599 | 0.744 | 0.069 | 0.008 | 0.042 | 0.479 | 1.070 | 1.070 | 1.070 | 1.070 | 0.697 |
| 1959 | 1.070 | 0.482 | 0.017 | 0.054 | 0.019 | 0.014 | 0.017 | 0.076 | 1.070 | 1.070 | 1.070 | 1.070 | 0.502 |
| 1960 | 1.070 | 1.070 | 0.613 | 0.745 | 0.892 | 0.417 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.985 | 0.928 |
| 1961 | 0.723 | 0.623 | 0.607 | 0.700 | 0.877 | 0.161 | 1.070 | 1.070 | 1.070 | 1.070 | 1.097 | 0.828 | 0.825 |
| 1962 | 0.682 | 0.628 | 0.595 | 0.735 | 0.892 | 0.464 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.868 |
| 1963 | 0.718 | 0.554 | 0.294 | 0.013 | 1.056 | 0.038 | 0.623 | 0.754 | 1.070 | 1.070 | 1.070 | 1.070 | 0.690 |
| 1964 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.020 | 0.672 | 0.070 | 1.070 | 1.070 | 1.070 | 0.396 | 0.809 |
| 1965 | 0.028 | 0.017 | 0.012 | 0.006 | 0.007 | 0.238 | 0.091 | 0.080 | 1.070 | 1.070 | 1.070 | 1.070 | 0.654 |
| 1966 | 1.070 | 1.070 | 1.070 | 0.820 | 0.901 | 0.063 | 1.070 | 0.707 | 1.070 | 1.070 | 1.070 | 1.070 | 0.921 |
| 1967 | 1.070 | 1.070 | 1.070 | 1.070 | 1.056 | 0.022 | 0.345 | 0.135 | 1.070 | 1.070 | 1.070 | 1.070 | 0.841 |
| 1968 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.063 | 1.070 | 0.462 | 1.070 | 1.070 | 1.070 | 0.833 | 0.913 |
| 1969 | 0.830 | 0.508 | 0.098 | 0.573 | 0.234 | 0.373 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.751 |
| 1970 | 0.898 | 0.068 | 1.070 | 1.070 | 1.070 | 0.250 | 0.569 | 0.024 | 1.070 | 1.070 | 1.070 | 1.070 | 0.775 |
| 1971 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.018 | 0.225 | 0.012 | 1.070 | 1.070 | 1.070 | 1.070 | 0.824 |
| 1972 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.184 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.996 |
| 1973 | 0.710 | 0.613 | 0.607 | 0.735 | 0.900 | 0.483 | 1.070 | 1.070 | 1.070 | 1.070 | 0.895 | 0.953 | 0.848 |
| 1974 | 0.685 | 0.630 | 0.580 | 0.747 | 0.897 | 0.376 | 1.070 | 1.070 | 1.070 | 0.769 | 0.922 | 0.886 | 0.808 |
| 1975 | 0.647 | 0.605 | 0.605 | 0.738 | 0.890 | 1.019 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.713 | 0.881 |
| 1976 | 0.686 | 0.628 | 0.607 | 0.742 | 0.860 | 0.391 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.279 | 0.879 |
| 1977 | 0.723 | 0.631 | 0.591 | 0.719 | 0.854 | 0.014 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.826 |
| 1978 | 0.454 | 0.273 | 0.557 | 1.070 | 0.686 | 0.087 | 0.343 | 0.122 | 1.070 | 1.070 | 1.070 | 1.070 | 0.654 |
| 1979 | 1.070 | 0.687 | 0.113 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.957 |
| 1980 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.305 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.005 |
| 1981 | 1.070 | 1.070 | 1.070 | 1.070 | 0.181 | 0.432 | 0.592 | 0.499 | 1.070 | 1.070 | 1.070 | 0.091 | 0.775 |
| 1982 | 0.576 | 0.220 | 0.028 | 0.016 | 0.036 | 0.016 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.606 |
| 1983 | 0.494 | 0.069 | 0.023 | 0.069 | 0.042 | 1.021 | 0.482 | 0.025 | 1.070 | 1.070 | 1.070 | 1.070 | 0.539 |
| 1984 | 0.546 | 0.043 | 0.020 | 0.009 | 0.008 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.675 |
| 1985 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.201 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.548 | 0.953 |
| 1986 | 0.143 | 0.059 | 0.079 | 0.031 | 1.070 | 0.387 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.682 |
| 1987 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.077 | 1.070 | 0.894 | 1.056 |
| 1988 | 0.714 | 0.632 | 0.597 | 0.747 | 0.898 | 0.202 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.851 |
| 1989 | 0.723 | 0.544 | 0.605 | 0.747 | 0.900 | 0.008 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.972 | 0.821 |
| 1990 | 0.723 | 0.583 | 0.607 | 0.747 | 0.794 | 0.967 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.903 |
| 1991 | 0.851 | 0.066 | 0.036 | 0.552 | 0.199 | 0.092 | 0.050 | 0.012 | 1.070 | 1.070 | 1.070 | 1.070 | 0.509 |
| 1992 | 1.070 | 0.639 | 0.091 | 0.034 | 0.013 | 1.064 | 0.455 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.726 |
| 1993 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.013 | 0.228 | 0.012 | 1.070 | 1.070 | 1.070 | 1.070 | 0.823 |
| 1994 | 1.070 | 1.070 | 0.336 | 0.191 | 0.111 | 0.027 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.766 |
| 1995 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.266 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.701 | 1.056 |
| 1996 | 0.664 | 0.616 | 0.600 | 0.747 | 0.901 | 0.212 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.847 |
| 1997 | 0.722 | 0.633 | 0.606 | 0.745 | 0.890 | 0.018 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.976 | 0.826 |
| 1998 | 1.070 | 1.070 | 0.898 | 0.023 | 0.044 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.883 |
| 1999 | 0.752 | 0.628 | 0.607 | 0.747 | 0.813 | 0.499 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.872 |
| 2000 | 0.934 | 0.609 | 0.592 | 0.747 | 0.816 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.947 | 0.922 |
| 2001 | 0.679 | 0.608 | 0.607 | 0.706 | 0.897 | 0.026 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.829 |
| 2002 | 0.722 | 0.633 | 0.473 | 0.532 | 0.236 | 0.086 | 0.290 | 0.090 | 1.070 | 1.070 | 1.070 | 1.070 | 0.609 |
| 2003 | 1.070 | 1.070 | 1.070 | 0.462 | 0.347 | 0.280 | 0.081 | 1.070 | 1.070 | 1.070 | 1.070 | 1.070 | 0.811 |
| 2004 | 1.070 | 1.070 | 0.862 | 0.013 | 0.006 | 0.002 | 0.003 | 0.001 | 1.070 | 1.070 | 1.070 | 0.001 | 0.519 |
| **Average** | **0.864** | **0.710** | **0.643** | **0.649** | **0.627** | **0.316** | **0.758** | **0.753** | **1.070** | **1.067** | **1.079** | **1.013** | **0.798** |

# APPENDIX A3– SCENARIO 3 MONTHLY PUMPING FROM THE RIVER TO THE HAIB OFF-CHANNEL STORAGE

## A-3: Scenario 3 Monthly pumping from the river to the Haib off-channel storage

| Year | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | AVE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.399 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.681 |
| 1921 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.196 | 1.800 | 1.800 | 1.800 | 1.800 | 1.506 | 1.152 | 1.586 |
| 1922 | 0.755 | 0.752 | 0.751 | 0.929 | 0.498 | 0.009 | 0.491 | 0.169 | 0.977 | 1.800 | 1.800 | 1.800 | 0.887 |
| 1923 | 1.800 | 1.800 | 0.912 | 0.102 | 0.061 | 0.033 | 0.464 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.178 |
| 1924 | 1.800 | 1.624 | 0.751 | 0.929 | 1.075 | 0.100 | 1.800 | 0.668 | 0.441 | 1.800 | 1.800 | 1.800 | 1.207 |
| 1925 | 0.083 | 0.023 | 0.061 | 0.024 | 0.005 | 0.032 | 0.469 | 0.242 | 1.591 | 1.800 | 1.800 | 1.800 | 0.653 |
| 1926 | 0.197 | 0.015 | 0.009 | 0.056 | 0.021 | 0.451 | 0.306 | 0.591 | 1.800 | 1.800 | 1.800 | 1.800 | 0.731 |
| 1927 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.310 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.674 |
| 1928 | 1.732 | 0.807 | 0.774 | 0.817 | 0.941 | 1.270 | 1.475 | 1.461 | 1.730 | 1.509 | 1.351 | 1.181 | 1.254 |
| 1929 | 0.895 | 0.778 | 0.075 | 0.502 | 0.185 | 0.017 | 0.396 | 0.141 | 1.800 | 1.800 | 1.800 | 1.800 | 0.843 |
| 1930 | 1.800 | 1.800 | 0.728 | 0.024 | 0.010 | 0.007 | 0.408 | 0.877 | 1.800 | 1.800 | 1.800 | 1.800 | 1.067 |
| 1931 | 0.771 | 0.215 | 0.051 | 0.016 | 0.098 | 0.032 | 0.025 | 0.013 | 1.800 | 1.800 | 1.800 | 0.041 | 0.551 |
| 1932 | 0.017 | 0.061 | 0.051 | 0.025 | 0.016 | 1.576 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.041 |
| 1933 | 1.800 | 1.800 | 1.800 | 0.476 | 0.024 | 1.141 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.486 |
| 1934 | 1.800 | 1.626 | 0.774 | 0.927 | 1.072 | 0.025 | 1.800 | 0.256 | 1.139 | 1.800 | 1.800 | 1.800 | 1.227 |
| 1935 | 1.757 | 0.807 | 0.618 | 0.047 | 0.157 | 0.055 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.183 |
| 1936 | 0.063 | 0.048 | 0.023 | 0.011 | 0.005 | 0.005 | 0.136 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.770 |
| 1937 | 1.800 | 1.371 | 0.855 | 0.310 | 0.034 | 0.067 | 0.578 | 0.467 | 1.800 | 1.800 | 1.800 | 1.800 | 1.052 |
| 1938 | 1.800 | 1.800 | 0.641 | 1.800 | 1.800 | 0.862 | 1.800 | 1.784 | 1.682 | 1.525 | 1.238 | 1.163 | 1.489 |
| 1939 | 0.891 | 0.804 | 0.760 | 0.262 | 0.372 | 0.108 | 1.466 | 1.800 | 1.800 | 1.800 | 1.800 | 1.438 | 1.104 |
| 1940 | 0.880 | 0.789 | 0.771 | 0.929 | 1.075 | 0.022 | 0.740 | 0.015 | 0.407 | 1.800 | 1.800 | 1.800 | 0.910 |
| 1941 | 0.471 | 0.261 | 0.089 | 0.009 | 0.008 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.116 |
| 1942 | 1.800 | 1.800 | 1.325 | 0.896 | 1.075 | 1.290 | 1.326 | 1.445 | 1.706 | 1.503 | 1.249 | 1.177 | 1.382 |
| 1943 | 0.887 | 0.801 | 0.772 | 0.461 | 0.179 | 0.108 | 0.049 | 0.019 | 1.800 | 1.800 | 1.800 | 1.800 | 0.868 |
| 1944 | 1.231 | 0.075 | 0.488 | 0.187 | 0.020 | 0.121 | 0.069 | 0.009 | 1.800 | 1.800 | 1.800 | 1.800 | 0.779 |
| 1945 | 1.800 | 1.800 | 1.800 | 0.458 | 0.142 | 0.081 | 0.061 | 0.031 | 1.800 | 1.800 | 1.800 | 1.800 | 1.111 |
| 1946 | 1.800 | 0.144 | 0.025 | 0.012 | 0.016 | 0.084 | 0.076 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.928 |
| 1947 | 1.800 | 1.800 | 1.800 | 0.982 | 0.073 | 0.039 | 0.049 | 0.075 | 0.899 | 1.800 | 1.800 | 1.800 | 1.073 |
| 1948 | 0.597 | 0.023 | 0.011 | 0.032 | 0.016 | 0.004 | 0.138 | 0.076 | 1.800 | 1.800 | 1.800 | 1.800 | 0.668 |
| 1949 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.794 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.607 | 1.784 |
| 1950 | 0.771 | 0.238 | 0.080 | 0.011 | 0.008 | 0.004 | 0.018 | 0.008 | 0.463 | 1.800 | 1.800 | 1.800 | 0.575 |
| 1951 | 1.602 | 0.059 | 1.800 | 1.800 | 1.800 | 0.037 | 1.800 | 0.940 | 1.479 | 1.800 | 1.800 | 1.800 | 1.390 |
| 1952 | 1.800 | 1.511 | 0.104 | 0.071 | 0.027 | 0.009 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.188 |
| 1953 | 1.800 | 1.073 | 0.773 | 0.928 | 1.067 | 0.333 | 1.800 | 1.800 | 1.800 | 1.656 | 1.348 | 1.138 | 1.291 |
| 1954 | 0.862 | 0.766 | 0.763 | 0.926 | 0.562 | 0.464 | 1.800 | 1.800 | 1.800 | 1.662 | 1.170 | 1.153 | 1.141 |
| 1955 | 0.868 | 0.804 | 0.774 | 0.929 | 1.075 | 0.026 | 0.820 | 1.800 | 1.800 | 1.800 | 1.800 | 1.712 | 1.180 |
| 1956 | 0.864 | 0.692 | 0.615 | 0.125 | 1.800 | 1.458 | 1.428 | 1.433 | 1.607 | 1.540 | 1.387 | 1.112 | 1.168 |
| 1957 | 0.786 | 0.807 | 0.774 | 0.929 | 0.549 | 0.010 | 0.358 | 1.800 | 1.800 | 1.800 | 1.800 | 0.980 | 1.031 |
| 1958 | 1.800 | 1.234 | 0.766 | 0.639 | 0.027 | 0.008 | 0.042 | 0.479 | 1.800 | 1.800 | 1.800 | 1.800 | 1.013 |
| 1959 | 1.800 | 0.036 | 0.017 | 0.054 | 0.019 | 0.014 | 0.017 | 0.076 | 1.800 | 1.800 | 1.800 | 1.800 | 0.765 |
| 1960 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.417 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.544 | 1.662 |
| 1961 | 0.895 | 0.797 | 0.774 | 0.882 | 1.051 | 0.161 | 1.800 | 1.800 | 1.800 | 1.800 | 1.320 | 1.024 | 1.171 |
| 1962 | 0.854 | 0.802 | 0.762 | 0.917 | 1.066 | 0.464 | 1.800 | 1.798 | 1.759 | 1.519 | 1.347 | 1.162 | 1.185 |
| 1963 | 0.890 | 0.259 | 0.065 | 0.012 | 1.056 | 0.038 | 0.623 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.990 |
| 1964 | 1.800 | 1.305 | 0.762 | 0.929 | 1.059 | 0.020 | 0.836 | 0.070 | 1.800 | 1.800 | 1.800 | 0.396 | 1.044 |
| 1965 | 0.028 | 0.017 | 0.012 | 0.006 | 0.007 | 0.238 | 0.091 | 0.080 | 1.800 | 1.800 | 1.800 | 1.800 | 0.633 |
| 1966 | 1.800 | 1.800 | 1.800 | 1.800 | 0.970 | 0.063 | 0.597 | 0.199 | 1.229 | 1.800 | 1.800 | 1.800 | 1.301 |
| 1967 | 1.800 | 1.800 | 1.800 | 1.542 | 0.034 | 0.022 | 0.311 | 0.135 | 1.800 | 1.800 | 1.800 | 1.800 | 1.219 |
| 1968 | 1.800 | 1.800 | 1.453 | 0.929 | 1.073 | 0.063 | 0.974 | 0.015 | 1.800 | 1.800 | 1.800 | 0.833 | 1.191 |
| 1969 | 0.830 | 0.508 | 0.098 | 0.573 | 0.234 | 1.509 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.210 |
| 1970 | 1.193 | 0.068 | 1.800 | 1.281 | 1.075 | 0.250 | 1.072 | 1.783 | 1.800 | 1.800 | 1.539 | 1.117 | 1.232 |
| 1971 | 0.895 | 0.798 | 0.772 | 0.929 | 1.072 | 0.018 | 0.305 | 0.012 | 0.607 | 1.800 | 1.800 | 1.800 | 0.893 |
| 1972 | 1.800 | 1.800 | 1.590 | 0.927 | 1.074 | 0.289 | 1.800 | 1.800 | 1.433 | 1.217 | 1.253 | 0.965 | 1.329 |
| 1973 | 0.882 | 0.787 | 0.774 | 0.917 | 1.074 | 0.483 | 1.800 | 1.800 | 1.721 | 1.506 | 1.092 | 1.149 | 1.163 |
| 1974 | 0.857 | 0.804 | 0.747 | 0.929 | 1.071 | 0.297 | 1.800 | 1.800 | 1.563 | 0.968 | 1.119 | 1.082 | 1.086 |
| 1975 | 0.819 | 0.779 | 0.772 | 0.920 | 1.064 | 1.211 | 1.475 | 1.517 | 1.736 | 1.422 | 1.272 | 0.909 | 1.157 |
| 1976 | 0.858 | 0.802 | 0.774 | 0.924 | 1.034 | 0.390 | 1.800 | 1.800 | 1.743 | 1.510 | 1.265 | 1.140 | 1.167 |
| 1977 | 0.895 | 0.805 | 0.758 | 0.901 | 1.028 | 0.014 | 1.540 | 0.047 | 1.584 | 1.800 | 1.800 | 1.093 | 1.015 |
| 1978 | 0.259 | 0.273 | 0.557 | 1.381 | 0.435 | 0.087 | 0.343 | 0.122 | 1.022 | 1.800 | 1.800 | 1.800 | 0.817 |
| 1979 | 1.800 | 0.407 | 0.099 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.541 |
| 1980 | 0.887 | 0.802 | 0.774 | 0.764 | 1.075 | 0.304 | 1.800 | 1.800 | 1.800 | 1.800 | 1.402 | 1.096 | 1.187 |
| 1981 | 0.895 | 0.785 | 0.768 | 0.928 | 0.783 | 0.432 | 0.592 | 0.499 | 1.697 | 1.800 | 1.800 | 0.081 | 0.919 |
| 1982 | 0.576 | 0.220 | 0.028 | 0.016 | 0.036 | 0.016 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.437 | 0.938 |
| 1983 | 0.177 | 0.069 | 0.023 | 0.069 | 0.042 | 1.021 | 1.546 | 1.661 | 1.800 | 1.800 | 1.800 | 1.619 | 0.964 |
| 1984 | 0.072 | 0.043 | 0.020 | 0.009 | 0.008 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.059 |
| 1985 | 1.800 | 1.800 | 1.800 | 1.800 | 1.635 | 0.201 | 0.557 | 1.583 | 1.800 | 1.800 | 1.800 | 0.407 | 1.416 |
| 1986 | 0.142 | 0.059 | 0.078 | 0.031 | 1.800 | 0.387 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.100 |
| 1987 | 1.800 | 1.549 | 0.774 | 0.898 | 1.017 | 1.286 | 1.431 | 1.415 | 1.587 | 1.276 | 1.380 | 1.090 | 1.292 |
| 1988 | 0.886 | 0.806 | 0.764 | 0.929 | 1.072 | 0.202 | 1.800 | 1.800 | 1.800 | 1.757 | 1.310 | 0.952 | 1.169 |
| 1989 | 0.895 | 0.718 | 0.772 | 0.929 | 0.706 | 0.008 | 0.025 | 1.114 | 1.800 | 1.800 | 1.800 | 1.800 | 1.027 |
| 1990 | 1.800 | 1.121 | 0.774 | 0.189 | 1.720 | 1.159 | 1.448 | 1.488 | 1.757 | 1.524 | 1.354 | 1.180 | 1.290 |
| 1991 | 0.752 | 0.066 | 0.036 | 0.552 | 0.199 | 0.092 | 0.050 | 0.012 | 1.230 | 1.800 | 1.800 | 1.800 | 0.693 |
| 1992 | 1.578 | 0.087 | 0.091 | 0.034 | 0.013 | 1.064 | 0.455 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.026 |
| 1993 | 1.800 | 1.800 | 1.800 | 0.486 | 0.032 | 0.013 | 0.024 | 0.012 | 1.626 | 1.800 | 1.800 | 1.800 | 1.079 |
| 1994 | 1.800 | 1.084 | 0.061 | 0.191 | 0.111 | 0.027 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.168 |
| 1995 | 1.800 | 1.800 | 1.800 | 1.115 | 1.068 | 0.037 | 1.800 | 1.800 | 1.800 | 1.767 | 1.214 | 1.178 | 1.429 |
| 1996 | 0.836 | 0.790 | 0.767 | 0.929 | 1.075 | 0.212 | 1.800 | 1.800 | 1.800 | 1.800 | 1.397 | 1.166 | 1.193 |
| 1997 | 0.894 | 0.807 | 0.773 | 0.927 | 0.351 | 0.018 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 0.621 | 1.113 |
| 1998 | 1.609 | 0.806 | 0.773 | 0.133 | 0.044 | 1.096 | 1.712 | 1.800 | 1.800 | 1.800 | 1.507 | 1.110 | 1.181 |
| 1999 | 0.895 | 0.802 | 0.774 | 0.929 | 0.987 | 0.499 | 1.800 | 1.800 | 1.800 | 1.610 | 1.225 | 1.038 | 1.177 |
| 2000 | 0.885 | 0.783 | 0.759 | 0.929 | 0.990 | 1.268 | 1.363 | 1.491 | 1.693 | 1.493 | 1.318 | 1.143 | 1.175 |
| 2001 | 0.851 | 0.782 | 0.774 | 0.888 | 1.071 | 0.026 | 1.800 | 1.800 | 1.800 | 1.800 | 1.501 | 1.164 | 1.183 |
| 2002 | 0.894 | 0.807 | 0.331 | 0.524 | 0.232 | 0.084 | 0.289 | 0.089 | 1.800 | 1.800 | 1.800 | 1.800 | 0.865 |
| 2003 | 1.800 | 1.800 | 0.866 | 0.044 | 0.347 | 0.280 | 0.081 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.182 |
| 2004 | 1.800 | 1.800 | 0.203 | 0.013 | 0.006 | 0.002 | 0.003 | 0.001 | 1.051 | 1.800 | 1.800 | 0.001 | 0.701 |
| **Average** | **1.201** | **0.920** | **0.762** | **0.699** | **0.690** | **0.397** | **1.084** | **1.158** | **1.647** | **1.736** | **1.660** | **1.442** | **1.112** |

# APPENDIX A4– SCENARIO 3E MONTHLY PUMPING FROM THE RIVER TO THE HAIB OFF-CHANNEL STORAGE

## A-4: Scenario 3e Monthly pumping from the river to the Haib off-channel storage

| Year | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | AVE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0.647 | 0.582 | 0.569 | 0.690 | 0.813 | 0.603 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.839 |
| 1921 | 1.030 | 0.971 | 0.569 | 0.690 | 0.813 | 0.377 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.884 |
| 1922 | 1.030 | 0.939 | 0.549 | 0.690 | 0.813 | 0.009 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.848 |
| 1923 | 1.030 | 1.030 | 0.862 | 0.690 | 0.185 | 0.033 | 0.466 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.786 |
| 1924 | 1.030 | 1.030 | 1.030 | 1.030 | 0.901 | 0.100 | 1.030 | 1.030 | 0.673 | 1.030 | 1.030 | 1.030 | 0.910 |
| 1925 | 0.084 | 0.023 | 0.061 | 0.024 | 0.005 | 0.032 | 0.469 | 0.242 | 1.030 | 1.030 | 1.030 | 1.030 | 0.418 |
| 1926 | 0.199 | 0.015 | 0.009 | 0.056 | 0.021 | 0.451 | 0.306 | 0.591 | 1.030 | 1.030 | 1.030 | 1.030 | 0.478 |
| 1927 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.310 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.969 |
| 1928 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 |
| 1929 | 1.030 | 0.836 | 0.030 | 0.502 | 0.185 | 0.017 | 0.396 | 0.141 | 1.030 | 1.030 | 1.030 | 1.030 | 0.602 |
| 1930 | 1.030 | 1.030 | 1.030 | 1.030 | 0.058 | 0.007 | 0.408 | 0.909 | 1.030 | 1.030 | 1.030 | 1.030 | 0.802 |
| 1931 | 1.030 | 0.639 | 0.051 | 0.016 | 0.098 | 0.032 | 0.025 | 0.013 | 1.030 | 1.030 | 1.030 | 0.041 | 0.417 |
| 1932 | 0.017 | 0.061 | 0.051 | 0.025 | 0.016 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.613 |
| 1933 | 1.030 | 1.030 | 1.030 | 1.030 | 0.793 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.011 |
| 1934 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.025 | 1.030 | 0.610 | 1.030 | 1.030 | 1.030 | 1.030 | 0.909 |
| 1935 | 1.030 | 1.030 | 1.030 | 0.086 | 0.157 | 0.055 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.795 |
| 1936 | 0.443 | 0.048 | 0.023 | 0.011 | 0.005 | 0.005 | 0.136 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.483 |
| 1937 | 1.030 | 1.030 | 1.030 | 1.030 | 0.656 | 0.067 | 0.578 | 0.467 | 1.030 | 1.030 | 1.030 | 1.030 | 0.833 |
| 1938 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.886 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.018 |
| 1939 | 1.030 | 1.030 | 0.856 | 0.030 | 0.372 | 0.108 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.798 |
| 1940 | 1.030 | 1.030 | 1.030 | 1.030 | 0.991 | 0.022 | 0.414 | 0.015 | 0.407 | 1.030 | 1.030 | 1.030 | 0.752 |
| 1941 | 0.471 | 0.261 | 0.089 | 0.009 | 0.008 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.669 |
| 1942 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 |
| 1943 | 1.030 | 1.030 | 0.763 | 0.159 | 0.179 | 0.108 | 0.049 | 0.019 | 1.030 | 1.030 | 1.030 | 1.030 | 0.619 |
| 1944 | 1.030 | 0.236 | 0.488 | 0.187 | 0.020 | 0.121 | 0.069 | 0.009 | 1.030 | 1.030 | 1.030 | 1.030 | 0.521 |
| 1945 | 1.030 | 1.030 | 1.030 | 1.030 | 0.281 | 0.081 | 0.061 | 0.031 | 1.030 | 1.030 | 1.030 | 1.030 | 0.724 |
| 1946 | 1.030 | 0.881 | 0.025 | 0.012 | 0.016 | 0.084 | 0.076 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.604 |
| 1947 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.039 | 0.271 | 0.075 | 0.899 | 1.030 | 1.030 | 1.030 | 0.791 |
| 1948 | 0.897 | 0.023 | 0.011 | 0.032 | 0.016 | 0.004 | 0.138 | 0.076 | 1.030 | 1.030 | 1.030 | 1.030 | 0.440 |
| 1949 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 |
| 1950 | 1.030 | 1.030 | 0.423 | 0.011 | 0.008 | 0.004 | 0.018 | 0.008 | 0.463 | 1.030 | 1.030 | 1.030 | 0.503 |
| 1951 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.037 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.946 |
| 1952 | 1.030 | 1.030 | 1.030 | 0.315 | 0.027 | 0.009 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.800 |
| 1953 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.244 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.963 |
| 1954 | 1.030 | 1.030 | 1.030 | 1.030 | 0.283 | 0.464 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.921 |
| 1955 | 1.030 | 1.030 | 0.828 | 0.690 | 0.813 | 0.026 | 1.004 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.879 |
| 1956 | 0.979 | 0.858 | 0.363 | 0.125 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.878 |
| 1957 | 1.030 | 1.030 | 0.677 | 0.690 | 0.813 | 0.010 | 0.394 | 1.030 | 1.030 | 1.030 | 1.030 | 0.980 | 0.811 |
| 1958 | 1.030 | 1.030 | 1.030 | 0.396 | 0.027 | 0.008 | 0.042 | 0.479 | 1.030 | 1.030 | 1.030 | 1.030 | 0.679 |
| 1959 | 1.030 | 0.521 | 0.017 | 0.054 | 0.019 | 0.014 | 0.017 | 0.076 | 1.030 | 1.030 | 1.030 | 1.030 | 0.486 |
| 1960 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.417 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.978 |
| 1961 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.161 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.956 |
| 1962 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.464 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.982 |
| 1963 | 0.990 | 0.180 | 0.066 | 0.013 | 1.030 | 0.038 | 0.638 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.672 |
| 1964 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.020 | 0.784 | 0.070 | 1.030 | 1.030 | 1.030 | 0.396 | 0.790 |
| 1965 | 0.028 | 0.017 | 0.012 | 0.006 | 0.007 | 0.238 | 0.091 | 0.080 | 1.030 | 1.030 | 1.030 | 1.030 | 0.380 |
| 1966 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.063 | 1.030 | 0.548 | 1.030 | 1.030 | 1.030 | 1.030 | 0.907 |
| 1967 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.022 | 0.437 | 0.135 | 1.030 | 1.030 | 1.030 | 1.030 | 0.820 |
| 1968 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.063 | 1.030 | 0.573 | 1.030 | 1.030 | 1.030 | 0.833 | 0.893 |
| 1969 | 0.830 | 0.508 | 0.098 | 0.573 | 0.234 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.787 |
| 1970 | 1.030 | 0.262 | 1.030 | 1.030 | 1.030 | 0.250 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.901 |
| 1971 | 1.030 | 1.030 | 1.030 | 1.030 | 0.888 | 0.018 | 0.023 | 0.012 | 0.607 | 1.030 | 1.030 | 1.030 | 0.727 |
| 1972 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.289 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.967 |
| 1973 | 1.030 | 1.030 | 1.030 | 0.715 | 0.813 | 0.483 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.939 |
| 1974 | 1.030 | 0.708 | 0.546 | 0.690 | 0.810 | 0.376 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.984 | 0.856 |
| 1975 | 0.604 | 0.570 | 0.568 | 0.683 | 0.805 | 0.919 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.859 |
| 1976 | 0.766 | 0.589 | 0.569 | 0.687 | 0.780 | 0.391 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.828 |
| 1977 | 1.030 | 0.898 | 0.556 | 0.667 | 0.775 | 0.014 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.841 |
| 1978 | 0.489 | 0.273 | 0.557 | 1.030 | 0.686 | 0.087 | 0.343 | 0.122 | 1.022 | 1.030 | 1.030 | 1.030 | 0.639 |
| 1979 | 1.030 | 0.725 | 0.113 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.927 |
| 1980 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.304 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.968 |
| 1981 | 1.030 | 1.030 | 0.972 | 0.690 | 0.623 | 0.432 | 0.592 | 0.499 | 1.030 | 1.030 | 1.030 | 0.091 | 0.754 |
| 1982 | 0.576 | 0.220 | 0.028 | 0.016 | 0.036 | 0.016 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.586 |
| 1983 | 0.527 | 0.069 | 0.023 | 0.069 | 0.042 | 1.021 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.659 |
| 1984 | 0.585 | 0.043 | 0.020 | 0.009 | 0.008 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.655 |
| 1985 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.201 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.651 | 0.929 |
| 1986 | 0.143 | 0.059 | 0.079 | 0.031 | 1.030 | 0.387 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.655 |
| 1987 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 |
| 1988 | 1.030 | 1.030 | 1.030 | 0.900 | 0.812 | 0.202 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.931 |
| 1989 | 1.030 | 0.967 | 0.567 | 0.690 | 0.813 | 0.008 | 0.686 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.824 |
| 1990 | 1.030 | 1.030 | 1.014 | 0.661 | 0.755 | 0.876 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.962 |
| 1991 | 0.888 | 0.066 | 0.036 | 0.552 | 0.199 | 0.092 | 0.050 | 0.012 | 1.030 | 1.030 | 1.030 | 1.030 | 0.499 |
| 1992 | 1.030 | 0.678 | 0.091 | 0.034 | 0.013 | 1.030 | 0.455 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.706 |
| 1993 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.013 | 0.314 | 0.012 | 1.030 | 1.030 | 1.030 | 1.030 | 0.798 |
| 1994 | 1.030 | 1.030 | 0.812 | 0.191 | 0.111 | 0.027 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.780 |
| 1995 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.267 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.965 |
| 1996 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.212 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.961 |
| 1997 | 1.030 | 1.030 | 0.989 | 0.689 | 0.782 | 0.018 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.621 | 0.858 |
| 1998 | 1.030 | 1.030 | 0.898 | 0.023 | 0.044 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.852 |
| 1999 | 1.030 | 1.030 | 0.981 | 0.690 | 0.742 | 0.499 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.928 |
| 2000 | 1.030 | 0.862 | 0.556 | 0.690 | 0.744 | 0.966 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.918 |
| 2001 | 0.899 | 0.572 | 0.569 | 0.657 | 0.810 | 0.026 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.807 |
| 2002 | 1.030 | 1.030 | 0.322 | 0.517 | 0.229 | 0.082 | 0.288 | 0.089 | 1.030 | 1.030 | 1.030 | 1.030 | 0.639 |
| 2003 | 1.030 | 1.030 | 1.030 | 0.533 | 0.347 | 0.280 | 0.081 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.790 |
| 2004 | 1.030 | 1.030 | 0.897 | 0.013 | 0.006 | 0.002 | 0.003 | 0.001 | 1.030 | 1.030 | 1.030 | 0.001 | 0.505 |
| **Average** | **0.918** | **0.796** | **0.687** | **0.622** | **0.602** | **0.33** | **0.737** | **0.76** | **1.005** | **1.03** | **1.03** | **0.975** | **0.789** |

# APPENDIX A5– SCENARIO 3B MONTHLY PUMPING FROM THE RIVER TO THE HAIB OFF-CHANNEL STORAGE

## A-5: Scenario 3b Monthly pumping from the river to the Haib off-channel storage

| Year | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | AVE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 0.399 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 1.864 |
| 1921 | 1.000 | 0.798 | 0.774 | 0.929 | 1.075 | 0.377 | 2.000 | 1.878 | 1.741 | 1.463 | 1.293 | 1.152 | 1.204 |
| 1922 | 0.755 | 0.752 | 0.751 | 0.929 | 1.075 | 0.009 | 0.666 | 0.169 | 0.977 | 2.000 | 2.000 | 2.000 | 0.998 |
| 1923 | 2.000 | 1.164 | 0.774 | 0.170 | 0.062 | 0.033 | 0.465 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 1.220 |
| 1924 | 0.967 | 0.807 | 0.751 | 0.929 | 1.075 | 0.100 | 2.000 | 0.517 | 0.441 | 2.000 | 2.000 | 2.000 | 1.122 |
| 1925 | 0.084 | 0.023 | 0.061 | 0.024 | 0.005 | 0.032 | 0.469 | 0.242 | 1.591 | 2.000 | 2.000 | 2.000 | 0.702 |
| 1926 | 0.197 | 0.015 | 0.009 | 0.056 | 0.021 | 0.451 | 0.306 | 0.591 | 2.000 | 2.000 | 2.000 | 2.000 | 0.797 |
| 1927 | 2.000 | 2.000 | 2.000 | 1.770 | 1.020 | 0.310 | 2.000 | 1.912 | 1.724 | 1.560 | 1.212 | 1.130 | 1.553 |
| 1928 | 0.888 | 0.807 | 0.774 | 0.817 | 0.941 | 1.270 | 1.475 | 1.461 | 1.730 | 1.509 | 1.351 | 1.181 | 1.182 |
| 1929 | 0.895 | 0.778 | 0.075 | 0.502 | 0.185 | 0.017 | 0.396 | 0.141 | 2.000 | 2.000 | 2.000 | 2.000 | 0.908 |
| 1930 | 2.000 | 1.820 | 0.526 | 0.024 | 0.010 | 0.007 | 0.408 | 0.877 | 2.000 | 2.000 | 2.000 | 2.000 | 1.134 |
| 1931 | 0.596 | 0.215 | 0.051 | 0.016 | 0.098 | 0.032 | 0.025 | 0.013 | 2.000 | 2.000 | 2.000 | 0.041 | 0.585 |
| 1932 | 0.017 | 0.061 | 0.051 | 0.025 | 0.016 | 1.576 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 1.140 |
| 1933 | 2.000 | 2.000 | 1.301 | 0.770 | 0.024 | 1.141 | 2.000 | 2.000 | 1.791 | 1.485 | 1.355 | 1.100 | 1.415 |
| 1934 | 0.830 | 0.805 | 0.774 | 0.927 | 1.072 | 0.025 | 1.907 | 0.160 | 1.139 | 2.000 | 2.000 | 2.000 | 1.127 |
| 1935 | 1.139 | 0.807 | 0.774 | 0.406 | 0.157 | 0.055 | 2.000 | 2.000 | 2.000 | 2.000 | 1.757 | 1.162 | 1.184 |
| 1936 | 0.335 | 0.048 | 0.023 | 0.011 | 0.005 | 0.005 | 0.136 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 0.876 |
| 1937 | 2.000 | 0.981 | 0.855 | 0.310 | 0.034 | 0.067 | 0.578 | 0.467 | 2.000 | 2.000 | 2.000 | 2.000 | 1.103 |
| 1938 | 2.000 | 1.354 | 0.643 | 0.772 | 1.064 | 0.863 | 1.834 | 1.526 | 1.682 | 1.525 | 1.238 | 1.163 | 1.303 |
| 1939 | 0.891 | 0.804 | 0.760 | 0.262 | 0.372 | 0.108 | 1.466 | 2.000 | 2.000 | 2.000 | 1.492 | 1.143 | 1.103 |
| 1940 | 0.880 | 0.789 | 0.771 | 0.929 | 1.075 | 0.022 | 0.740 | 0.015 | 0.407 | 2.000 | 2.000 | 2.000 | 0.959 |
| 1941 | 0.471 | 0.261 | 0.089 | 0.009 | 0.008 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 1.233 |
| 1942 | 1.293 | 0.807 | 0.774 | 0.896 | 1.075 | 1.290 | 1.326 | 1.445 | 1.706 | 1.503 | 1.249 | 1.177 | 1.211 |
| 1943 | 0.887 | 0.801 | 0.772 | 0.461 | 0.179 | 0.108 | 0.049 | 0.019 | 2.000 | 2.000 | 2.000 | 2.000 | 0.934 |
| 1944 | 1.164 | 0.075 | 0.488 | 0.187 | 0.020 | 0.121 | 0.068 | 0.009 | 2.000 | 2.000 | 2.000 | 2.000 | 0.839 |
| 1945 | 2.000 | 2.000 | 1.941 | 0.341 | 0.142 | 0.081 | 0.061 | 0.031 | 2.000 | 2.000 | 2.000 | 2.000 | 1.212 |
| 1946 | 1.695 | 0.093 | 0.025 | 0.012 | 0.016 | 0.084 | 0.076 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 0.997 |
| 1947 | 2.000 | 1.954 | 0.762 | 0.916 | 0.749 | 0.039 | 0.049 | 0.075 | 0.899 | 2.000 | 2.000 | 2.000 | 1.113 |
| 1948 | 0.414 | 0.023 | 0.011 | 0.032 | 0.016 | 0.004 | 0.138 | 0.076 | 2.000 | 2.000 | 2.000 | 2.000 | 0.719 |
| 1949 | 2.000 | 2.000 | 2.000 | 1.444 | 0.983 | 1.220 | 1.415 | 1.508 | 1.730 | 1.519 | 1.367 | 1.179 | 1.532 |
| 1950 | 0.865 | 0.616 | 0.080 | 0.011 | 0.008 | 0.004 | 0.018 | 0.008 | 0.463 | 2.000 | 2.000 | 2.000 | 0.663 |
| 1951 | 1.429 | 0.059 | 2.000 | 2.000 | 2.000 | 0.037 | 2.000 | 0.629 | 1.479 | 2.000 | 2.000 | 2.000 | 1.465 |
| 1952 | 1.058 | 0.807 | 0.772 | 0.632 | 0.027 | 0.009 | 1.978 | 2.000 | 2.000 | 2.000 | 1.428 | 1.114 | 1.148 |
| 1953 | 0.873 | 0.806 | 0.773 | 0.928 | 1.067 | 0.370 | 2.000 | 1.838 | 1.689 | 1.500 | 1.348 | 1.138 | 1.191 |
| 1954 | 0.862 | 0.766 | 0.763 | 0.926 | 0.563 | 0.464 | 2.000 | 2.000 | 1.718 | 1.337 | 1.170 | 1.153 | 1.142 |
| 1955 | 0.868 | 0.804 | 0.774 | 0.929 | 1.075 | 0.026 | 0.831 | 2.000 | 2.000 | 2.000 | 1.732 | 1.180 | 1.181 |
| 1956 | 0.864 | 0.692 | 0.615 | 0.125 | 1.994 | 1.271 | 1.428 | 1.433 | 1.607 | 1.540 | 1.387 | 1.112 | 1.168 |
| 1957 | 0.786 | 0.807 | 0.774 | 0.929 | 0.549 | 0.010 | 0.358 | 2.000 | 2.000 | 2.000 | 2.000 | 0.980 | 1.097 |
| 1958 | 1.439 | 0.794 | 0.766 | 0.639 | 0.027 | 0.008 | 0.042 | 0.479 | 2.000 | 2.000 | 2.000 | 2.000 | 1.012 |
| 1959 | 2.000 | 0.036 | 0.017 | 0.054 | 0.019 | 0.014 | 0.017 | 0.076 | 2.000 | 2.000 | 2.000 | 2.000 | 0.848 |
| 1960 | 2.000 | 2.000 | 1.860 | 0.927 | 1.066 | 0.417 | 2.000 | 1.781 | 1.745 | 1.527 | 1.367 | 1.181 | 1.488 |
| 1961 | 0.895 | 0.797 | 0.774 | 0.882 | 1.051 | 0.161 | 2.000 | 2.000 | 1.692 | 1.537 | 1.294 | 1.024 | 1.172 |
| 1962 | 0.854 | 0.802 | 0.762 | 0.917 | 1.066 | 0.464 | 2.000 | 1.606 | 1.759 | 1.519 | 1.347 | 1.162 | 1.185 |
| 1963 | 0.890 | 0.272 | 0.066 | 0.013 | 1.056 | 0.038 | 0.623 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 1.074 |
| 1964 | 1.230 | 0.806 | 0.762 | 0.929 | 1.059 | 0.020 | 1.188 | 0.070 | 2.000 | 2.000 | 2.000 | 0.396 | 1.033 |
| 1965 | 0.028 | 0.017 | 0.012 | 0.006 | 0.007 | 0.238 | 0.091 | 0.080 | 2.000 | 2.000 | 2.000 | 2.000 | 0.699 |
| 1966 | 2.000 | 2.000 | 2.000 | 1.518 | 1.050 | 0.063 | 0.597 | 0.199 | 1.229 | 2.000 | 2.000 | 2.000 | 1.383 |
| 1967 | 1.900 | 0.805 | 0.774 | 0.929 | 1.071 | 0.022 | 0.625 | 0.135 | 1.997 | 2.000 | 2.000 | 2.000 | 1.183 |
| 1968 | 1.403 | 0.807 | 0.772 | 0.929 | 1.073 | 0.063 | 2.000 | 0.240 | 2.000 | 2.000 | 2.000 | 0.833 | 1.170 |
| 1969 | 0.830 | 0.508 | 0.098 | 0.573 | 0.234 | 1.509 | 2.000 | 2.000 | 2.000 | 2.000 | 1.490 | 1.149 | 1.196 |
| 1970 | 0.852 | 0.389 | 1.132 | 0.925 | 1.075 | 0.250 | 1.072 | 1.783 | 2.000 | 1.922 | 1.219 | 1.117 | 1.141 |
| 1971 | 0.895 | 0.798 | 0.772 | 0.929 | 1.072 | 0.018 | 0.305 | 0.012 | 0.607 | 2.000 | 2.000 | 2.000 | 0.942 |
| 1972 | 2.000 | 1.759 | 0.727 | 0.927 | 1.074 | 0.289 | 2.000 | 1.786 | 1.254 | 1.217 | 1.253 | 0.965 | 1.269 |
| 1973 | 0.882 | 0.787 | 0.774 | 0.917 | 1.074 | 0.483 | 2.000 | 1.674 | 1.656 | 1.506 | 1.092 | 1.149 | 1.163 |
| 1974 | 0.857 | 0.804 | 0.747 | 0.929 | 1.071 | 0.297 | 2.000 | 1.615 | 1.552 | 0.968 | 1.119 | 1.082 | 1.086 |
| 1975 | 0.819 | 0.779 | 0.772 | 0.920 | 1.064 | 1.211 | 1.475 | 1.517 | 1.736 | 1.422 | 1.272 | 0.909 | 1.157 |
| 1976 | 0.858 | 0.802 | 0.774 | 0.924 | 1.034 | 0.390 | 2.000 | 1.727 | 1.627 | 1.510 | 1.265 | 1.140 | 1.168 |
| 1977 | 0.895 | 0.805 | 0.758 | 0.901 | 1.028 | 0.014 | 1.540 | 0.047 | 1.584 | 2.000 | 2.000 | 1.093 | 1.048 |
| 1978 | 0.259 | 0.273 | 0.557 | 1.381 | 0.435 | 0.087 | 0.343 | 0.122 | 1.022 | 2.000 | 2.000 | 2.000 | 0.866 |
| 1979 | 2.000 | 0.398 | 0.092 | 2.000 | 2.000 | 2.000 | 1.760 | 1.495 | 1.755 | 1.433 | 1.344 | 1.181 | 1.456 |
| 1980 | 0.879 | 0.802 | 0.774 | 0.764 | 1.075 | 0.304 | 2.000 | 1.909 | 1.759 | 1.552 | 1.386 | 1.096 | 1.188 |
| 1981 | 0.895 | 0.785 | 0.768 | 0.928 | 0.783 | 0.432 | 0.592 | 0.499 | 1.697 | 2.000 | 2.000 | 0.081 | 0.951 |
| 1982 | 0.576 | 0.220 | 0.028 | 0.016 | 0.036 | 0.016 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 1.437 | 1.021 |
| 1983 | 0.177 | 0.069 | 0.023 | 0.069 | 0.042 | 1.021 | 1.546 | 1.661 | 2.000 | 2.000 | 2.000 | 1.619 | 1.014 |
| 1984 | 0.072 | 0.043 | 0.020 | 0.009 | 0.008 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 1.175 |
| 1985 | 1.933 | 0.780 | 0.758 | 0.925 | 1.058 | 0.201 | 1.309 | 1.588 | 2.000 | 2.000 | 1.696 | 0.408 | 1.219 |
| 1986 | 0.143 | 0.059 | 0.079 | 0.031 | 1.838 | 0.387 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 1.705 | 1.178 |
| 1987 | 0.891 | 0.806 | 0.774 | 0.898 | 1.017 | 1.286 | 1.431 | 1.415 | 1.587 | 1.276 | 1.380 | 1.090 | 1.154 |
| 1988 | 0.886 | 0.806 | 0.764 | 0.929 | 1.072 | 0.202 | 2.000 | 1.961 | 1.734 | 1.461 | 1.310 | 0.952 | 1.171 |
| 1989 | 0.895 | 0.718 | 0.772 | 0.929 | 0.696 | 0.008 | 0.024 | 1.114 | 2.000 | 2.000 | 2.000 | 2.000 | 1.092 |
| 1990 | 1.340 | 0.757 | 0.774 | 0.743 | 1.157 | 1.159 | 1.448 | 1.488 | 1.757 | 1.524 | 1.354 | 1.180 | 1.222 |
| 1991 | 0.752 | 0.066 | 0.036 | 0.552 | 0.199 | 0.092 | 0.050 | 0.012 | 1.230 | 2.000 | 2.000 | 2.000 | 0.741 |
| 1992 | 1.397 | 0.087 | 0.091 | 0.034 | 0.013 | 1.064 | 0.455 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 1.093 |
| 1993 | 2.000 | 2.000 | 0.839 | 0.929 | 0.126 | 0.013 | 0.024 | 0.012 | 1.626 | 2.000 | 2.000 | 2.000 | 1.125 |
| 1994 | 2.000 | 0.888 | 0.061 | 0.191 | 0.111 | 0.027 | 1.830 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 1.254 |
| 1995 | 1.156 | 0.807 | 0.638 | 0.922 | 1.068 | 0.267 | 2.000 | 1.701 | 1.702 | 1.553 | 1.214 | 1.178 | 1.180 |
| 1996 | 0.836 | 0.790 | 0.767 | 0.929 | 1.075 | 0.212 | 2.000 | 2.000 | 1.754 | 1.506 | 1.340 | 1.166 | 1.195 |
| 1997 | 0.894 | 0.807 | 0.773 | 0.927 | 0.182 | 0.018 | 2.000 | 2.000 | 2.000 | 2.000 | 1.478 | 0.621 | 1.138 |
| 1998 | 1.322 | 0.806 | 0.773 | 0.133 | 0.044 | 1.096 | 1.712 | 2.000 | 2.000 | 1.704 | 1.181 | 1.110 | 1.155 |
| 1999 | 0.895 | 0.802 | 0.774 | 0.929 | 0.987 | 0.499 | 2.000 | 1.747 | 1.735 | 1.536 | 1.225 | 1.038 | 1.178 |
| 2000 | 0.885 | 0.783 | 0.759 | 0.929 | 0.990 | 1.268 | 1.363 | 1.491 | 1.693 | 1.493 | 1.318 | 1.143 | 1.175 |
| 2001 | 0.851 | 0.782 | 0.774 | 0.888 | 1.071 | 0.026 | 1.923 | 2.000 | 1.912 | 1.477 | 1.383 | 1.164 | 1.185 |
| 2002 | 0.894 | 0.807 | 0.331 | 0.524 | 0.232 | 0.084 | 0.289 | 0.089 | 2.000 | 2.000 | 2.000 | 2.000 | 0.931 |
| 2003 | 2.000 | 1.683 | 0.774 | 0.233 | 0.347 | 0.280 | 0.081 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 1.281 |
| 2004 | 0.915 | 0.788 | 0.774 | 0.131 | 0.006 | 0.002 | 0.003 | 0.001 | 1.051 | 2.000 | 2.000 | 0.001 | 0.634 |
| **Average** | **1.109** | **0.790** | **0.675** | **0.670** | **0.668** | **0.401** | **1.181** | **1.202** | **1.729** | **1.819** | **1.714** | **1.464** | **1.114** |

# APPENDIX A6– SCENARIO 3C MONTHLY PUMPING FROM THE RIVER TO THE HAIB OFF-CHANNEL STORAGE

## A-6: Scenario 3c Monthly pumping from the river to the Haib off-channel storage

| Year | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | AVE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 0.399 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.681 |
| 1921 | 0.9 | 0.798 | 0.774 | 0.929 | 1.075 | 0.377 | 1.8 | 1.8 | 1.8 | 1.581 | 1.293 | 1.152 | 1.187 |
| 1922 | 0.755 | 0.752 | 0.751 | 0.929 | 1.075 | 0.009 | 0.858 | 0.169 | 0.977 | 1.8 | 1.8 | 1.8 | 0.965 |
| 1923 | 1.8 | 1.236 | 0.774 | 0.346 | 0.062 | 0.033 | 0.465 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.141 |
| 1924 | 1.187 | 0.807 | 0.751 | 0.929 | 1.075 | 0.1 | 1.8 | 0.668 | 0.441 | 1.8 | 1.8 | 1.8 | 1.088 |
| 1925 | 0.084 | 0.023 | 0.061 | 0.024 | 0.005 | 0.032 | 0.469 | 0.242 | 1.591 | 1.8 | 1.8 | 1.8 | 0.653 |
| 1926 | 0.197 | 0.015 | 0.009 | 0.056 | 0.021 | 0.451 | 0.306 | 0.591 | 1.8 | 1.8 | 1.8 | 1.8 | 0.731 |
| 1927 | 1.8 | 1.8 | 1.8 | 1.529 | 1.02 | 0.31 | 1.8 | 1.8 | 1.8 | 1.688 | 1.212 | 1.13 | 1.473 |
| 1928 | 0.888 | 0.807 | 0.774 | 0.817 | 0.941 | 1.27 | 1.475 | 1.461 | 1.73 | 1.509 | 1.351 | 1.181 | 1.182 |
| 1929 | 0.895 | 0.778 | 0.075 | 0.502 | 0.185 | 0.017 | 0.396 | 0.141 | 1.8 | 1.8 | 1.8 | 1.8 | 0.843 |
| 1930 | 1.8 | 1.8 | 0.728 | 0.024 | 0.01 | 0.007 | 0.408 | 0.877 | 1.8 | 1.8 | 1.8 | 1.8 | 1.067 |
| 1931 | 0.771 | 0.215 | 0.051 | 0.016 | 0.098 | 0.032 | 0.025 | 0.013 | 1.8 | 1.8 | 1.8 | 0.041 | 0.551 |
| 1932 | 0.017 | 0.061 | 0.051 | 0.025 | 0.016 | 1.576 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.041 |
| 1933 | 1.8 | 1.8 | 0.782 | 0.929 | 0.465 | 1.141 | 1.8 | 1.665 | 1.74 | 1.485 | 1.355 | 1.1 | 1.338 |
| 1934 | 0.83 | 0.805 | 0.774 | 0.927 | 1.072 | 0.025 | 1.8 | 0.256 | 1.139 | 1.8 | 1.8 | 1.8 | 1.077 |
| 1935 | 1.345 | 0.807 | 0.774 | 0.247 | 0.157 | 0.055 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.539 | 1.157 |
| 1936 | 0.063 | 0.048 | 0.023 | 0.011 | 0.005 | 0.005 | 0.136 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 0.77 |
| 1937 | 1.8 | 1.371 | 0.855 | 0.31 | 0.034 | 0.067 | 0.578 | 0.467 | 1.8 | 1.8 | 1.8 | 1.8 | 1.052 |
| 1938 | 1.8 | 1.458 | 0.654 | 0.761 | 1.064 | 0.865 | 1.8 | 1.538 | 1.682 | 1.525 | 1.238 | 1.163 | 1.293 |
| 1939 | 0.891 | 0.804 | 0.76 | 0.262 | 0.372 | 0.108 | 1.466 | 1.8 | 1.8 | 1.8 | 1.744 | 1.143 | 1.075 |
| 1940 | 0.88 | 0.789 | 0.771 | 0.929 | 1.075 | 0.022 | 0.74 | 0.015 | 0.407 | 1.8 | 1.8 | 1.8 | 0.91 |
| 1941 | 0.471 | 0.261 | 0.089 | 0.009 | 0.008 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.116 |
| 1942 | 1.6 | 0.807 | 0.774 | 0.896 | 1.075 | 1.29 | 1.326 | 1.445 | 1.706 | 1.503 | 1.249 | 1.177 | 1.237 |
| 1943 | 0.887 | 0.801 | 0.772 | 0.461 | 0.179 | 0.108 | 0.049 | 0.019 | 1.8 | 1.8 | 1.8 | 1.8 | 0.868 |
| 1944 | 1.229 | 0.075 | 0.488 | 0.187 | 0.02 | 0.121 | 0.069 | 0.009 | 1.8 | 1.8 | 1.8 | 1.8 | 0.779 |
| 1945 | 1.8 | 1.8 | 1.8 | 0.458 | 0.142 | 0.081 | 0.061 | 0.031 | 1.8 | 1.8 | 1.8 | 1.8 | 1.111 |
| 1946 | 1.8 | 0.144 | 0.025 | 0.012 | 0.016 | 0.084 | 0.076 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 0.928 |
| 1947 | 1.8 | 1.8 | 0.852 | 0.916 | 0.944 | 0.039 | 0.049 | 0.075 | 0.899 | 1.8 | 1.8 | 1.8 | 1.058 |
| 1948 | 0.597 | 0.023 | 0.011 | 0.032 | 0.016 | 0.004 | 0.138 | 0.076 | 1.8 | 1.8 | 1.8 | 1.8 | 0.668 |
| 1949 | 1.8 | 1.8 | 1.8 | 1.31 | 0.983 | 1.22 | 1.415 | 1.508 | 1.73 | 1.519 | 1.367 | 1.179 | 1.47 |
| 1950 | 0.865 | 0.723 | 0.08 | 0.011 | 0.008 | 0.004 | 0.018 | 0.008 | 0.463 | 1.8 | 1.8 | 1.8 | 0.623 |
| 1951 | 1.602 | 0.059 | 1.8 | 1.8 | 1.8 | 0.037 | 1.8 | 0.94 | 1.479 | 1.8 | 1.8 | 1.8 | 1.39 |
| 1952 | 0.99 | 0.807 | 0.772 | 0.632 | 0.027 | 0.009 | 1.8 | 1.8 | 1.8 | 1.8 | 1.787 | 1.114 | 1.108 |
| 1953 | 0.873 | 0.806 | 0.773 | 0.928 | 1.067 | 0.37 | 1.8 | 1.8 | 1.8 | 1.534 | 1.348 | 1.138 | 1.184 |
| 1954 | 0.862 | 0.766 | 0.763 | 0.926 | 0.563 | 0.464 | 1.8 | 1.8 | 1.8 | 1.517 | 1.17 | 1.153 | 1.13 |
| 1955 | 0.868 | 0.804 | 0.774 | 0.929 | 1.075 | 0.026 | 0.82 | 1.8 | 1.8 | 1.8 | 1.8 | 1.389 | 1.154 |
| 1956 | 0.864 | 0.692 | 0.615 | 0.125 | 1.8 | 1.42 | 1.428 | 1.433 | 1.607 | 1.54 | 1.387 | 1.112 | 1.165 |
| 1957 | 0.786 | 0.807 | 0.774 | 0.929 | 0.549 | 0.01 | 0.358 | 1.8 | 1.8 | 1.8 | 1.8 | 0.98 | 1.031 |
| 1958 | 1.727 | 0.794 | 0.766 | 0.639 | 0.027 | 0.008 | 0.042 | 0.479 | 1.8 | 1.8 | 1.8 | 1.8 | 0.971 |
| 1959 | 1.8 | 0.036 | 0.017 | 0.054 | 0.019 | 0.014 | 0.017 | 0.076 | 1.8 | 1.8 | 1.8 | 1.8 | 0.765 |
| 1960 | 1.8 | 1.8 | 1.8 | 1.038 | 1.066 | 0.417 | 1.8 | 1.8 | 1.8 | 1.57 | 1.367 | 1.181 | 1.452 |
| 1961 | 0.895 | 0.797 | 0.774 | 0.882 | 1.051 | 0.161 | 1.8 | 1.8 | 1.8 | 1.702 | 1.294 | 1.024 | 1.161 |
| 1962 | 0.854 | 0.802 | 0.762 | 0.917 | 1.066 | 0.464 | 1.8 | 1.748 | 1.759 | 1.519 | 1.347 | 1.162 | 1.18 |
| 1963 | 0.89 | 0.313 | 0.066 | 0.013 | 1.056 | 0.038 | 0.623 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 0.994 |
| 1964 | 1.459 | 0.806 | 0.762 | 0.929 | 1.059 | 0.02 | 1.188 | 0.07 | 1.8 | 1.8 | 1.8 | 0.396 | 1.003 |
| 1965 | 0.028 | 0.017 | 0.012 | 0.006 | 0.007 | 0.238 | 0.091 | 0.08 | 1.8 | 1.8 | 1.8 | 1.8 | 0.633 |
| 1966 | 1.8 | 1.8 | 1.8 | 1.427 | 1.075 | 0.063 | 0.794 | 0.199 | 1.229 | 1.8 | 1.8 | 1.8 | 1.294 |
| 1967 | 1.786 | 0.805 | 0.774 | 0.929 | 1.071 | 0.022 | 0.625 | 0.135 | 1.8 | 1.8 | 1.8 | 1.8 | 1.108 |
| 1968 | 1.649 | 0.807 | 0.772 | 0.929 | 1.073 | 0.063 | 1.8 | 0.362 | 1.8 | 1.8 | 1.8 | 0.833 | 1.136 |
| 1969 | 0.83 | 0.508 | 0.098 | 0.573 | 0.234 | 1.509 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.308 | 1.169 |
| 1970 | 0.852 | 0.389 | 1.128 | 0.925 | 1.075 | 0.25 | 1.072 | 1.783 | 1.8 | 1.8 | 1.365 | 1.117 | 1.127 |
| 1971 | 0.895 | 0.798 | 0.772 | 0.929 | 1.072 | 0.018 | 0.305 | 0.012 | 0.607 | 1.8 | 1.8 | 1.8 | 0.893 |
| 1972 | 1.8 | 1.8 | 0.838 | 0.927 | 1.074 | 0.289 | 1.8 | 1.8 | 1.354 | 1.217 | 1.253 | 0.965 | 1.258 |
| 1973 | 0.882 | 0.787 | 0.774 | 0.917 | 1.074 | 0.483 | 1.8 | 1.8 | 1.664 | 1.506 | 1.092 | 1.149 | 1.158 |
| 1974 | 0.857 | 0.804 | 0.747 | 0.929 | 1.071 | 0.297 | 1.8 | 1.743 | 1.552 | 0.968 | 1.119 | 1.082 | 1.08 |
| 1975 | 0.819 | 0.779 | 0.772 | 0.92 | 1.064 | 1.211 | 1.475 | 1.517 | 1.736 | 1.422 | 1.272 | 0.909 | 1.157 |
| 1976 | 0.858 | 0.802 | 0.774 | 0.924 | 1.034 | 0.39 | 1.8 | 1.8 | 1.681 | 1.51 | 1.265 | 1.14 | 1.162 |
| 1977 | 0.895 | 0.805 | 0.758 | 0.901 | 1.028 | 0.014 | 1.541 | 0.047 | 1.584 | 1.8 | 1.8 | 1.093 | 1.015 |
| 1978 | 0.259 | 0.273 | 0.557 | 1.381 | 0.435 | 0.087 | 0.343 | 0.122 | 1.022 | 1.8 | 1.8 | 1.8 | 0.817 |
| 1979 | 1.8 | 0.407 | 0.099 | 1.8 | 1.8 | 1.8 | 1.8 | 1.592 | 1.755 | 1.433 | 1.344 | 1.181 | 1.402 |
| 1980 | 0.879 | 0.802 | 0.774 | 0.764 | 1.075 | 0.304 | 1.8 | 1.8 | 1.8 | 1.711 | 1.386 | 1.096 | 1.178 |
| 1981 | 0.895 | 0.785 | 0.768 | 0.928 | 0.783 | 0.432 | 0.592 | 0.499 | 1.697 | 1.8 | 1.8 | 0.081 | 0.919 |
| 1982 | 0.576 | 0.22 | 0.028 | 0.016 | 0.036 | 0.016 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.437 | 0.938 |
| 1983 | 0.177 | 0.069 | 0.023 | 0.069 | 0.042 | 1.021 | 1.546 | 1.661 | 1.8 | 1.8 | 1.8 | 1.619 | 0.964 |
| 1984 | 0.072 | 0.043 | 0.02 | 0.009 | 0.008 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.059 |
| 1985 | 1.8 | 0.833 | 0.758 | 0.925 | 1.058 | 0.201 | 1.408 | 1.588 | 1.8 | 1.8 | 1.794 | 0.408 | 1.196 |
| 1986 | 0.143 | 0.059 | 0.079 | 0.031 | 1.8 | 0.387 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.1 |
| 1987 | 1.036 | 0.806 | 0.774 | 0.898 | 1.017 | 1.286 | 1.431 | 1.415 | 1.587 | 1.276 | 1.38 | 1.09 | 1.166 |
| 1988 | 0.886 | 0.806 | 0.764 | 0.929 | 1.072 | 0.202 | 1.8 | 1.8 | 1.8 | 1.642 | 1.31 | 0.952 | 1.16 |
| 1989 | 0.895 | 0.718 | 0.772 | 0.929 | 0.706 | 0.008 | 0.025 | 1.114 | 1.8 | 1.8 | 1.8 | 1.8 | 1.027 |
| 1990 | 1.569 | 0.757 | 0.774 | 0.553 | 1.341 | 1.159 | 1.448 | 1.488 | 1.757 | 1.524 | 1.354 | 1.18 | 1.24 |
| 1991 | 0.752 | 0.066 | 0.036 | 0.552 | 0.199 | 0.092 | 0.05 | 0.012 | 1.23 | 1.8 | 1.8 | 1.8 | 0.693 |
| 1992 | 1.578 | 0.087 | 0.091 | 0.034 | 0.013 | 1.064 | 0.455 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.026 |
| 1993 | 1.8 | 1.8 | 0.768 | 0.929 | 0.493 | 0.013 | 0.024 | 0.012 | 1.626 | 1.8 | 1.8 | 1.8 | 1.067 |
| 1994 | 1.8 | 1.084 | 0.061 | 0.191 | 0.111 | 0.027 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.168 |
| 1995 | 1.224 | 0.807 | 0.638 | 0.922 | 1.068 | 0.267 | 1.8 | 1.8 | 1.733 | 1.553 | 1.214 | 1.178 | 1.181 |
| 1996 | 0.836 | 0.79 | 0.767 | 0.929 | 1.075 | 0.212 | 1.8 | 1.8 | 1.8 | 1.735 | 1.34 | 1.166 | 1.183 |
| 1997 | 0.894 | 0.807 | 0.773 | 0.927 | 0.371 | 0.018 | 1.8 | 1.8 | 1.8 | 1.8 | 1.788 | 0.621 | 1.114 |
| 1998 | 1.315 | 0.806 | 0.773 | 0.133 | 0.044 | 1.096 | 1.712 | 1.8 | 1.8 | 1.8 | 1.232 | 1.11 | 1.132 |
| 1999 | 0.895 | 0.802 | 0.774 | 0.929 | 0.987 | 0.499 | 1.8 | 1.8 | 1.8 | 1.541 | 1.225 | 1.038 | 1.172 |
| 2000 | 0.885 | 0.783 | 0.759 | 0.929 | 0.99 | 1.268 | 1.363 | 1.491 | 1.693 | 1.493 | 1.318 | 1.143 | 1.175 |
| 2001 | 0.851 | 0.782 | 0.774 | 0.888 | 1.071 | 0.026 | 1.8 | 1.8 | 1.8 | 1.78 | 1.383 | 1.164 | 1.172 |
| 2002 | 0.894 | 0.807 | 0.331 | 0.524 | 0.232 | 0.084 | 0.289 | 0.089 | 1.8 | 1.8 | 1.8 | 1.8 | 0.865 |
| 2003 | 1.8 | 1.8 | 0.803 | 0.104 | 0.347 | 0.28 | 0.081 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.182 |
| 2004 | 1.336 | 0.788 | 0.774 | 0.131 | 0.006 | 0.002 | 0.003 | 0.001 | 1.051 | 1.8 | 1.8 | 0.001 | 0.637 |
| **Average** | **1.097** | **0.783** | **0.659** | **0.658** | **0.675** | **0.395** | **1.114** | **1.15** | **1.641** | **1.707** | **1.621** | **1.385** | **1.07** |

# APPENDIX A7– SCENARIO 3F MONTHLY PUMPING FROM THE RIVER TO THE HAIB OFF-CHANNEL STORAGE

## A-7: Scenario 3f Monthly pumping from the river to the Haib off-channel storage

| Year | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | AVE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0.423 | 0.420 | 0.405 | 0.449 | 0.440 | 0.491 | 0.519 | 0.498 | 0.631 | 0.528 | 0.514 | 0.123 | 0.454 |
| 1921 | 0.189 | 0.421 | 0.507 | 0.867 | 0.512 | 0.377 | 0.643 | 0.499 | 0.633 | 0.521 | 0.506 | 0.493 | 0.514 |
| 1922 | 0.415 | 0.417 | 0.271 | 0.038 | 0.017 | 0.009 | 0.187 | 0.060 | 0.957 | 1.030 | 1.030 | 1.030 | 0.451 |
| 1923 | 0.270 | 0.208 | 0.454 | 0.090 | 0.053 | 0.033 | 0.455 | 1.030 | 1.030 | 1.030 | 0.904 | 0.488 | 0.502 |
| 1924 | 0.415 | 0.421 | 0.404 | 0.416 | 0.200 | 0.100 | 0.064 | 0.046 | 0.399 | 1.030 | 1.030 | 1.030 | 0.459 |
| 1925 | 0.014 | 0.007 | 0.056 | 0.020 | 0.002 | 0.032 | 0.367 | 0.205 | 1.030 | 1.030 | 1.030 | 1.030 | 0.398 |
| 1926 | 0.012 | 0.008 | 0.005 | 0.053 | 0.017 | 0.451 | 0.235 | 0.523 | 1.030 | 1.030 | 1.030 | 1.030 | 0.449 |
| 1927 | 0.137 | 0.178 | 0.494 | 0.213 | 0.467 | 0.310 | 0.201 | 0.164 | 1.030 | 1.030 | 1.030 | 1.030 | 0.520 |
| 1928 | 0.139 | 0.169 | 0.097 | 0.716 | 1.030 | 1.030 | 0.765 | 0.494 | 0.633 | 0.524 | 0.510 | 0.495 | 0.550 |
| 1929 | 0.046 | 0.068 | 0.025 | 0.497 | 0.181 | 0.017 | 0.354 | 0.131 | 1.030 | 1.030 | 1.030 | 1.030 | 0.449 |
| 1930 | 0.052 | 0.019 | 0.013 | 0.010 | 0.006 | 0.007 | 0.388 | 0.451 | 1.030 | 1.030 | 1.030 | 0.698 | 0.391 |
| 1931 | 0.211 | 0.112 | 0.019 | 0.009 | 0.075 | 0.032 | 0.014 | 0.009 | 1.030 | 1.030 | 1.030 | 0.032 | 0.297 |
| 1932 | 0.015 | 0.058 | 0.047 | 0.022 | 0.013 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.611 |
| 1933 | 1.030 | 0.186 | 0.104 | 0.044 | 0.020 | 1.030 | 1.030 | 1.030 | 1.030 | 0.765 | 0.511 | 0.489 | 0.606 |
| 1934 | 0.420 | 0.421 | 0.112 | 0.067 | 0.044 | 0.025 | 0.361 | 0.132 | 1.030 | 1.030 | 1.030 | 1.030 | 0.471 |
| 1935 | 0.492 | 0.152 | 0.089 | 0.043 | 0.140 | 0.055 | 1.030 | 1.030 | 1.030 | 0.786 | 0.512 | 0.081 | 0.452 |
| 1936 | 0.048 | 0.038 | 0.017 | 0.007 | 0.003 | 0.005 | 0.133 | 1.030 | 1.030 | 1.030 | 1.030 | 0.997 | 0.445 |
| 1937 | 0.332 | 0.093 | 0.670 | 0.221 | 0.028 | 0.067 | 0.536 | 0.461 | 1.030 | 1.030 | 1.030 | 0.796 | 0.523 |
| 1938 | 0.138 | 0.170 | 0.439 | 1.030 | 0.497 | 0.491 | 0.371 | 0.643 | 0.629 | 0.525 | 0.502 | 0.493 | 0.495 |
| 1939 | 0.100 | 0.062 | 0.035 | 0.024 | 0.297 | 0.108 | 1.030 | 1.030 | 1.030 | 1.025 | 0.514 | 0.492 | 0.475 |
| 1940 | 0.424 | 0.379 | 0.433 | 0.379 | 0.043 | 0.022 | 0.010 | 0.008 | 0.402 | 1.030 | 1.030 | 1.030 | 0.429 |
| 1941 | 0.188 | 0.188 | 0.063 | 0.005 | 0.005 | 1.030 | 1.030 | 1.030 | 1.030 | 0.792 | 0.512 | 0.485 | 0.529 |
| 1942 | 0.422 | 0.421 | 0.405 | 0.447 | 0.219 | 0.708 | 0.511 | 0.493 | 0.631 | 0.524 | 0.503 | 0.494 | 0.482 |
| 1943 | 0.191 | 0.194 | 0.183 | 0.136 | 0.144 | 0.108 | 0.034 | 0.015 | 1.030 | 1.030 | 1.030 | 1.030 | 0.423 |
| 1944 | 0.076 | 0.047 | 0.279 | 0.055 | 0.014 | 0.121 | 0.042 | 0.005 | 1.030 | 1.030 | 1.030 | 1.030 | 0.393 |
| 1945 | 1.030 | 1.030 | 0.101 | 0.062 | 0.117 | 0.081 | 0.043 | 0.026 | 1.030 | 1.030 | 1.030 | 1.030 | 0.547 |
| 1946 | 0.199 | 0.038 | 0.009 | 0.004 | 0.011 | 0.084 | 0.031 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.458 |
| 1947 | 1.030 | 0.288 | 0.201 | 0.120 | 0.068 | 0.039 | 0.029 | 0.072 | 0.895 | 1.030 | 1.030 | 1.030 | 0.483 |
| 1948 | 0.104 | 0.019 | 0.009 | 0.030 | 0.014 | 0.004 | 0.008 | 0.028 | 1.030 | 1.030 | 1.030 | 1.030 | 0.357 |
| 1949 | 1.030 | 1.030 | 0.672 | 0.995 | 0.434 | 0.490 | 0.518 | 0.497 | 0.633 | 0.525 | 0.512 | 0.145 | 0.625 |
| 1950 | 0.080 | 0.193 | 0.061 | 0.006 | 0.004 | 0.004 | 0.015 | 0.006 | 0.461 | 1.030 | 1.030 | 0.183 | 0.252 |
| 1951 | 0.104 | 0.045 | 1.030 | 1.030 | 0.088 | 0.037 | 0.924 | 0.048 | 1.030 | 1.030 | 1.030 | 1.030 | 0.617 |
| 1952 | 1.030 | 0.026 | 0.027 | 0.040 | 0.020 | 0.009 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.608 | 0.574 |
| 1953 | 0.423 | 0.421 | 0.405 | 0.449 | 0.440 | 0.383 | 0.415 | 0.198 | 1.030 | 0.640 | 0.510 | 0.492 | 0.483 |
| 1954 | 0.422 | 0.418 | 0.304 | 0.129 | 0.047 | 0.464 | 1.030 | 0.809 | 0.631 | 0.512 | 0.498 | 0.493 | 0.479 |
| 1955 | 0.423 | 0.175 | 0.120 | 0.057 | 0.027 | 0.026 | 0.117 | 1.030 | 1.030 | 1.030 | 1.030 | 0.697 | 0.478 |
| 1956 | 0.058 | 0.790 | 0.270 | 0.093 | 0.943 | 0.494 | 0.519 | 0.492 | 0.624 | 0.527 | 0.513 | 0.490 | 0.482 |
| 1957 | 0.417 | 0.421 | 0.056 | 0.030 | 0.019 | 0.010 | 0.012 | 1.030 | 1.030 | 1.030 | 1.030 | 0.066 | 0.428 |
| 1958 | 1.006 | 0.420 | 0.033 | 0.023 | 0.015 | 0.008 | 0.033 | 0.445 | 1.030 | 1.030 | 1.030 | 1.030 | 0.506 |
| 1959 | 0.058 | 0.029 | 0.013 | 0.050 | 0.017 | 0.014 | 0.014 | 0.032 | 1.030 | 1.030 | 1.030 | 1.030 | 0.358 |
| 1960 | 1.030 | 1.030 | 0.767 | 0.449 | 0.440 | 0.417 | 0.598 | 0.498 | 0.634 | 0.526 | 0.512 | 0.160 | 0.589 |
| 1961 | 0.131 | 1.030 | 0.432 | 0.428 | 0.322 | 0.161 | 0.996 | 0.498 | 0.627 | 0.526 | 0.506 | 0.483 | 0.509 |
| 1962 | 0.422 | 0.341 | 0.268 | 0.288 | 0.261 | 0.464 | 1.030 | 0.562 | 0.635 | 0.525 | 0.510 | 0.493 | 0.482 |
| 1963 | 0.143 | 0.116 | 0.039 | 0.009 | 0.777 | 0.155 | 0.099 | 1.030 | 1.030 | 1.030 | 0.848 | 0.486 | 0.477 |
| 1964 | 0.425 | 0.122 | 0.235 | 0.104 | 0.030 | 0.020 | 0.041 | 0.024 | 1.030 | 1.030 | 1.030 | 0.047 | 0.343 |
| 1965 | 0.020 | 0.011 | 0.007 | 0.003 | 0.005 | 0.238 | 0.087 | 0.068 | 1.030 | 1.030 | 1.030 | 1.030 | 0.376 |
| 1966 | 1.030 | 1.030 | 1.030 | 0.105 | 0.060 | 0.063 | 0.566 | 0.187 | 1.030 | 1.030 | 1.030 | 1.030 | 0.680 |
| 1967 | 0.585 | 0.421 | 0.053 | 0.040 | 0.022 | 0.073 | 0.061 | 0.122 | 1.030 | 1.030 | 1.030 | 1.030 | 0.455 |
| 1968 | 0.838 | 0.180 | 0.104 | 0.051 | 0.025 | 0.063 | 0.025 | 0.013 | 1.030 | 1.030 | 1.030 | 0.118 | 0.374 |
| 1969 | 0.462 | 0.354 | 0.023 | 0.313 | 0.054 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.540 | 0.492 | 0.614 |
| 1970 | 0.422 | 0.053 | 0.758 | 0.449 | 0.036 | 0.250 | 0.611 | 1.030 | 0.611 | 0.528 | 0.501 | 0.490 | 0.480 |
| 1971 | 0.308 | 0.174 | 0.426 | 0.232 | 0.029 | 0.018 | 0.012 | 0.008 | 0.603 | 1.030 | 1.030 | 1.030 | 0.405 |
| 1972 | 1.030 | 0.246 | 0.521 | 0.138 | 0.048 | 0.730 | 0.051 | 1.030 | 1.030 | 0.709 | 0.503 | 0.479 | 0.546 |
| 1973 | 0.424 | 0.420 | 0.405 | 0.448 | 0.440 | 0.483 | 0.375 | 0.644 | 0.627 | 0.524 | 0.492 | 0.492 | 0.481 |
| 1974 | 0.422 | 0.421 | 0.404 | 0.449 | 0.440 | 0.376 | 0.528 | 0.586 | 0.620 | 0.486 | 0.494 | 0.488 | 0.476 |
| 1975 | 0.419 | 0.419 | 0.405 | 0.448 | 0.440 | 0.490 | 0.522 | 0.498 | 0.633 | 0.518 | 0.505 | 0.475 | 0.481 |
| 1976 | 0.422 | 0.421 | 0.405 | 0.449 | 0.437 | 0.391 | 0.619 | 0.498 | 0.625 | 0.524 | 0.504 | 0.492 | 0.482 |
| 1977 | 0.425 | 0.039 | 0.018 | 0.009 | 0.039 | 0.014 | 0.010 | 0.039 | 1.030 | 1.030 | 1.030 | 0.260 | 0.326 |
| 1978 | 0.237 | 0.180 | 0.479 | 1.030 | 0.338 | 0.087 | 0.323 | 0.118 | 1.019 | 1.030 | 1.030 | 1.030 | 0.573 |
| 1979 | 0.126 | 0.144 | 0.080 | 1.030 | 1.030 | 0.796 | 0.521 | 0.496 | 0.634 | 0.519 | 0.510 | 0.495 | 0.532 |
| 1980 | 0.146 | 0.154 | 0.089 | 1.030 | 0.705 | 0.304 | 0.105 | 1.030 | 0.689 | 0.527 | 0.513 | 0.489 | 0.483 |
| 1981 | 0.425 | 0.047 | 0.127 | 0.051 | 0.018 | 0.534 | 0.189 | 0.435 | 1.030 | 1.030 | 1.030 | 0.062 | 0.414 |
| 1982 | 0.312 | 0.154 | 0.017 | 0.010 | 0.018 | 0.016 | 1.030 | 1.030 | 1.030 | 1.030 | 1.030 | 0.579 | 0.518 |
| 1983 | 0.099 | 0.033 | 0.012 | 0.064 | 0.023 | 1.021 | 1.030 | 1.030 | 1.030 | 0.663 | 0.511 | 0.194 | 0.476 |
| 1984 | 0.030 | 0.020 | 0.013 | 0.005 | 0.003 | 1.030 | 1.030 | 1.030 | 1.030 | 0.854 | 0.510 | 0.493 | 0.503 |
| 1985 | 0.424 | 0.419 | 0.404 | 0.217 | 0.215 | 0.201 | 0.416 | 1.030 | 0.928 | 0.526 | 0.514 | 0.187 | 0.458 |
| 1986 | 0.044 | 0.029 | 0.055 | 0.021 | 1.030 | 0.388 | 1.030 | 1.030 | 0.934 | 0.521 | 0.503 | 0.491 | 0.505 |
| 1987 | 0.425 | 0.421 | 0.405 | 0.327 | 0.559 | 0.495 | 0.519 | 0.491 | 0.622 | 0.508 | 0.512 | 0.488 | 0.481 |
| 1988 | 0.424 | 0.421 | 0.227 | 0.234 | 0.223 | 0.202 | 0.523 | 0.175 | 1.030 | 1.030 | 0.825 | 0.478 | 0.479 |
| 1989 | 0.425 | 0.256 | 0.116 | 0.043 | 0.023 | 0.008 | 0.018 | 0.788 | 1.030 | 1.030 | 1.030 | 0.979 | 0.476 |
| 1990 | 0.086 | 0.768 | 0.380 | 0.044 | 0.876 | 0.486 | 0.520 | 0.496 | 0.635 | 0.525 | 0.511 | 0.275 | 0.465 |
| 1991 | 0.079 | 0.044 | 0.022 | 0.511 | 0.183 | 0.092 | 0.039 | 0.010 | 1.030 | 1.030 | 1.030 | 1.030 | 0.422 |
| 1992 | 0.559 | 0.031 | 0.017 | 0.008 | 0.004 | 1.030 | 0.406 | 1.030 | 1.030 | 1.030 | 0.935 | 0.492 | 0.548 |
| 1993 | 0.150 | 0.427 | 0.127 | 0.052 | 0.024 | 0.013 | 0.016 | 0.009 | 1.030 | 1.030 | 1.030 | 1.030 | 0.407 |
| 1994 | 0.734 | 0.117 | 0.050 | 0.079 | 0.048 | 0.027 | 1.030 | 1.030 | 1.030 | 1.030 | 0.891 | 0.492 | 0.544 |
| 1995 | 0.423 | 0.167 | 0.642 | 0.448 | 0.117 | 0.267 | 1.030 | 0.522 | 0.631 | 0.527 | 0.501 | 0.494 | 0.481 |
| 1996 | 0.421 | 0.420 | 0.405 | 0.252 | 0.238 | 0.212 | 0.193 | 0.126 | 1.030 | 1.030 | 0.983 | 0.494 | 0.481 |
| 1997 | 0.307 | 0.103 | 0.033 | 0.049 | 0.035 | 0.018 | 1.030 | 1.030 | 1.030 | 1.030 | 0.638 | 0.211 | 0.456 |
| 1998 | 0.691 | 0.421 | 0.022 | 0.018 | 0.038 | 1.030 | 0.418 | 1.030 | 0.821 | 0.511 | 0.498 | 0.490 | 0.501 |
| 1999 | 0.425 | 0.421 | 0.405 | 0.154 | 0.738 | 0.495 | 0.039 | 0.961 | 0.633 | 0.526 | 0.501 | 0.484 | 0.482 |
| 2000 | 0.424 | 0.077 | 0.736 | 0.449 | 0.434 | 0.494 | 0.514 | 0.496 | 0.630 | 0.523 | 0.508 | 0.492 | 0.482 |
| 2001 | 0.422 | 0.419 | 0.039 | 0.812 | 0.440 | 0.026 | 0.103 | 1.030 | 0.958 | 0.522 | 0.513 | 0.493 | 0.482 |
| 2002 | 0.141 | 0.174 | 0.151 | 0.440 | 0.201 | 0.086 | 0.219 | 0.079 | 1.030 | 1.030 | 1.030 | 1.030 | 0.464 |
| 2003 | 0.578 | 0.142 | 0.081 | 0.034 | 0.327 | 0.280 | 0.065 | 1.030 | 1.030 | 1.030 | 0.830 | 0.490 | 0.492 |
| 2004 | 0.413 | 0.420 | 0.016 | 0.007 | 0.004 | 0.002 | 0.001 | 0.001 | 1.030 | 1.030 | 1.030 | - | 0.327 |
| **Average** | **0.371** | **0.276** | **0.240** | **0.245** | **0.218** | **0.293** | **0.420** | **0.526** | **0.887** | **0.845** | **0.793** | **0.611** | **0.475** |

# APPENDIX A8– SCENARIO 2 WITH ACTUAL STORAGE CHARACTERISTICS: MONTHLY PUMPING FROM THE RIVER TO THE HAIB OFF-CHANNEL STORAGE

## A-8: Scenario 2 with actual storage characteristics: Monthly pumping from the river to the Haib off-channel storage

| Year | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0.000 | 0.593 | 0.571 | 0.629 | 0.587 | 0.603 | 0.814 | 0.678 | 0.868 | 0.721 | 0.706 | 0.123 | 0.574 |
| 1921 | 0.189 | 0.421 | 0.507 | 0.867 | 0.596 | 0.377 | 1.995 | 0.679 | 0.870 | 0.715 | 0.699 | 0.685 | 0.715 |
| 1922 | 0.586 | 0.590 | 0.271 | 0.038 | 0.017 | 0.009 | 0.187 | 0.060 | 2.000 | 2.000 | 1.557 | 0.680 | 0.659 |
| 1923 | 0.270 | 0.208 | 0.454 | 0.090 | 0.053 | 0.033 | 0.455 | 2.000 | 2.000 | 1.001 | 0.683 | 0.681 | 0.662 |
| 1924 | 0.586 | 0.594 | 0.570 | 0.416 | 0.200 | 0.100 | 0.064 | 0.046 | 1.722 | 2.000 | 1.074 | 0.684 | 0.665 |
| 1925 | 0.014 | 0.007 | 0.056 | 0.020 | 0.002 | 0.032 | 0.367 | 0.205 | 2.000 | 2.000 | 2.000 | 1.225 | 0.653 |
| 1926 | 0.012 | 0.008 | 0.005 | 0.053 | 0.017 | 0.451 | 0.235 | 0.523 | 2.000 | 2.000 | 1.932 | 0.685 | 0.655 |
| 1927 | 0.137 | 0.178 | 0.494 | 0.213 | 0.467 | 0.310 | 0.201 | 0.164 | 2.000 | 2.000 | 1.173 | 0.684 | 0.661 |
| 1928 | 0.139 | 0.169 | 0.097 | 0.716 | 1.883 | 0.682 | 0.091 | 1.015 | 1.126 | 0.718 | 0.703 | 0.068 | 0.617 |
| 1929 | 0.046 | 0.068 | 0.025 | 0.497 | 0.181 | 0.017 | 0.354 | 0.131 | 2.000 | 2.000 | 2.000 | 1.205 | 0.704 |
| 1930 | 0.052 | 0.019 | 0.013 | 0.010 | 0.006 | 0.007 | 0.388 | 0.550 | 2.000 | 2.000 | 2.000 | 0.652 | 0.635 |
| 1931 | 0.211 | 0.112 | 0.019 | 0.009 | 0.075 | 0.032 | 0.014 | 0.009 | 2.000 | 2.000 | 2.000 | 0.032 | 0.537 |
| 1932 | 0.015 | 0.058 | 0.047 | 0.022 | 0.013 | 0.006 | 2.000 | 2.000 | 2.000 | 0.715 | 0.701 | 0.681 | 0.787 |
| 1933 | 0.594 | 0.186 | 0.104 | 0.044 | 0.020 | 1.174 | 2.000 | 0.920 | 0.870 | 0.716 | 0.703 | 0.682 | 0.667 |
| 1934 | 0.591 | 0.594 | 0.112 | 0.067 | 0.044 | 0.025 | 0.361 | 0.132 | 2.000 | 2.000 | 1.397 | 0.687 | 0.660 |
| 1935 | 0.167 | 0.152 | 0.089 | 0.043 | 0.140 | 0.055 | 2.000 | 2.000 | 1.225 | 0.715 | 0.704 | 0.081 | 0.614 |
| 1936 | 0.048 | 0.038 | 0.017 | 0.007 | 0.003 | 0.005 | 0.133 | 2.000 | 2.000 | 2.000 | 1.551 | 0.686 | 0.703 |
| 1937 | 0.332 | 0.093 | 0.670 | 0.221 | 0.028 | 0.067 | 0.536 | 0.461 | 2.000 | 2.000 | 0.701 | 0.685 | 0.660 |
| 1938 | 0.138 | 0.170 | 0.439 | 1.603 | 0.610 | 0.679 | 0.371 | 1.008 | 0.866 | 0.719 | 0.696 | 0.686 | 0.667 |
| 1939 | 0.595 | 0.062 | 0.035 | 0.024 | 0.297 | 0.108 | 1.261 | 0.417 | 2.000 | 1.817 | 0.706 | 0.685 | 0.659 |
| 1940 | 0.594 | 0.379 | 0.433 | 0.379 | 0.043 | 0.022 | 0.010 | 0.008 | 2.000 | 2.000 | 1.462 | 0.685 | 0.662 |
| 1941 | 0.188 | 0.188 | 0.063 | 0.005 | 0.005 | 2.000 | 1.910 | 0.675 | 0.871 | 0.718 | 0.704 | 0.679 | 0.667 |
| 1942 | 0.592 | 0.594 | 0.571 | 0.490 | 0.219 | 1.196 | 0.705 | 0.673 | 0.868 | 0.717 | 0.696 | 0.687 | 0.668 |
| 1943 | 0.191 | 0.194 | 0.183 | 0.136 | 0.144 | 0.108 | 0.034 | 0.015 | 2.000 | 2.000 | 2.000 | 0.951 | 0.657 |
| 1944 | 0.076 | 0.047 | 0.279 | 0.055 | 0.014 | 0.121 | 0.042 | 0.005 | 2.000 | 2.000 | 2.000 | 1.280 | 0.653 |
| 1945 | 0.588 | 0.590 | 0.101 | 0.062 | 0.117 | 0.081 | 0.043 | 0.026 | 2.000 | 2.000 | 1.701 | 0.686 | 0.659 |
| 1946 | 0.199 | 0.038 | 0.009 | 0.004 | 0.011 | 0.084 | 0.031 | 1.384 | 2.000 | 2.000 | 1.476 | 0.678 | 0.655 |
| 1947 | 0.594 | 0.288 | 0.201 | 0.120 | 0.068 | 0.039 | 0.029 | 0.072 | 2.000 | 2.000 | 1.877 | 0.687 | 0.659 |
| 1948 | 0.104 | 0.019 | 0.009 | 0.030 | 0.014 | 0.004 | 0.008 | 0.028 | 2.000 | 2.000 | 2.000 | 1.673 | 0.650 |
| 1949 | 0.588 | 0.594 | 0.571 | 0.626 | 0.605 | 0.678 | 0.711 | 0.677 | 0.869 | 0.718 | 0.704 | 0.433 | 0.648 |
| 1950 | 0.080 | 0.193 | 0.061 | 0.006 | 0.004 | 0.004 | 0.015 | 0.006 | 2.000 | 2.000 | 2.000 | 0.183 | 0.540 |
| 1951 | 0.104 | 0.045 | 2.000 | 1.749 | 0.088 | 0.037 | 0.924 | 0.048 | 2.000 | 1.165 | 0.704 | 0.680 | 0.797 |
| 1952 | 0.595 | 0.026 | 0.027 | 0.040 | 0.020 | 0.009 | 1.517 | 2.000 | 1.614 | 0.720 | 0.681 | 0.683 | 0.662 |
| 1953 | 0.593 | 0.503 | 0.659 | 0.629 | 0.517 | 0.383 | 0.415 | 0.198 | 2.000 | 0.727 | 0.703 | 0.684 | 0.669 |
| 1954 | 0.593 | 0.591 | 0.304 | 0.129 | 0.047 | 0.464 | 2.000 | 0.930 | 0.868 | 0.707 | 0.691 | 0.685 | 0.665 |
| 1955 | 0.593 | 0.175 | 0.120 | 0.057 | 0.027 | 0.026 | 0.117 | 2.000 | 0.870 | 0.720 | 0.700 | 0.687 | 0.664 |
| 1956 | 0.058 | 0.801 | 0.270 | 0.093 | 1.804 | 0.682 | 0.711 | 0.673 | 0.862 | 0.720 | 0.705 | 0.683 | 0.667 |
| 1957 | 0.588 | 0.594 | 0.056 | 0.030 | 0.019 | 0.010 | 0.012 | 2.000 | 2.000 | 1.265 | 0.706 | 0.066 | 0.612 |
| 1958 | 1.187 | 0.593 | 0.033 | 0.023 | 0.015 | 0.008 | 0.033 | 0.445 | 2.000 | 2.000 | 1.569 | 0.684 | 0.711 |
| 1959 | 0.058 | 0.029 | 0.013 | 0.050 | 0.017 | 0.014 | 0.014 | 0.032 | 2.000 | 2.000 | 2.000 | 0.678 | 0.650 |
| 1960 | 0.594 | 0.590 | 0.570 | 0.629 | 0.580 | 0.417 | 0.964 | 0.726 | 0.870 | 0.719 | 0.704 | 0.160 | 0.627 |
| 1961 | 0.499 | 1.217 | 0.571 | 0.428 | 0.322 | 0.161 | 1.734 | 0.678 | 0.865 | 0.720 | 0.699 | 0.677 | 0.711 |
| 1962 | 0.592 | 0.341 | 0.268 | 0.288 | 0.261 | 0.464 | 2.000 | 0.845 | 0.871 | 0.718 | 0.703 | 0.686 | 0.668 |
| 1963 | 0.143 | 0.116 | 0.039 | 0.009 | 0.777 | 0.155 | 0.099 | 0.253 | 2.000 | 2.000 | 1.700 | 0.679 | 0.657 |
| 1964 | 0.594 | 0.122 | 0.235 | 0.104 | 0.030 | 0.020 | 0.041 | 0.024 | 2.000 | 2.000 | 0.702 | 0.047 | 0.607 |
| 1965 | 0.020 | 0.011 | 0.007 | 0.003 | 0.005 | 0.238 | 0.087 | 0.068 | 2.000 | 2.000 | 1.531 | 0.667 | 0.700 |
| 1966 | 0.591 | 0.593 | 0.571 | 0.105 | 0.060 | 0.063 | 0.566 | 0.187 | 2.000 | 1.947 | 0.695 | 0.683 | 0.664 |
| 1967 | 0.578 | 0.594 | 0.053 | 0.040 | 0.022 | 0.073 | 0.061 | 0.122 | 2.000 | 2.000 | 1.747 | 0.680 | 0.658 |
| 1968 | 0.592 | 0.180 | 0.104 | 0.051 | 0.025 | 0.063 | 0.025 | 0.013 | 2.000 | 2.000 | 2.000 | 0.118 | 0.593 |
| 1969 | 0.462 | 0.354 | 0.023 | 0.313 | 0.054 | 0.373 | 1.126 | 2.000 | 1.881 | 0.714 | 0.703 | 0.685 | 0.726 |
| 1970 | 0.125 | 0.053 | 1.556 | 0.628 | 0.036 | 0.250 | 0.084 | 0.012 | 2.000 | 1.892 | 0.694 | 0.683 | 0.664 |
| 1971 | 0.595 | 0.174 | 0.426 | 0.232 | 0.029 | 0.018 | 0.012 | 0.008 | 1.993 | 2.000 | 1.797 | 0.684 | 0.658 |
| 1972 | 0.595 | 0.246 | 0.521 | 0.138 | 0.048 | 0.730 | 0.051 | 2.000 | 1.481 | 0.699 | 0.696 | 0.673 | 0.660 |
| 1973 | 0.594 | 0.592 | 0.571 | 0.628 | 0.611 | 0.483 | 0.375 | 1.195 | 0.865 | 0.717 | 0.686 | 0.685 | 0.667 |
| 1974 | 0.592 | 0.594 | 0.533 | 0.590 | 0.504 | 0.376 | 0.528 | 1.315 | 0.858 | 0.683 | 0.688 | 0.681 | 0.663 |
| 1975 | 0.590 | 0.592 | 0.571 | 0.628 | 0.577 | 0.710 | 0.715 | 0.678 | 0.870 | 0.712 | 0.698 | 0.670 | 0.668 |
| 1976 | 0.592 | 0.556 | 0.545 | 0.650 | 0.541 | 0.391 | 1.113 | 0.678 | 0.863 | 0.718 | 0.697 | 0.684 | 0.668 |
| 1977 | 0.595 | 0.039 | 0.018 | 0.009 | 0.039 | 0.014 | 0.010 | 0.039 | 2.000 | 2.000 | 2.000 | 0.260 | 0.580 |
| 1978 | 0.237 | 0.180 | 0.479 | 1.098 | 0.338 | 0.087 | 0.323 | 0.118 | 2.000 | 2.000 | 1.342 | 0.687 | 0.735 |
| 1979 | 0.126 | 0.144 | 0.080 | 2.000 | 0.618 | 0.683 | 0.714 | 0.677 | 0.871 | 0.713 | 0.702 | 0.687 | 0.669 |
| 1980 | 0.134 | 0.161 | 0.096 | 1.968 | 0.611 | 0.305 | 0.105 | 1.635 | 0.871 | 0.720 | 0.705 | 0.682 | 0.669 |
| 1981 | 0.595 | 0.047 | 0.127 | 0.051 | 0.018 | 0.534 | 0.189 | 0.435 | 2.000 | 2.000 | 1.308 | 0.062 | 0.609 |
| 1982 | 0.298 | 0.154 | 0.017 | 0.010 | 0.018 | 0.016 | 2.000 | 2.000 | 1.919 | 0.721 | 0.702 | 0.579 | 0.703 |
| 1983 | 0.099 | 0.033 | 0.012 | 0.064 | 0.023 | 1.021 | 0.359 | 0.017 | 2.000 | 2.000 | 1.748 | 0.194 | 0.626 |
| 1984 | 0.030 | 0.020 | 0.013 | 0.005 | 0.003 | 2.000 | 2.000 | 1.394 | 0.868 | 0.719 | 0.703 | 0.685 | 0.704 |
| 1985 | 0.594 | 0.592 | 0.570 | 0.217 | 0.215 | 0.201 | 0.186 | 0.940 | 2.000 | 1.106 | 0.706 | 0.187 | 0.626 |
| 1986 | 0.044 | 0.029 | 0.055 | 0.021 | 1.444 | 0.388 | 2.000 | 1.550 | 0.879 | 0.715 | 0.696 | 0.684 | 0.705 |
| 1987 | 0.595 | 0.594 | 0.571 | 0.327 | 0.916 | 0.683 | 0.712 | 0.671 | 0.860 | 0.703 | 0.705 | 0.681 | 0.667 |
| 1988 | 0.594 | 0.594 | 0.227 | 0.234 | 0.223 | 0.202 | 0.523 | 0.175 | 2.000 | 1.906 | 0.700 | 0.672 | 0.664 |
| 1989 | 0.595 | 0.256 | 0.116 | 0.043 | 0.023 | 0.008 | 0.018 | 0.788 | 2.000 | 0.719 | 0.698 | 0.686 | 0.660 |
| 1990 | 0.086 | 1.077 | 0.380 | 0.044 | 1.442 | 0.674 | 0.713 | 0.676 | 0.871 | 0.719 | 0.703 | 0.275 | 0.635 |
| 1991 | 0.079 | 0.044 | 0.022 | 0.511 | 0.183 | 0.092 | 0.039 | 0.010 | 2.000 | 2.000 | 2.000 | 1.345 | 0.687 |
| 1992 | 0.559 | 0.031 | 0.017 | 0.008 | 0.004 | 1.064 | 0.406 | 1.851 | 1.871 | 0.713 | 0.700 | 0.685 | 0.663 |
| 1993 | 0.150 | 0.427 | 0.127 | 0.052 | 0.024 | 0.013 | 0.016 | 0.009 | 2.000 | 2.000 | 2.000 | 1.135 | 0.656 |
| 1994 | 0.273 | 0.117 | 0.050 | 0.079 | 0.048 | 0.027 | 1.452 | 2.000 | 1.787 | 0.705 | 0.706 | 0.685 | 0.661 |
| 1995 | 0.593 | 0.168 | 0.974 | 0.628 | 0.116 | 0.266 | 1.617 | 0.674 | 0.868 | 0.721 | 0.694 | 0.687 | 0.667 |
| 1996 | 0.591 | 0.593 | 0.571 | 0.252 | 0.238 | 0.212 | 0.193 | 0.126 | 2.000 | 1.903 | 0.702 | 0.686 | 0.666 |
| 1997 | 0.307 | 0.103 | 0.033 | 0.049 | 0.035 | 0.018 | 2.000 | 2.000 | 1.325 | 0.719 | 0.704 | 0.211 | 0.625 |
| 1998 | 1.048 | 0.594 | 0.022 | 0.018 | 0.038 | 1.595 | 0.418 | 1.722 | 0.864 | 0.705 | 0.692 | 0.683 | 0.703 |
| 1999 | 0.595 | 0.449 | 0.620 | 0.154 | 1.187 | 0.499 | 0.039 | 1.507 | 0.870 | 0.719 | 0.695 | 0.678 | 0.669 |
| 2000 | 0.594 | 0.077 | 1.068 | 0.629 | 0.606 | 0.682 | 0.707 | 0.676 | 0.867 | 0.717 | 0.701 | 0.685 | 0.669 |
| 2001 | 0.592 | 0.592 | 0.039 | 1.157 | 0.611 | 0.026 | 0.103 | 1.908 | 0.871 | 0.716 | 0.705 | 0.526 | 0.655 |
| 2002 | 0.141 | 0.174 | 0.151 | 0.440 | 0.201 | 0.086 | 0.219 | 0.079 | 2.000 | 2.000 | 1.943 | 0.684 | 0.671 |
| 2003 | 0.595 | 0.142 | 0.081 | 0.034 | 0.327 | 0.280 | 0.065 | 2.000 | 2.000 | 1.030 | 0.701 | 0.683 | 0.663 |
| 2004 | 0.584 | 0.592 | 0.016 | 0.007 | 0.004 | 0.002 | 0.001 | 0.001 | 1.516 | 2.000 | 2.000 | 0.000 | 0.554 |
| | | | | | | | | | | | | | |
| **Average** | **0.383** | **0.303** | **0.286** | **0.304** | **0.271** | **0.322** | **0.586** | **0.746** | **1.574** | **1.337** | **1.109** | **0.620** | **0.660** |

# APPENDIX A9– SCENARIO 3 WITH ACTUAL STORAGE CHARACTERISTICS: MONTHLY PUMPING FROM THE RIVER TO THE HAIB

## A-9: Scenario 3 with actual storage characteristics: Monthly pumping from the river to the Haib off-channel storage

| Year | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0 | 0.593 | 0.571 | 0.629 | 0.587 | 0.603 | 0.817 | 0.679 | 0.869 | 0.722 | 0.707 | 0.123 | 0.575 |
| 1921 | 0.189 | 0.421 | 0.507 | 0.867 | 0.596 | 0.377 | 2 | 0.681 | 0.872 | 0.716 | 0.7 | 0.686 | 0.716 |
| 1922 | 0.586 | 0.59 | 0.271 | 0.038 | 0.017 | 0.009 | 0.187 | 0.06 | 0.957 | 2 | 2 | 1.294 | 0.659 |
| 1923 | 0.27 | 0.208 | 0.454 | 0.09 | 0.053 | 0.033 | 0.455 | 2 | 2 | 1.015 | 0.684 | 0.682 | 0.663 |
| 1924 | 0.586 | 0.594 | 0.57 | 0.416 | 0.2 | 0.1 | 0.064 | 0.046 | 0.399 | 2 | 2 | 1.082 | 0.664 |
| 1925 | 0.014 | 0.007 | 0.056 | 0.02 | 0.002 | 0.032 | 0.367 | 0.205 | 1.586 | 2 | 2 | 1.66 | 0.654 |
| 1926 | 0.012 | 0.008 | 0.005 | 0.053 | 0.017 | 0.451 | 0.235 | 0.523 | 2 | 2 | 1.948 | 0.686 | 0.656 |
| 1927 | 0.137 | 0.178 | 0.494 | 0.213 | 0.467 | 0.31 | 0.201 | 0.164 | 2 | 2 | 1.187 | 0.685 | 0.663 |
| 1928 | 0.139 | 0.169 | 0.097 | 0.716 | 1.885 | 0.683 | 0.716 | 0.676 | 0.871 | 0.719 | 0.704 | 0.64 | 0.665 |
| 1929 | 0.046 | 0.068 | 0.025 | 0.497 | 0.181 | 0.017 | 0.354 | 0.131 | 2 | 2 | 2 | 0.698 | 0.662 |
| 1930 | 0.052 | 0.019 | 0.013 | 0.01 | 0.006 | 0.007 | 0.388 | 0.42 | 2 | 2 | 2 | 0.685 | 0.627 |
| 1931 | 0.211 | 0.112 | 0.019 | 0.009 | 0.075 | 0.032 | 0.014 | 0.009 | 2 | 2 | 2 | 0.032 | 0.537 |
| 1932 | 0.015 | 0.058 | 0.047 | 0.022 | 0.013 | 1.576 | 2 | 2 | 1.783 | 0.716 | 0.702 | 0.682 | 0.803 |
| 1933 | 0.594 | 0.186 | 0.104 | 0.044 | 0.02 | 1.174 | 2 | 0.927 | 0.872 | 0.717 | 0.704 | 0.683 | 0.668 |
| 1934 | 0.591 | 0.594 | 0.112 | 0.067 | 0.044 | 0.025 | 0.361 | 0.132 | 1.136 | 2 | 2 | 0.957 | 0.66 |
| 1935 | 0.594 | 0.152 | 0.089 | 0.043 | 0.14 | 0.055 | 2 | 1.964 | 0.865 | 0.716 | 0.706 | 0.081 | 0.617 |
| 1936 | 0.048 | 0.038 | 0.017 | 0.007 | 0.003 | 0.005 | 0.133 | 2 | 2 | 2 | 1.567 | 0.687 | 0.704 |
| 1937 | 0.332 | 0.093 | 0.67 | 0.221 | 0.028 | 0.067 | 0.536 | 0.461 | 2 | 2 | 0.92 | 0.686 | 0.661 |
| 1938 | 0.138 | 0.17 | 0.439 | 1.604 | 0.611 | 0.68 | 0.371 | 1.011 | 0.868 | 0.72 | 0.696 | 0.687 | 0.668 |
| 1939 | 0.1 | 0.062 | 0.035 | 0.024 | 0.297 | 0.108 | 1.261 | 2 | 1.928 | 0.702 | 0.707 | 0.685 | 0.66 |
| 1940 | 0.594 | 0.379 | 0.433 | 0.379 | 0.043 | 0.022 | 0.01 | 0.008 | 0.402 | 2 | 2 | 1.761 | 0.661 |
| 1941 | 0.188 | 0.188 | 0.063 | 0.005 | 0.005 | 2 | 1.916 | 0.677 | 0.873 | 0.719 | 0.705 | 0.679 | 0.668 |
| 1942 | 0.593 | 0.594 | 0.571 | 0.627 | 0.219 | 1.062 | 0.706 | 0.675 | 0.869 | 0.719 | 0.697 | 0.688 | 0.669 |
| 1943 | 0.191 | 0.194 | 0.183 | 0.136 | 0.144 | 0.108 | 0.034 | 0.015 | 1.839 | 2 | 2 | 1.131 | 0.658 |
| 1944 | 0.076 | 0.047 | 0.279 | 0.055 | 0.014 | 0.121 | 0.042 | 0.005 | 2 | 2 | 2 | 1.297 | 0.655 |
| 1945 | 0.588 | 0.59 | 0.101 | 0.062 | 0.117 | 0.081 | 0.043 | 0.026 | 2 | 2 | 1.715 | 0.687 | 0.661 |
| 1946 | 0.199 | 0.038 | 0.009 | 0.004 | 0.011 | 0.084 | 0.031 | 2 | 2 | 2 | 0.891 | 0.678 | 0.657 |
| 1947 | 0.595 | 0.288 | 0.201 | 0.12 | 0.068 | 0.039 | 0.029 | 0.072 | 0.895 | 2 | 2 | 1.496 | 0.642 |
| 1948 | 0.104 | 0.019 | 0.009 | 0.03 | 0.014 | 0.004 | 0.008 | 0.028 | 2 | 2 | 2 | 1.87 | 0.666 |
| 1949 | 0.588 | 0.594 | 0.571 | 0.626 | 0.606 | 0.679 | 0.712 | 0.679 | 0.871 | 0.72 | 0.705 | 0.145 | 0.625 |
| 1950 | 0.08 | 0.193 | 0.061 | 0.006 | 0.004 | 0.004 | 0.015 | 0.006 | 0.522 | 2 | 2 | 0.183 | 0.415 |
| 1951 | 0.104 | 0.045 | 2 | 2 | 0.088 | 0.037 | 0.924 | 0.048 | 1.442 | 2 | 1.875 | 0.681 | 0.935 |
| 1952 | 0.595 | 0.026 | 0.027 | 0.04 | 0.02 | 0.009 | 1.517 | 2 | 1.624 | 0.721 | 0.682 | 0.684 | 0.663 |
| 1953 | 0.594 | 0.503 | 0.66 | 0.629 | 0.517 | 0.383 | 0.415 | 0.198 | 2 | 0.735 | 0.704 | 0.685 | 0.67 |
| 1954 | 0.593 | 0.591 | 0.304 | 0.129 | 0.047 | 0.464 | 2 | 0.935 | 0.869 | 0.708 | 0.692 | 0.686 | 0.666 |
| 1955 | 0.594 | 0.175 | 0.12 | 0.057 | 0.027 | 0.026 | 0.117 | 2 | 2 | 1.477 | 0.701 | 0.688 | 0.663 |
| 1956 | 0.058 | 0.801 | 0.27 | 0.093 | 1.807 | 0.683 | 0.713 | 0.674 | 0.863 | 0.721 | 0.706 | 0.683 | 0.669 |
| 1957 | 0.588 | 0.594 | 0.056 | 0.03 | 0.019 | 0.01 | 0.012 | 2 | 2 | 1.278 | 0.707 | 0.066 | 0.613 |
| 1958 | 1.188 | 0.593 | 0.033 | 0.023 | 0.015 | 0.008 | 0.033 | 0.445 | 2 | 2 | 1.584 | 0.685 | 0.712 |
| 1959 | 0.058 | 0.029 | 0.013 | 0.05 | 0.017 | 0.014 | 0.014 | 0.032 | 2 | 2 | 2 | 1.69 | 0.652 |
| 1960 | 0.594 | 0.591 | 0.57 | 0.629 | 0.58 | 0.417 | 0.964 | 0.731 | 0.872 | 0.72 | 0.705 | 0.16 | 0.628 |
| 1961 | 0.131 | 1.598 | 0.571 | 0.428 | 0.322 | 0.161 | 1.738 | 0.68 | 0.866 | 0.721 | 0.7 | 0.678 | 0.712 |
| 1962 | 0.593 | 0.341 | 0.268 | 0.288 | 0.261 | 0.464 | 2 | 0.851 | 0.873 | 0.72 | 0.704 | 0.687 | 0.669 |
| 1963 | 0.143 | 0.116 | 0.039 | 0.009 | 0.777 | 0.155 | 0.099 | 2 | 2 | 1.252 | 0.692 | 0.68 | 0.662 |
| 1964 | 0.595 | 0.122 | 0.235 | 0.104 | 0.03 | 0.02 | 0.041 | 0.024 | 2 | 2 | 2 | 0.047 | 0.597 |
| 1965 | 0.02 | 0.011 | 0.007 | 0.003 | 0.005 | 0.238 | 0.087 | 0.068 | 2 | 2 | 2 | 2 | 0.695 |
| 1966 | 0.763 | 0.593 | 0.571 | 0.105 | 0.06 | 0.063 | 0.566 | 0.187 | 1.221 | 2 | 1.427 | 0.683 | 0.679 |
| 1967 | 0.578 | 0.594 | 0.053 | 0.04 | 0.022 | 0.073 | 0.061 | 0.122 | 1.986 | 2 | 1.775 | 0.681 | 0.659 |
| 1968 | 0.592 | 0.18 | 0.104 | 0.051 | 0.025 | 0.063 | 0.025 | 0.013 | 2 | 2 | 2 | 0.118 | 0.593 |
| 1969 | 0.462 | 0.354 | 0.023 | 0.313 | 0.054 | 1.509 | 2 | 1.094 | 0.869 | 0.716 | 0.704 | 0.686 | 0.732 |
| 1970 | 0.42 | 0.053 | 1.263 | 0.629 | 0.036 | 0.25 | 0.591 | 1.769 | 0.849 | 0.722 | 0.695 | 0.684 | 0.667 |
| 1971 | 0.308 | 0.174 | 0.426 | 0.232 | 0.029 | 0.018 | 0.012 | 0.008 | 0.603 | 2 | 2 | 2 | 0.642 |
| 1972 | 0.764 | 0.246 | 0.521 | 0.138 | 0.048 | 0.73 | 0.051 | 2 | 1.488 | 0.7 | 0.697 | 0.674 | 0.676 |
| 1973 | 0.594 | 0.593 | 0.571 | 0.629 | 0.612 | 0.483 | 0.375 | 1.198 | 0.866 | 0.719 | 0.687 | 0.686 | 0.669 |
| 1974 | 0.593 | 0.594 | 0.533 | 0.59 | 0.504 | 0.376 | 0.528 | 1.32 | 0.859 | 0.683 | 0.689 | 0.681 | 0.663 |
| 1975 | 0.59 | 0.592 | 0.571 | 0.629 | 0.577 | 0.712 | 0.716 | 0.679 | 0.871 | 0.713 | 0.699 | 0.67 | 0.668 |
| 1976 | 0.593 | 0.556 | 0.545 | 0.65 | 0.541 | 0.391 | 1.117 | 0.679 | 0.864 | 0.719 | 0.698 | 0.685 | 0.669 |
| 1977 | 0.595 | 0.039 | 0.018 | 0.009 | 0.039 | 0.014 | 0.01 | 0.039 | 1.576 | 2 | 2 | 0.26 | 0.544 |
| 1978 | 0.237 | 0.18 | 0.479 | 1.098 | 0.338 | 0.087 | 0.323 | 0.118 | 1.019 | 2 | 2 | 1.427 | 0.768 |
| 1979 | 0.126 | 0.144 | 0.08 | 2 | 0.62 | 0.684 | 0.715 | 0.678 | 0.873 | 0.714 | 0.703 | 0.688 | 0.67 |
| 1980 | 0.146 | 0.154 | 0.089 | 1.97 | 0.612 | 0.304 | 0.105 | 1.64 | 0.873 | 0.722 | 0.706 | 0.682 | 0.67 |
| 1981 | 0.595 | 0.047 | 0.127 | 0.051 | 0.018 | 0.534 | 0.189 | 0.435 | 1.673 | 2 | 1.644 | 0.062 | 0.61 |
| 1982 | 0.298 | 0.154 | 0.017 | 0.01 | 0.018 | 0.016 | 2 | 2 | 1.931 | 0.722 | 0.703 | 0.579 | 0.704 |
| 1983 | 0.099 | 0.033 | 0.012 | 0.064 | 0.023 | 1.021 | 1.423 | 1.654 | 1.628 | 0.717 | 0.705 | 0.194 | 0.633 |
| 1984 | 0.03 | 0.02 | 0.013 | 0.005 | 0.003 | 2 | 2 | 1.404 | 0.87 | 0.721 | 0.704 | 0.686 | 0.705 |
| 1985 | 0.595 | 0.592 | 0.57 | 0.217 | 0.215 | 0.201 | 0.385 | 1.579 | 1.54 | 0.721 | 0.707 | 0.187 | 0.628 |
| 1986 | 0.044 | 0.029 | 0.055 | 0.021 | 1.444 | 0.388 | 2 | 1.569 | 0.872 | 0.716 | 0.697 | 0.684 | 0.706 |
| 1987 | 0.595 | 0.594 | 0.571 | 0.327 | 0.917 | 0.684 | 0.713 | 0.673 | 0.861 | 0.704 | 0.706 | 0.682 | 0.668 |
| 1988 | 0.595 | 0.594 | 0.227 | 0.234 | 0.223 | 0.202 | 0.523 | 0.175 | 1.094 | 2 | 1.521 | 0.673 | 0.664 |
| 1989 | 0.595 | 0.256 | 0.116 | 0.043 | 0.023 | 0.008 | 0.018 | 0.788 | 2 | 2 | 1.45 | 0.687 | 0.66 |
| 1990 | 0.086 | 1.077 | 0.38 | 0.044 | 1.444 | 0.675 | 0.714 | 0.678 | 0.873 | 0.72 | 0.704 | 0.275 | 0.636 |
| 1991 | 0.079 | 0.044 | 0.022 | 0.511 | 0.183 | 0.092 | 0.039 | 0.01 | 1.227 | 2 | 2 | 1.719 | 0.652 |
| 1992 | 0.559 | 0.031 | 0.017 | 0.008 | 0.004 | 1.064 | 0.406 | 2 | 2 | 0.85 | 0.701 | 0.686 | 0.697 |
| 1993 | 0.15 | 0.427 | 0.127 | 0.052 | 0.024 | 0.013 | 0.016 | 0.009 | 1.554 | 2 | 2 | 1.602 | 0.656 |
| 1994 | 0.594 | 0.117 | 0.05 | 0.079 | 0.048 | 0.027 | 1.452 | 2 | 1.492 | 0.706 | 0.707 | 0.686 | 0.664 |
| 1995 | 0.594 | 0.167 | 0.975 | 0.629 | 0.117 | 0.267 | 1.619 | 0.676 | 0.869 | 0.722 | 0.695 | 0.688 | 0.668 |
| 1996 | 0.591 | 0.593 | 0.571 | 0.252 | 0.238 | 0.212 | 0.193 | 0.126 | 2 | 1.914 | 0.703 | 0.687 | 0.667 |
| 1997 | 0.307 | 0.103 | 0.033 | 0.049 | 0.035 | 0.018 | 2 | 2 | 1.336 | 0.721 | 0.705 | 0.211 | 0.626 |
| 1998 | 1.049 | 0.594 | 0.022 | 0.018 | 0.038 | 1.595 | 0.418 | 1.728 | 0.865 | 0.706 | 0.693 | 0.683 | 0.704 |
| 1999 | 0.595 | 0.449 | 0.62 | 0.154 | 1.189 | 0.499 | 0.039 | 1.511 | 0.871 | 0.721 | 0.696 | 0.679 | 0.669 |
| 2000 | 0.595 | 0.077 | 1.069 | 0.629 | 0.606 | 0.683 | 0.708 | 0.678 | 0.869 | 0.718 | 0.702 | 0.685 | 0.669 |
| 2001 | 0.592 | 0.592 | 0.039 | 1.158 | 0.612 | 0.026 | 0.103 | 1.912 | 0.873 | 0.717 | 0.706 | 0.526 | 0.656 |
| 2002 | 0.141 | 0.174 | 0.151 | 0.44 | 0.201 | 0.086 | 0.219 | 0.079 | 2 | 2 | 1.959 | 0.685 | 0.672 |
| 2003 | 0.595 | 0.142 | 0.081 | 0.034 | 0.327 | 0.28 | 0.065 | 2 | 2 | 1.043 | 0.702 | 0.684 | 0.664 |
| 2004 | 0.584 | 0.593 | 0.016 | 0.007 | 0.004 | 0.002 | 0.001 | 0.001 | 1.051 | 2 | 2 | 0 | 0.515 |
| | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | |
| **Average** | **0.386** | **0.307** | **0.282** | **0.309** | **0.272** | **0.353** | **0.625** | **0.826** | **1.363** | **1.32** | **1.189** | **0.726** | **0.66** |

# APPENDIX A10– SCENARIO 3G2 WITH ACTUAL STORAGE CHARACTERISTICS: MONTHLY PUMPING FROM THE RIVER TO THE HAIB OFF-CHANNEL STORAGE

## A-10: Scenario 3g2 with actual storage characteristics: Monthly pumping from the river to the Haib off-channel storage

| Year | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0.000 | 0.197 | 0.197 | 0.199 | 0.204 | 0.207 | 0.211 | 0.215 | 0.215 | 0.215 | 0.211 | 0.123 | 0.182 |
| 1921 | 0.189 | 0.289 | 0.197 | 0.199 | 0.204 | 0.208 | 0.212 | 0.215 | 0.216 | 0.212 | 0.208 | 0.204 | 0.213 |
| 1922 | 0.196 | 0.196 | 0.196 | 0.038 | 0.017 | 0.009 | 0.187 | 0.060 | 0.903 | 0.214 | 0.208 | 0.202 | 0.203 |
| 1923 | 0.199 | 0.197 | 0.197 | 0.090 | 0.053 | 0.033 | 0.455 | 0.397 | 0.216 | 0.214 | 0.201 | 0.203 | 0.204 |
| 1924 | 0.196 | 0.197 | 0.196 | 0.199 | 0.200 | 0.100 | 0.064 | 0.046 | 0.399 | 0.463 | 0.209 | 0.204 | 0.205 |
| 1925 | 0.014 | 0.007 | 0.056 | 0.020 | 0.002 | 0.032 | 0.367 | 0.205 | 1.000 | 0.290 | 0.209 | 0.205 | 0.200 |
| 1926 | 0.012 | 0.008 | 0.005 | 0.053 | 0.017 | 0.451 | 0.235 | 0.523 | 0.485 | 0.214 | 0.204 | 0.204 | 0.202 |
| 1927 | 0.137 | 0.178 | 0.277 | 0.199 | 0.203 | 0.208 | 0.201 | 0.164 | 0.276 | 0.215 | 0.206 | 0.204 | 0.206 |
| 1928 | 0.139 | 0.169 | 0.097 | 0.383 | 0.201 | 0.208 | 0.212 | 0.213 | 0.215 | 0.213 | 0.209 | 0.205 | 0.205 |
| 1929 | 0.046 | 0.068 | 0.025 | 0.497 | 0.181 | 0.017 | 0.354 | 0.131 | 0.506 | 0.213 | 0.209 | 0.203 | 0.204 |
| 1930 | 0.052 | 0.019 | 0.013 | 0.010 | 0.006 | 0.007 | 0.388 | 0.420 | 0.863 | 0.213 | 0.211 | 0.204 | 0.201 |
| 1931 | 0.199 | 0.112 | 0.019 | 0.009 | 0.075 | 0.032 | 0.014 | 0.009 | 1.000 | 0.549 | 0.211 | 0.032 | 0.187 |
| 1932 | 0.015 | 0.058 | 0.047 | 0.022 | 0.013 | 1.000 | 0.395 | 0.214 | 0.214 | 0.212 | 0.208 | 0.203 | 0.217 |
| 1933 | 0.199 | 0.186 | 0.104 | 0.044 | 0.020 | 0.638 | 0.209 | 0.214 | 0.216 | 0.213 | 0.209 | 0.203 | 0.205 |
| 1934 | 0.198 | 0.197 | 0.112 | 0.067 | 0.044 | 0.025 | 0.361 | 0.132 | 0.681 | 0.214 | 0.204 | 0.205 | 0.203 |
| 1935 | 0.199 | 0.152 | 0.089 | 0.043 | 0.140 | 0.055 | 0.738 | 0.214 | 0.213 | 0.212 | 0.210 | 0.081 | 0.194 |
| 1936 | 0.048 | 0.038 | 0.017 | 0.007 | 0.003 | 0.005 | 0.133 | 1.000 | 0.630 | 0.211 | 0.210 | 0.204 | 0.210 |
| 1937 | 0.199 | 0.093 | 0.292 | 0.199 | 0.028 | 0.067 | 0.525 | 0.214 | 0.214 | 0.210 | 0.208 | 0.204 | 0.204 |
| 1938 | 0.138 | 0.170 | 0.279 | 0.195 | 0.204 | 0.207 | 0.212 | 0.215 | 0.214 | 0.214 | 0.206 | 0.204 | 0.205 |
| 1939 | 0.100 | 0.062 | 0.035 | 0.024 | 0.297 | 0.108 | 0.783 | 0.214 | 0.202 | 0.207 | 0.211 | 0.204 | 0.203 |
| 1940 | 0.199 | 0.197 | 0.197 | 0.199 | 0.043 | 0.022 | 0.010 | 0.008 | 0.402 | 0.791 | 0.209 | 0.204 | 0.203 |
| 1941 | 0.188 | 0.188 | 0.063 | 0.005 | 0.005 | 0.737 | 0.212 | 0.214 | 0.216 | 0.213 | 0.210 | 0.201 | 0.205 |
| 1942 | 0.198 | 0.197 | 0.197 | 0.199 | 0.204 | 0.208 | 0.209 | 0.213 | 0.215 | 0.213 | 0.207 | 0.205 | 0.205 |
| 1943 | 0.191 | 0.194 | 0.183 | 0.136 | 0.144 | 0.108 | 0.034 | 0.015 | 0.812 | 0.212 | 0.209 | 0.205 | 0.204 |
| 1944 | 0.076 | 0.047 | 0.279 | 0.055 | 0.014 | 0.121 | 0.042 | 0.005 | 1.000 | 0.371 | 0.210 | 0.197 | 0.201 |
| 1945 | 0.197 | 0.195 | 0.101 | 0.062 | 0.117 | 0.081 | 0.043 | 0.026 | 0.978 | 0.214 | 0.208 | 0.204 | 0.203 |
| 1946 | 0.198 | 0.038 | 0.009 | 0.004 | 0.011 | 0.084 | 0.031 | 1.000 | 0.406 | 0.212 | 0.203 | 0.201 | 0.201 |
| 1947 | 0.199 | 0.197 | 0.196 | 0.120 | 0.068 | 0.039 | 0.029 | 0.072 | 0.887 | 0.213 | 0.207 | 0.205 | 0.204 |
| 1948 | 0.104 | 0.019 | 0.009 | 0.030 | 0.014 | 0.004 | 0.008 | 0.028 | 1.000 | 0.790 | 0.205 | 0.197 | 0.198 |
| 1949 | 0.197 | 0.197 | 0.197 | 0.198 | 0.202 | 0.206 | 0.211 | 0.214 | 0.215 | 0.214 | 0.210 | 0.145 | 0.200 |
| 1950 | 0.080 | 0.193 | 0.061 | 0.006 | 0.004 | 0.004 | 0.015 | 0.006 | 0.461 | 1.000 | 0.466 | 0.183 | 0.202 |
| 1951 | 0.104 | 0.045 | 0.456 | 0.199 | 0.088 | 0.037 | 0.500 | 0.048 | 0.380 | 0.210 | 0.210 | 0.202 | 0.207 |
| 1952 | 0.199 | 0.026 | 0.027 | 0.040 | 0.020 | 0.009 | 1.000 | 0.293 | 0.216 | 0.214 | 0.201 | 0.203 | 0.203 |
| 1953 | 0.199 | 0.197 | 0.197 | 0.199 | 0.204 | 0.208 | 0.211 | 0.198 | 0.231 | 0.213 | 0.209 | 0.204 | 0.206 |
| 1954 | 0.199 | 0.196 | 0.196 | 0.129 | 0.047 | 0.427 | 0.210 | 0.212 | 0.215 | 0.209 | 0.205 | 0.204 | 0.204 |
| 1955 | 0.199 | 0.175 | 0.120 | 0.057 | 0.027 | 0.026 | 0.117 | 0.875 | 0.215 | 0.214 | 0.208 | 0.205 | 0.204 |
| 1956 | 0.058 | 0.339 | 0.197 | 0.093 | 0.312 | 0.208 | 0.211 | 0.212 | 0.212 | 0.214 | 0.210 | 0.203 | 0.205 |
| 1957 | 0.197 | 0.197 | 0.056 | 0.030 | 0.019 | 0.010 | 0.012 | 1.000 | 0.278 | 0.212 | 0.210 | 0.066 | 0.192 |
| 1958 | 0.330 | 0.197 | 0.033 | 0.023 | 0.015 | 0.008 | 0.033 | 0.445 | 0.838 | 0.214 | 0.209 | 0.204 | 0.213 |
| 1959 | 0.058 | 0.029 | 0.013 | 0.050 | 0.017 | 0.014 | 0.014 | 0.032 | 1.000 | 0.781 | 0.205 | 0.201 | 0.198 |
| 1960 | 0.199 | 0.196 | 0.196 | 0.199 | 0.204 | 0.208 | 0.211 | 0.215 | 0.216 | 0.214 | 0.210 | 0.160 | 0.202 |
| 1961 | 0.131 | 0.312 | 0.197 | 0.198 | 0.203 | 0.161 | 0.259 | 0.215 | 0.213 | 0.214 | 0.208 | 0.201 | 0.209 |
| 1962 | 0.198 | 0.197 | 0.196 | 0.199 | 0.204 | 0.205 | 0.211 | 0.214 | 0.216 | 0.214 | 0.209 | 0.204 | 0.206 |
| 1963 | 0.143 | 0.116 | 0.039 | 0.009 | 0.695 | 0.155 | 0.099 | 0.370 | 0.216 | 0.215 | 0.205 | 0.202 | 0.204 |
| 1964 | 0.199 | 0.122 | 0.235 | 0.104 | 0.030 | 0.020 | 0.041 | 0.024 | 1.000 | 0.237 | 0.209 | 0.047 | 0.190 |
| 1965 | 0.020 | 0.011 | 0.007 | 0.003 | 0.005 | 0.238 | 0.087 | 0.068 | 1.000 | 0.710 | 0.209 | 0.197 | 0.211 |
| 1966 | 0.198 | 0.197 | 0.197 | 0.105 | 0.060 | 0.063 | 0.566 | 0.187 | 0.272 | 0.215 | 0.206 | 0.203 | 0.205 |
| 1967 | 0.192 | 0.197 | 0.053 | 0.040 | 0.022 | 0.073 | 0.061 | 0.122 | 1.000 | 0.238 | 0.209 | 0.202 | 0.201 |
| 1968 | 0.198 | 0.180 | 0.104 | 0.051 | 0.025 | 0.063 | 0.025 | 0.013 | 1.000 | 0.356 | 0.211 | 0.118 | 0.195 |
| 1969 | 0.280 | 0.195 | 0.023 | 0.313 | 0.054 | 0.410 | 0.211 | 0.213 | 0.214 | 0.212 | 0.209 | 0.204 | 0.212 |
| 1970 | 0.198 | 0.053 | 0.334 | 0.199 | 0.036 | 0.250 | 0.333 | 0.214 | 0.207 | 0.215 | 0.206 | 0.203 | 0.204 |
| 1971 | 0.199 | 0.174 | 0.218 | 0.199 | 0.029 | 0.018 | 0.012 | 0.008 | 0.603 | 0.583 | 0.206 | 0.204 | 0.203 |
| 1972 | 0.199 | 0.197 | 0.195 | 0.138 | 0.048 | 0.417 | 0.051 | 0.366 | 0.203 | 0.206 | 0.207 | 0.199 | 0.203 |
| 1973 | 0.199 | 0.196 | 0.197 | 0.199 | 0.204 | 0.208 | 0.211 | 0.214 | 0.213 | 0.213 | 0.202 | 0.204 | 0.205 |
| 1974 | 0.198 | 0.197 | 0.196 | 0.199 | 0.204 | 0.208 | 0.211 | 0.208 | 0.211 | 0.199 | 0.203 | 0.202 | 0.203 |
| 1975 | 0.197 | 0.196 | 0.197 | 0.199 | 0.204 | 0.206 | 0.212 | 0.215 | 0.215 | 0.211 | 0.207 | 0.198 | 0.205 |
| 1976 | 0.198 | 0.197 | 0.197 | 0.199 | 0.203 | 0.208 | 0.209 | 0.215 | 0.213 | 0.213 | 0.207 | 0.204 | 0.205 |
| 1977 | 0.199 | 0.039 | 0.018 | 0.009 | 0.039 | 0.014 | 0.010 | 0.039 | 1.000 | 0.642 | 0.211 | 0.204 | 0.200 |
| 1978 | 0.199 | 0.180 | 0.212 | 0.199 | 0.204 | 0.087 | 0.323 | 0.118 | 0.323 | 0.213 | 0.206 | 0.205 | 0.205 |
| 1979 | 0.126 | 0.144 | 0.080 | 0.438 | 0.201 | 0.208 | 0.212 | 0.214 | 0.216 | 0.211 | 0.209 | 0.205 | 0.205 |
| 1980 | 0.146 | 0.154 | 0.089 | 0.396 | 0.204 | 0.207 | 0.105 | 0.318 | 0.216 | 0.214 | 0.210 | 0.203 | 0.206 |
| 1981 | 0.199 | 0.047 | 0.127 | 0.051 | 0.018 | 0.534 | 0.189 | 0.435 | 0.216 | 0.215 | 0.210 | 0.062 | 0.193 |
| 1982 | 0.312 | 0.154 | 0.017 | 0.010 | 0.018 | 0.016 | 1.000 | 0.229 | 0.216 | 0.215 | 0.209 | 0.204 | 0.215 |
| 1983 | 0.099 | 0.033 | 0.012 | 0.064 | 0.023 | 0.944 | 0.212 | 0.215 | 0.215 | 0.213 | 0.210 | 0.194 | 0.204 |
| 1984 | 0.030 | 0.020 | 0.013 | 0.005 | 0.003 | 1.000 | 0.320 | 0.212 | 0.215 | 0.214 | 0.209 | 0.204 | 0.204 |
| 1985 | 0.199 | 0.196 | 0.196 | 0.199 | 0.204 | 0.201 | 0.218 | 0.215 | 0.216 | 0.214 | 0.211 | 0.187 | 0.205 |
| 1986 | 0.044 | 0.029 | 0.055 | 0.021 | 0.870 | 0.208 | 0.211 | 0.215 | 0.216 | 0.212 | 0.206 | 0.203 | 0.206 |
| 1987 | 0.199 | 0.197 | 0.197 | 0.199 | 0.203 | 0.208 | 0.211 | 0.212 | 0.212 | 0.207 | 0.210 | 0.203 | 0.205 |
| 1988 | 0.199 | 0.197 | 0.196 | 0.199 | 0.204 | 0.202 | 0.216 | 0.175 | 0.255 | 0.212 | 0.208 | 0.199 | 0.205 |
| 1989 | 0.199 | 0.195 | 0.116 | 0.043 | 0.023 | 0.008 | 0.018 | 0.788 | 0.408 | 0.214 | 0.207 | 0.205 | 0.203 |
| 1990 | 0.086 | 0.313 | 0.197 | 0.044 | 0.361 | 0.205 | 0.212 | 0.214 | 0.216 | 0.214 | 0.209 | 0.205 | 0.205 |
| 1991 | 0.079 | 0.044 | 0.022 | 0.511 | 0.183 | 0.092 | 0.039 | 0.010 | 0.829 | 0.212 | 0.209 | 0.204 | 0.204 |
| 1992 | 0.199 | 0.031 | 0.017 | 0.008 | 0.004 | 0.917 | 0.211 | 0.215 | 0.212 | 0.211 | 0.208 | 0.204 | 0.204 |
| 1993 | 0.150 | 0.247 | 0.127 | 0.052 | 0.024 | 0.013 | 0.016 | 0.009 | 1.000 | 0.381 | 0.208 | 0.205 | 0.202 |
| 1994 | 0.199 | 0.117 | 0.050 | 0.079 | 0.048 | 0.027 | 0.890 | 0.210 | 0.214 | 0.208 | 0.210 | 0.204 | 0.204 |
| 1995 | 0.199 | 0.167 | 0.222 | 0.199 | 0.117 | 0.267 | 0.232 | 0.213 | 0.215 | 0.214 | 0.206 | 0.205 | 0.205 |
| 1996 | 0.198 | 0.197 | 0.197 | 0.199 | 0.204 | 0.208 | 0.193 | 0.126 | 0.321 | 0.213 | 0.209 | 0.205 | 0.206 |
| 1997 | 0.199 | 0.103 | 0.033 | 0.049 | 0.035 | 0.018 | 0.974 | 0.214 | 0.215 | 0.214 | 0.210 | 0.205 | 0.204 |
| 1998 | 0.197 | 0.197 | 0.022 | 0.018 | 0.038 | 0.714 | 0.211 | 0.210 | 0.213 | 0.208 | 0.205 | 0.203 | 0.203 |
| 1999 | 0.199 | 0.197 | 0.197 | 0.154 | 0.249 | 0.208 | 0.039 | 0.380 | 0.215 | 0.214 | 0.206 | 0.201 | 0.205 |
| 2000 | 0.199 | 0.077 | 0.312 | 0.199 | 0.202 | 0.208 | 0.210 | 0.214 | 0.214 | 0.213 | 0.208 | 0.204 | 0.205 |
| 2001 | 0.198 | 0.196 | 0.039 | 0.356 | 0.204 | 0.026 | 0.103 | 0.495 | 0.216 | 0.212 | 0.210 | 0.204 | 0.205 |
| 2002 | 0.141 | 0.174 | 0.151 | 0.324 | 0.201 | 0.086 | 0.219 | 0.079 | 0.460 | 0.211 | 0.209 | 0.204 | 0.205 |
| 2003 | 0.199 | 0.142 | 0.081 | 0.034 | 0.327 | 0.280 | 0.065 | 0.490 | 0.214 | 0.210 | 0.209 | 0.203 | 0.205 |
| 2004 | 0.195 | 0.197 | 0.016 | 0.007 | 0.004 | 0.002 | 0.001 | 0.001 | 1.000 | 0.594 | 0.211 | 0.000 | 0.184 |
| | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | |
| **Average** | **0.162** | **0.148** | **0.130** | **0.129** | **0.124** | **0.193** | **0.227** | **0.231** | **0.423** | **0.276** | **0.211** | **0.189** | **0.203** |