


The 2020-2021 hydrological season synoptic report on Surface Water Hydrology in the Orange-Senqu Basin

From the Surface Water Hydrological Committee of ORASECOM

March 2022

Report nr: 001/2022

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Prepared by

AquaLinks Research and Implementation (Pty) Ltd

ORASECOM SECRETARIAT

The 2020-2021 hydrological season synoptic report on Surface Water Hydrology in the Orange-Senqu Basin

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CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data from the Climate Hazards Center from the University of California, Santa Barbara.
EFR	Environmental Flow Requirement
FAO	Food and Agricultural Organisation
GEF	Global Environmental Facility
GPCC	Global Precipitation Climatology Centre
IFR	Instream Flow Requirements
LHDA	Lesotho Highlands Development Authority
MCM	Million Cubic Metre
NHS	National Hydrological Service
NMS	National Meteorological Service
NOAA	National Oceanic and Atmospheric Administration of the United States
ORASECOM	Orange Senqu River Commission
RAMSAR-site	A wetland site designated to be of international importance under the Ramsar Convention, also known as "The Convention on Wetlands" (1971)
RSMC	Regional Specialized Meteorological Centre
SADC	Southern African Development Community
SADC-CSC	SADC Climate Services Centre
SPI	Standardized Precipitation Index
SPEI	Standardized Precipitation Evaporation Index
SWHC	Surface Water Hydrological Committee
TDA	Transboundary Diagnostic Analysis
UNDP	United Nations Development Programme
UNU-INWEH	United Nations University - Institute for Water, Environment and Health.
WaPOR	Water Productivity Open-access portal from FAO

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- Michael Ramaano for project management on behalf of the ORASECOM secretariat.

1 INTRODUCTION

1.1 Context

Welcome to the first synoptic surface water report of the Orange Senqu Commission (ORASECOM), for the hydrological year 2020-2021. This report was initiated by the Surface Water Hydrology Committee of ORASECOM, in first instance for internal use, to have a way of reviewing the season for the whole basin with similarly presented data for all countries. Others interested in the management of the Orange-Senqu Basin at an international scale may also find the report useful.

The intention is that this is a first report which will be compiled in a similar way in follow up years, but every year improved according to the needs at that time. Abstractions, water use licenses and environmental flow requirements are some of the topics that have not been included in this first report.

For those that are less familiar with hydrology in Southern Africa, a hydrological year starts in this region on 1 October and lasts until 30 September, so that one wet season is not split into two reporting years. The 2020-2021 hydrological year thus started 1 October 2020 and ended 30 September 2021.

While this report focuses on surface water quantity information, one needs to be aware that ORASECOM also produces 'State of the Orange-Senqu River Basin'-reports, which focus on water quality. ORASECOM produces these reports once every few years after a Joint Basin Survey. The last Joint Basin Survey took place in the last quarter of 2021 and a new report is expected in 2022.

The intention is to make a similar synoptic report every year, so that also climate change and water use change can be monitored. For this report, the normal WHO recommended 1961-1990 reference period was chosen to monitor climate change against. Thus, where data were already available in 1961, the mean of the 1961-1990 period is displayed. However, it appeared that for many gauges they were not yet operational in 1961. The start of the data series is indicated in each graph.

1.2 Scope and Content of the report

Chapter 2 describes the weather in 2020-2021. The report is to understand the surface water hydrology, but as weather is the driver of surface water flows, also information on weather has been presented.

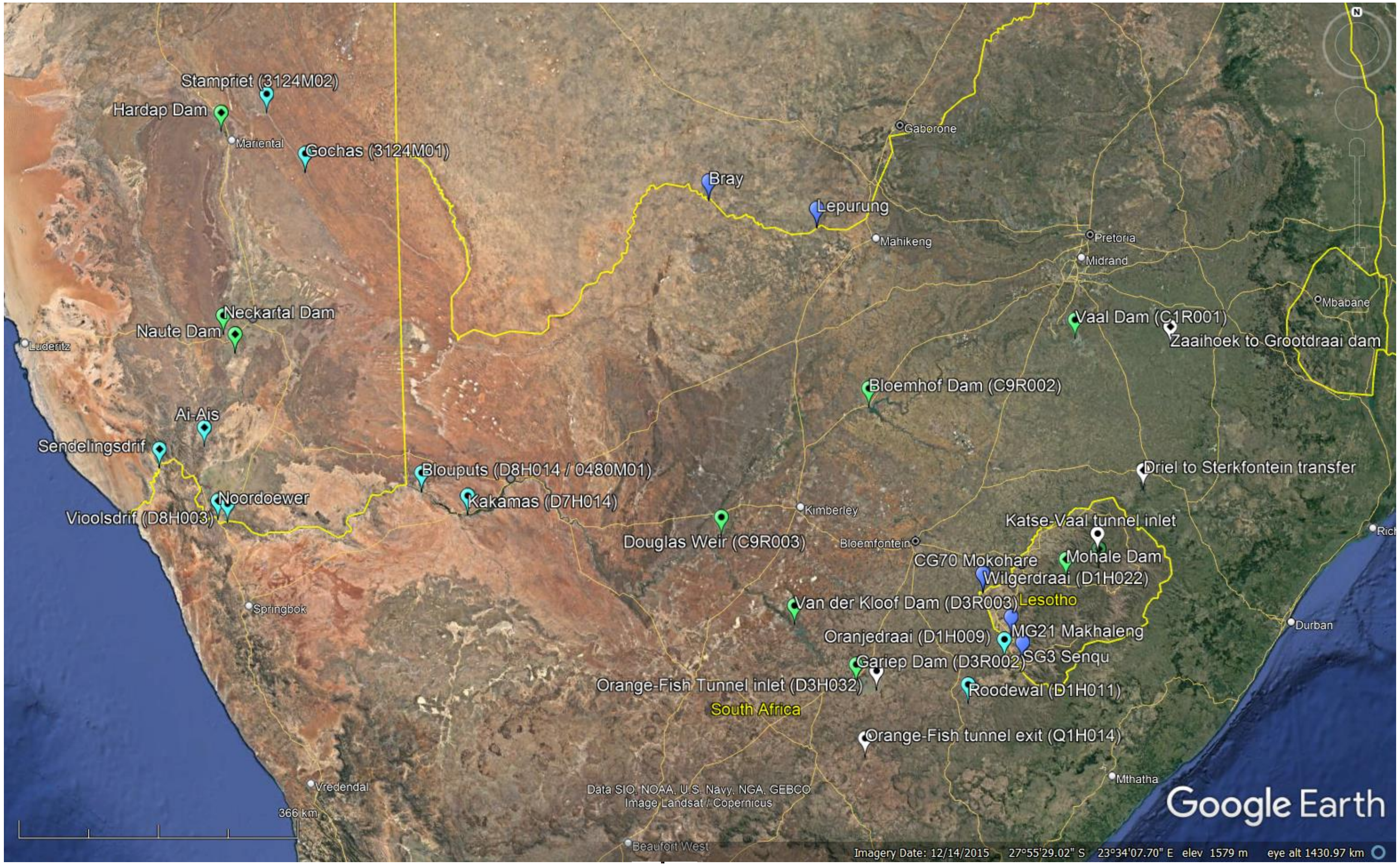
Chapter 3 describes the selected river flows at gauging stations. This excluding the gauging stations that are representative of outflows and inflows of reservoirs, which are described in Chapter 4.

Chapter 4 is providing the developments in storage in the main reservoirs, with an explanation of inflows and outflows provided in Appendix B, as far as data were available for this.

Chapter 5 describes the river transfer schemes, which are artificial transfers of water from one to the other river basin, thus in and out of the Orange-Senqu Basin and therefore influencing the water availability in the basin.

Chapter 6 compares water levels rather than flows, to show how the variation in flows has influence on water levels. Although this gives little indication of water levels further away from the gauging stations, the intention is to show clearly on a daily timestep scale how floods move through the basin. For 2020-2021, there were no extreme large scale river floods, but as this report is also an example of how to report in the coming years, this has been included.

Chapter 7 describes the status of the gauges that were consulted for this report. The location of the gauges and reservoirs referred to in this synoptic report are shown in Figure 1, but for those who would like to know more exact locations, the coordinates are provided in Appendix C and a kmz-file for opening in Google Earth can be distributed with this report. The selection of gauges and reservoirs to report on was done in consultation with the SWHC. Gauges were selected that were considered interesting for international river basin management. To orientate in the basin, Appendix A includes additional maps and a schematic.



Legend: river gauge reservoir transfer scheme key gauge but no data made available for this report.
(A square indicates exact location in kmz, a circle indicates a location estimated by AquaLinks.)

Figure 1: Gauges included in the 2020-2021 report (blue = river gauge, green = reservoir/weir gauge, white = transfer; circle is exact location known, square is location estimated.)

2 THE WEATHER DURING THE YEAR

1.3 The seasonal outlook of SARCOF

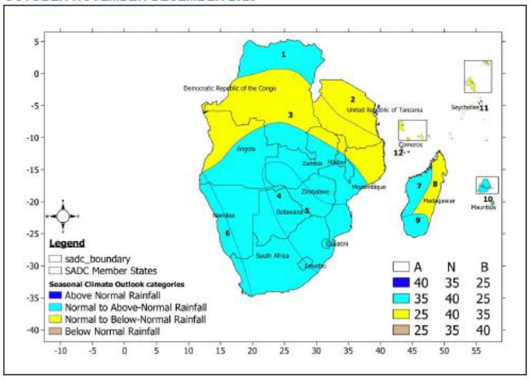
The Southern Africa Regional Climate Outlook Forum (SARCOF) is an annual event, facilitated by the Southern African Development Community Climate Services Centre (SADC-CSC), to make a regional seasonal weather forecast that is published at the start of the rain season. It is a consensus document including the insights of different climate scientists of the National Meteorological Services (NMSs) and the National Hydrological Services (NHSs) of the SADC-region and the SADC-CSC, with inputs from various other organisations.

The outlook below is here presented to hind cast the season, to look back at what information was available at the beginning of the season for surface water management, which may explain some of the dam releases, and additionally to provide input the NHSs to check how well the forecast performed. This is just one year but gives some insight in the skill of the SARCOF-outlook, which can be used to provide feedback to SARCOF.

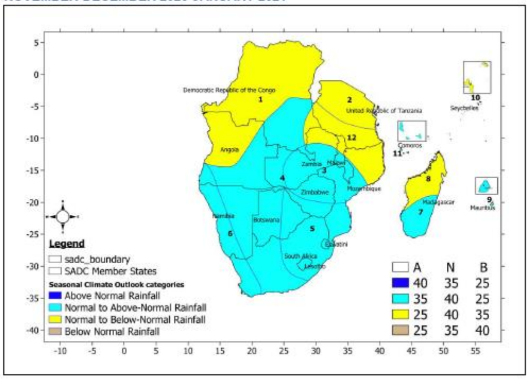
The follow up sections on the weather will show that for the 2020-2021 hydrological year the outlook was quite accurate. The rainfall was indeed mainly normal to above normal for most of the season for the Orange-Senqu Basin and January and February were relatively wet, as was forecasted. This was partly related to the occurrence of Cyclone Eloise (see section 1.6).

SARCOF forecasts for 2020-2021

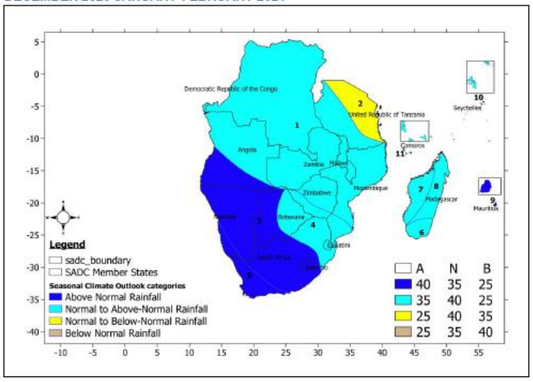
OCTOBER-NOVEMBER-DECEMBER 2020



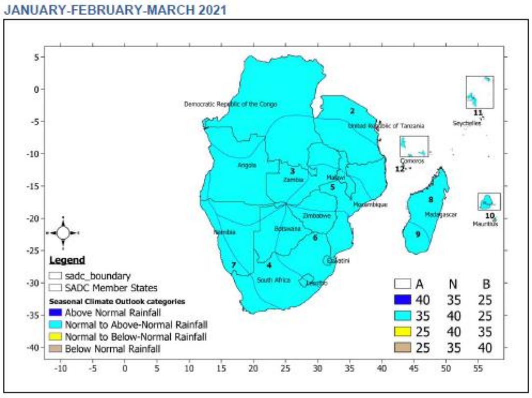
NOVEMBER-DECEMBER 2020-JANUARY 2021



DECEMBER 2020-JANUARY-FEBRUARY 2021



JANUARY-FEBRUARY-MARCH 2021



Seasonal Climate Outlook categories

- Above Normal Rainfall
- Normal to Above-Normal Rainfall
- Normal to Below-Normal Rainfall
- Below Normal Rainfall

A	N	B
40	35	25
35	40	25
25	40	35
25	35	40

Explanation: The colours for each zone indicate the probabilities of rainfall in each of the four categories, above normal, normal to above, normal to below and below normal. The first colour (blue) indicates the probability of rainfall occurring in the above-normal category, the second colour (cyan) is for normal to above-normal rainfall, while the third colour (yellow) represent the probability for normal to below-normal rainfall and the last colour (brown) is for below-normal rainfall. The table on right gives the probabilities that with such a colour, above (A), normal (N) or below normal (B) rainfall will be falling. Thus, even if the colour is dark blue, there is still 25% chance of below normal rainfall. Note that the periods overlap.

Figure 2: SARCOF forecasts for 2020-2021

1.4 Precipitation and evapotranspiration

The monthly maps of the basin below are derived with the FAO-WAPOR datasets. They are included in this 2020-2021 report, not only to evaluate this season, but also for the fact that in this way similar maps in future annual reports will help to understand the differences with 2020-2021.

Precipitation estimates by satellite (Climate Hazards Group InfraRed Precipitation with Station data, CHIRPS) are displayed for each month in Figure 3. For rainfall under 60 mm/month it can be expected that most rainfall evapotranspires and does not generate much river flow in the bigger rivers, therefore this is displayed as white for the purpose of this report. From the figure, one can see that January and February 2021 were wettest, surprisingly mainly over a considerable part of the Botswana and Northwest province of South Africa part of the basin. In January 2021, the cyclone Eloise came into Southern Africa, and it dissipated around 25 January. A worth of caution in the interpretation: 1) white areas within the dark blue areas have no estimate, and 2) the database set CHIRPS is developed for Seasonal Drought monitoring and Trend Analysis, not for flood forecasting, therefore high rainfall extremes may be less accurate.

Reference evapotranspiration is a measure for the amount of transpiration that would occur from well-watered grass. It is displayed for each month in Figure 4. It gives an indication of how much water would be needed for irrigation of crops during a certain month. For different crops, crop factors dependent on the growing stage are available. During cloudy and/or colder days, reference evapotranspiration might be less. In the context of monitoring climate change, the changing demand for water is also important. The set of pictures, derived from the FAO-UN database, is particularly important to get a spatial view, but it is also important to compare this report in consecutive years with each other. On the western side of the basin there is more than double the amount of reference evapotranspiration than on the eastern side, but there is understandably also limited irrigation there.

Actual evapotranspiration is the flux of water that really goes up in the air. The estimates of monthly totals are displayed in Figure 5. How much actually evapotranspires, depends on the water availability, the actual ground cover and the potential evaporation. In many months and in many locations, the actual evapotranspiration will be limited by water availability. The maps show that for October to November and for June to September, most of the basin is hardly any actual evapotranspiration. From October to March though, in the upper basin there is 40-160 mm/month. The average in the long run can of course not be higher than the precipitation.

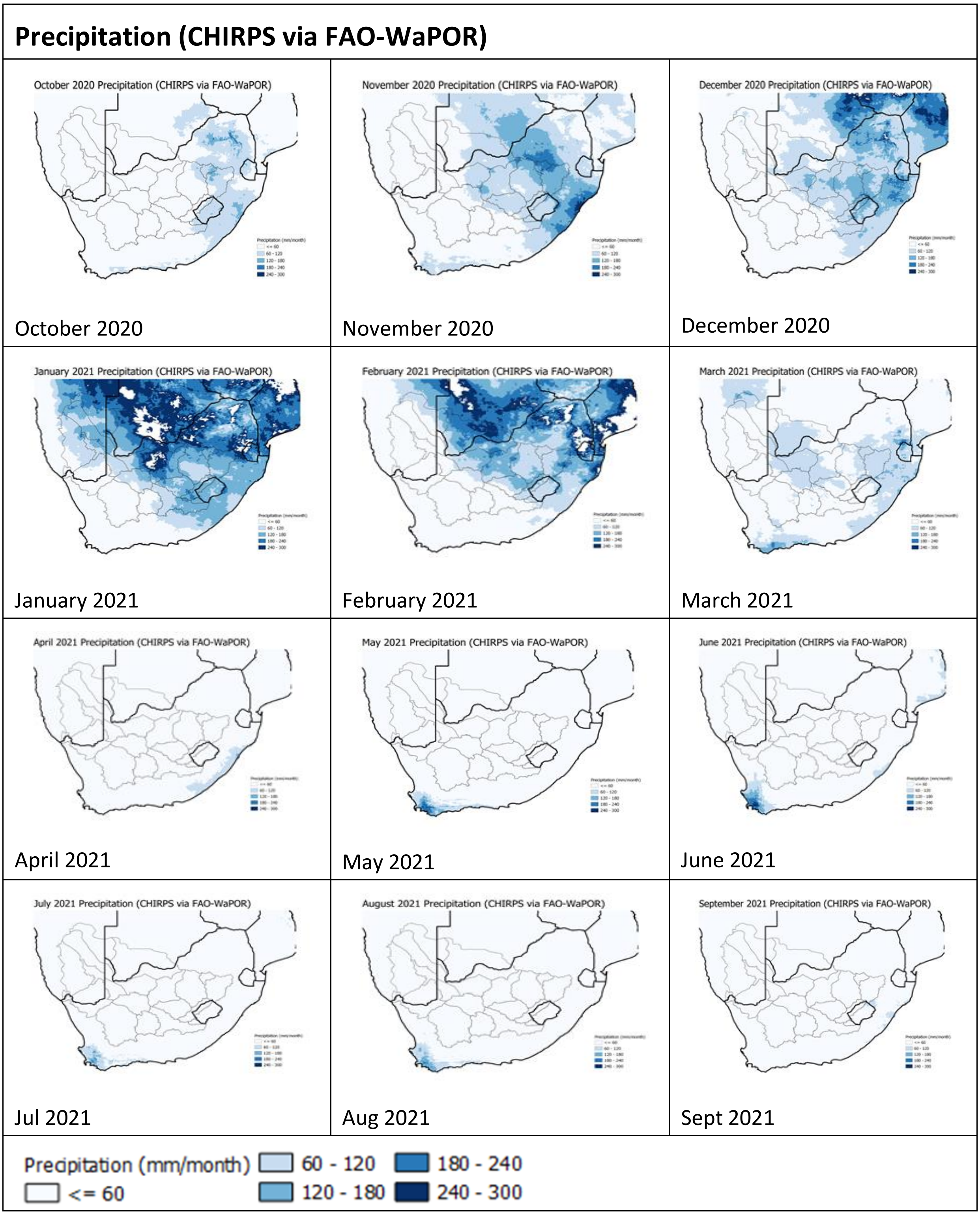


Figure 3: Monthly precipitation totals, as measured by CHIRPS and mapped for this report

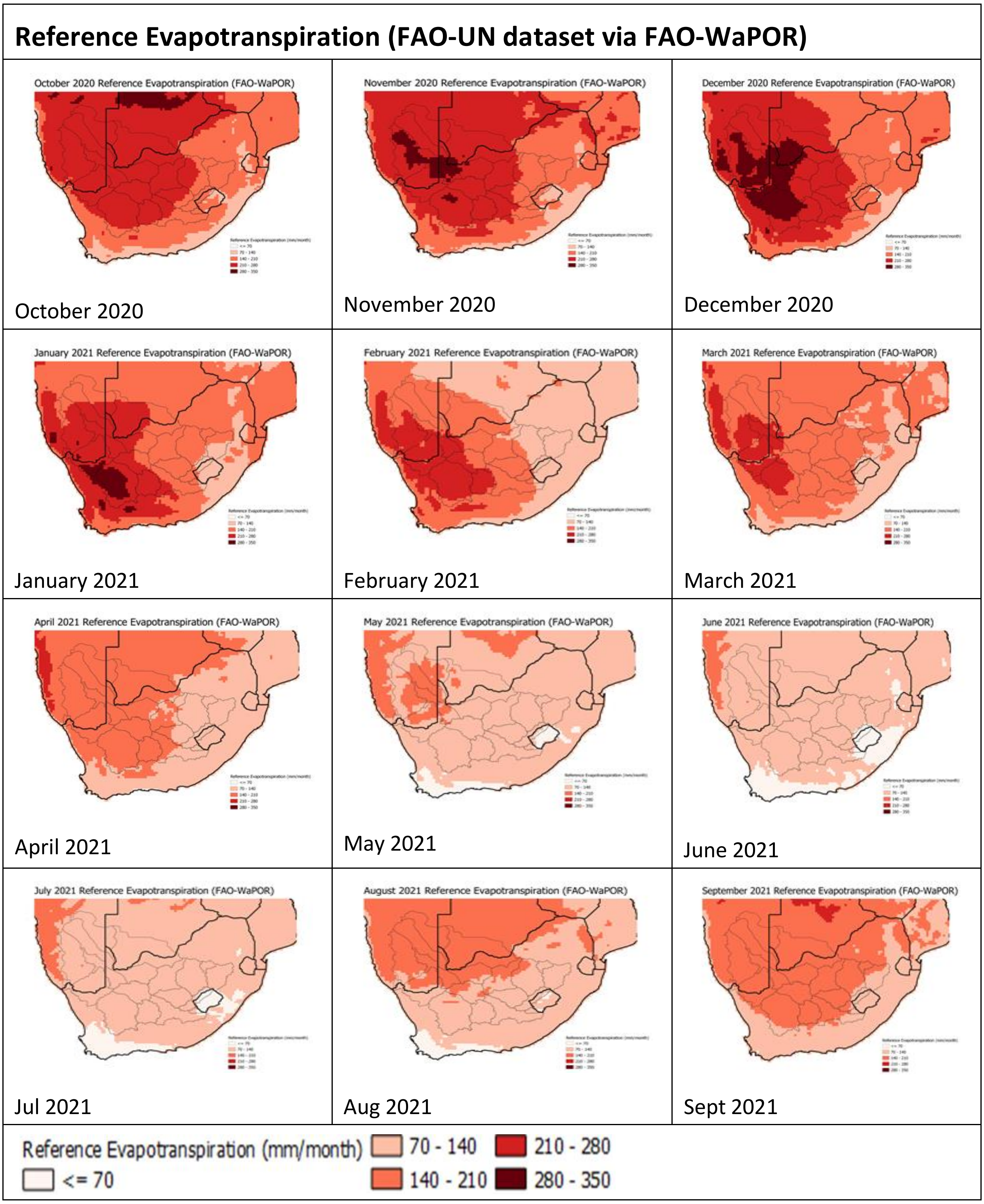
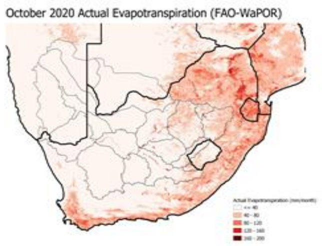
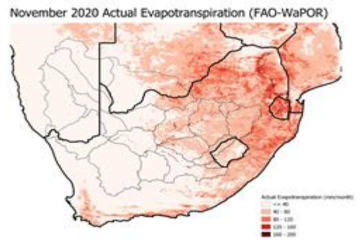


Figure 4: Reference evapotranspiration monthly totals, from FAO-UN dataset and mapped for this report

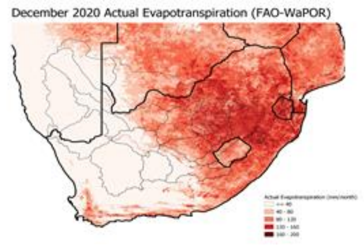
Actual Evapotranspiration (FAO-WaPOR; based on Penman-Monteith and remote sensing data)



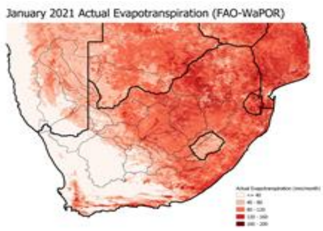
October 2020



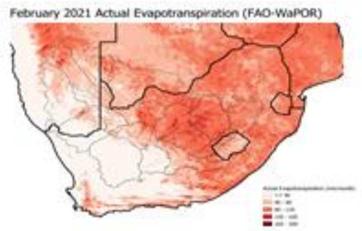
November 2020



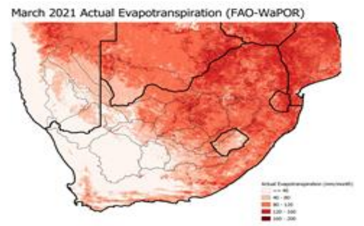
December 2020



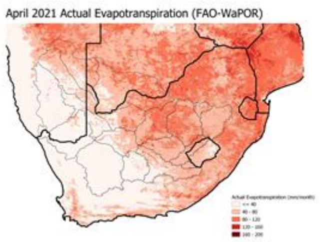
January 2021



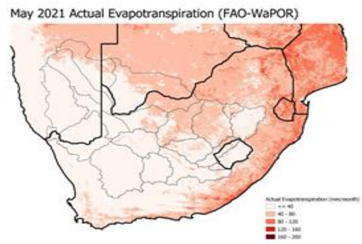
February 2021



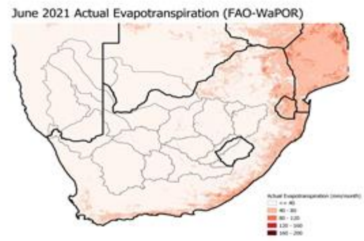
March 2021



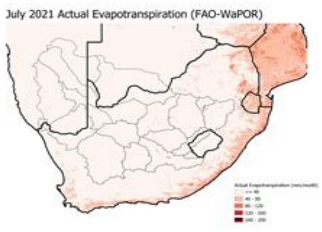
April 2021



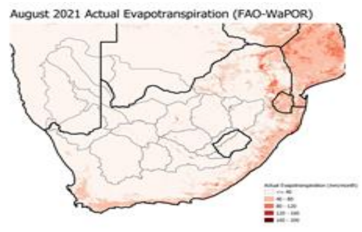
May 2021



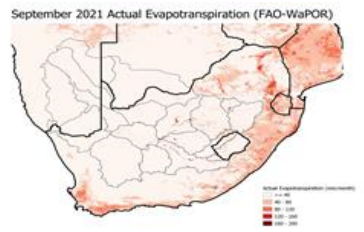
June 2021



Jul 2021



Aug 2021



Sept 2021

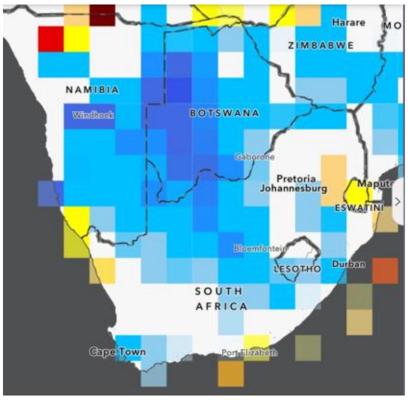
Actual Evapotranspiration (mm/month) <= 40; 40 - 80; 80 - 120; 120 - 160; 160 - 200

Figure 5: Actual evapotranspiration monthly totals, as estimated by FAO-WaPOR and mapped for this report

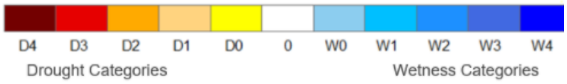
1.5 Drought indices

In the previous section, the spatial patterns of weather for the 2020-2021 season itself were shown. In this section, maps of indices are shown to see how the 2020-2021 compares to historical records. According to these indices, the 2020-2021 year has been most extraordinary for the western Botswana region with relatively wet and low potential evapotranspiration combination. For Lesotho, which is a main source area for water in the basin, all three indicators show that 2020-2021 was a fairly normal year. In general, the indices do not evaluate this as a dry year for any large area in the basin, apart from possibly the area close to the estuary.

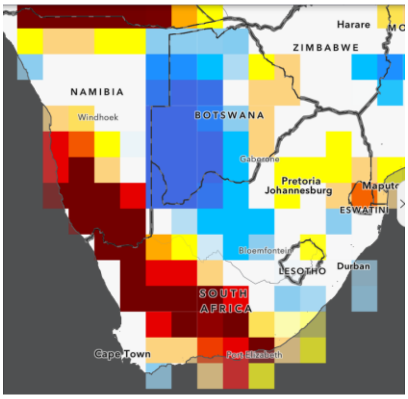
12-month Drought Indices (Global Drought Information System of NOAA)



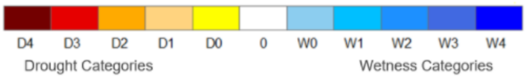
GPCC Global Drought Index (DI) [DWD]
https://opendata.dwd.de/climate_environment/GPCC/html/gpcc_di_doi_download.html
DI is an indicator that combines Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index (SPEI), and temperature (used to calculate potential evapotranspiration (PET)) data.



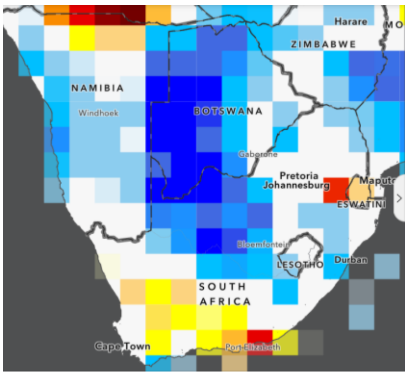
GPCC Drought Index valid date - 20211010



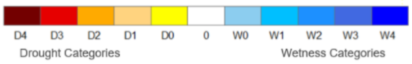
GPCC Standardized Precipitation Evapotranspiration Index (SPEI) [CSIC]
https://spei.csic.es/
SPEI is a drought indicator that combines precipitation and potential evapotranspiration (PET). Warmer colors indicate drier conditions, colder (blue) colors indicate wetter conditions.



Standardized Precipitation Evapotranspiration Index valid date - 20211010



GPCC Standardized Precipitation Index (SPI) [NOAA NIDIS/NCEI]
https://www.ncdc.noaa.gov/temp-and-precip/drought/nadm/indices/spi/div
The SPI is an index based on the probability of recording a given amount of precipitation, and the probabilities are standardized so that an index of zero indicates the median precipitation amount (half of the historical precipitation amounts are below the median, and half are above the median). The index is negative for drought, and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive.



Standardized Precipitation Index valid date - 20211010

Figure 6: 12 month drought indices 2020-2021 hydrological year (NOAA website)

1.6 Cyclone occurrence

In January 2021 there was cyclone Eloise, which made landfall 23 January north of Beira and had its centre close to Gaborone on 25 January 2021 when it already was dissipating but still influenced rainfall in the catchment (link to four day simulation by AfriWX based on MeteoSat satellite images and see Figure 7 below). From the various Cyclone Eloise news flash updates of Reliefweb (UNOCHA, 2021) and summaries on Wikipedia (2022), the following impacts on the Orange-Senqu Basin were reported.

Box 1 Impacts of cyclone Eloise as reported on Reliefweb and on Global Catastrophe Recap

Update no 8, as of 25 January 2021: "In Botswana, the Government's Meteorological Services has issued an advisory for widespread rainfall from 24 to 28 January across all districts, with amounts of 70 mm or more forecast over Southern-Central District. Several districts may experience localized flooding, strong winds and lightning, which may cause possible damage to property."

Update no 10, as of 27 January 2021: "As of 26 January, the ex-Eloise weather system was a much-weakened extra-tropical depression situated over the southwestern parts of Botswana, according to the South African Weather Service(SAWS). In South Africa, the low pressure system is expected to bring scattered to widespread rains to the central parts of the country from the afternoon of 26 January until the weekend. On 27 January, however, the ex-Eloise weather system is expected to interact with a cold front passing South Africa, which could bring significant amounts of rainfall over eastern Northern Cape, western North-West Province and western Free State, according to SAWS. SAWS has issued warnings for 'disruptive rainfall' from 26 January to 29 January, including a yellow alert for western North-West Province and the extreme north-eastern parts of Northern Cape, spreading to western and central Free State."

Update no 12, as of "In South Africa, heavy rains continue in multiple locations. Orange warnings for disruptive rainfall are in place for southern and eastern Mpumalanga, Gauteng and the western Bushveld of Limpopo, as well as north-eastern North-West Province, while yellow warning alerts are in place for eastern and central Free State and eastern North-West Province, according to the South Africa Weather System."

Deaths, blocked roads and infrastructure damage were only reported for other areas than the Orange-Senqu basin. The southern Africa wide damage by floods resulting from Cyclone Eloise was estimated by the Global Catastrophe Recap (AON, 2021 January and February reports) as "tens of millions of dollars", but these are probably mostly outside the basin.

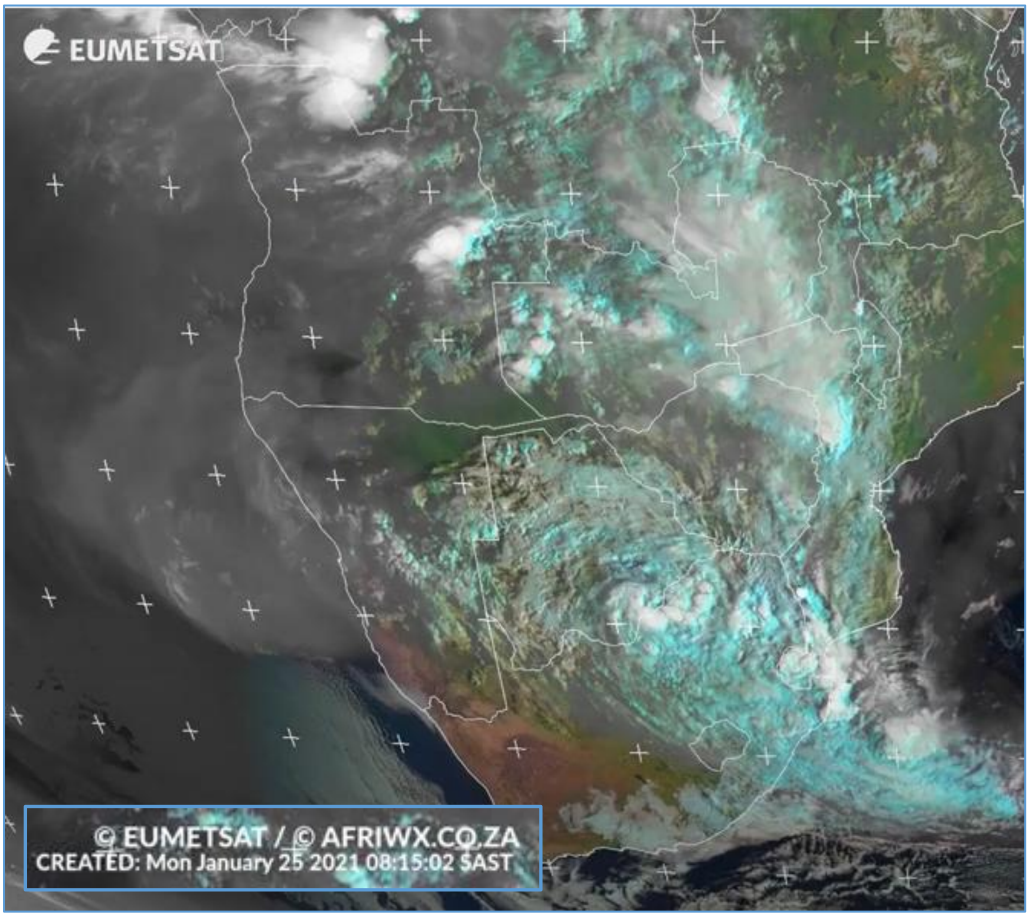


Figure 7: Cyclone Eloise in the morning of 25 January 2021 when it is already dissipating but having still impact on rainfall in the basin.

3 RIVER FLOWS

This chapter is about the surface water itself, in terms of river flows. In consultation with the SWHC river gauges were selected that are important for transboundary water resources management (see Appendix C). Therefore, quite a few gauges are selected in the lower Orange where Namibia and South Africa each border the river and where the South African river gauges also give an impression of the Botswana inflows into the Orange (if at all). Also, gauges close to the Lesotho-South Africa border were selected, but unfortunately no data were available for those gauges. It needs to be realised that many gauges are downstream of major dams and abstractions and thus are not natural flows.

Below from upstream to downstream, the flows are briefly described. This is followed with Figure 8 which presents graphs for the individual stations. The left graphs show time series of the monthly totals of flow and the right graphs display the cumulative of the total flow that passed the station since the beginning of the hydrological year (start of October). The time series give an indication of the variation of flow during the year, and the cumulative gives an indication of to what extent totals since the start of the season at a certain point in the season are different. The three previous hydrological years are also displayed (if available). The graphs are sorted from upstream to downstream, with flows in tributaries sorted for the location of confluence with the Orange. The blue envelope behind the graphs shows in each graph the maximum and minimum recorded values in each month of the year over the whole historical record, excluding the 2020-2021 season, in order to see if the latest season broke any records on measured values. Please note that the length of the record is indicated in the lower right of the graph.

It needs to be noted that the records have been presented as verified records, as claimed by the Departments of Water from which the data were obtained. This also assumes updated rating curves. However, might on the basis of this report or for other reasons, the quality of data be doubted, then this will need to be reported to the SWHC and corrected in the next hydrological report.

On the Mohokare / Caledon River, as the river gauges from the Ministry of Water Affairs in Lesotho are currently not read and the South African station Wilgerdraai (D1H022) is also not available, no data were reported here. Wilgerdraai is also not expected to be available in future years. The Oranjedraai station in South Africa is the best currently available for estimates of flow out of Lesotho.

On the upper Orange River, the Oranjedraai station (D1H009) just downstream of the confluence of the Senqu and Makhaleng rivers, is the most upstream station. This station as a long record (since 1958). The flows in January were very much higher than the average flows for that month, but the total flow over the whole hydrological year is only 16% higher than the mean total flows, at 4569 Mm^3/month as in most years the peak flows come later than January. The total flows are considerably higher than the three previous years, as these were all below the mean flows. The high flow in January is mainly due to the high flows at the end of January 2021, related to Cyclone Eloise.

In the upper Orange catchment area, the tributary Kraai River at Roodewal (D1H011) is a gauge that has been used for studies on environmental flow requirements (EFR K7 in Louw and Koekemoer, 2010). It had missing data in January, with the water levels surpassing the rating curve, thus the cumulative flows cannot be determined as from January. At the end of January, the water levels measured were very high, as will be discussed in Chapter 6. For February, the flows measured were still 132 Mm^3/month. The flows were peaking earlier than in previous years and in the mean (with records since 1965).

For the lower Orange River at Kakamas (D7H014) there was a distinct peak total flow in February with a total flow of 4424 Mm^3/month. This is not as high as the February record in 2010-2011 which was 5001 Mm^3/month (with records since 1993). And higher peak flows, up to 6012 Mm^3/month have previously been recorded in January. The peak flow is however more than six times higher than the mean in February. The total flow over the season was only 22% higher than the mean total flow, at 6140 Mm^3. While not exceptionally high, this was far higher than the flows previous three years. The station of Kakamas is downstream of Douglas Weir and Van der Kloof dam, which are described in the Chapter 4 on Reservoirs.

For the Auob River in Namibia at Stampriet and Gochas records on flows from Namibia are not available for 2020-2021. The Auob river flows from Namibia to Botswana into the Molopo-Nossob catchment.

For the Molopo River bordering Botswana and South Africa, the two river gauges in Botswana, one installed during cyclone Dineo (2017) are currently not functional. The Drought Indices (section 1.5) indicated that Botswana was considerably wetter than normal, so some flow might have been expected. Unfortunately, the Blouputs stations of South Africa, which is just downstream of the Molopo River confluence, is missing for the crucial month of February in which the Molopo River might have been flowing, given the relatively wet season indicated in section 1.5.

For the lower Orange River at Blouputs (D8H014) flows in February were higher than the rating curve. Blouputs is, as the crow flies, only about 60 km from Kakamas, just after the confluence with the Molopo River coming from Botswana. The graphs show that since the recording started in 2014 only, flows in January and March were considerably higher than so far measured at respectively 970 Mm^3/month and 865 Mm^3/month, but they are in the same order of magnitude than the flows measured in Kakamas, so for these months not much flow was probably entering from the Molopo River.

For the lower Orange River at Vioolsdrif (D8H003), which is South Africa's most downstream station, the peak in 2020-2021 is clearly also in February at 4755 Mm^3/month. This is more than four times as high than the mean in February (with data since 1935) but not extreme in the total record, which has been higher than 6000 Mm^3/month several times, with the latest as recent as 2010-2011. The Noordoewer and Sendelingsdrif stations from Namibia are further downstream.

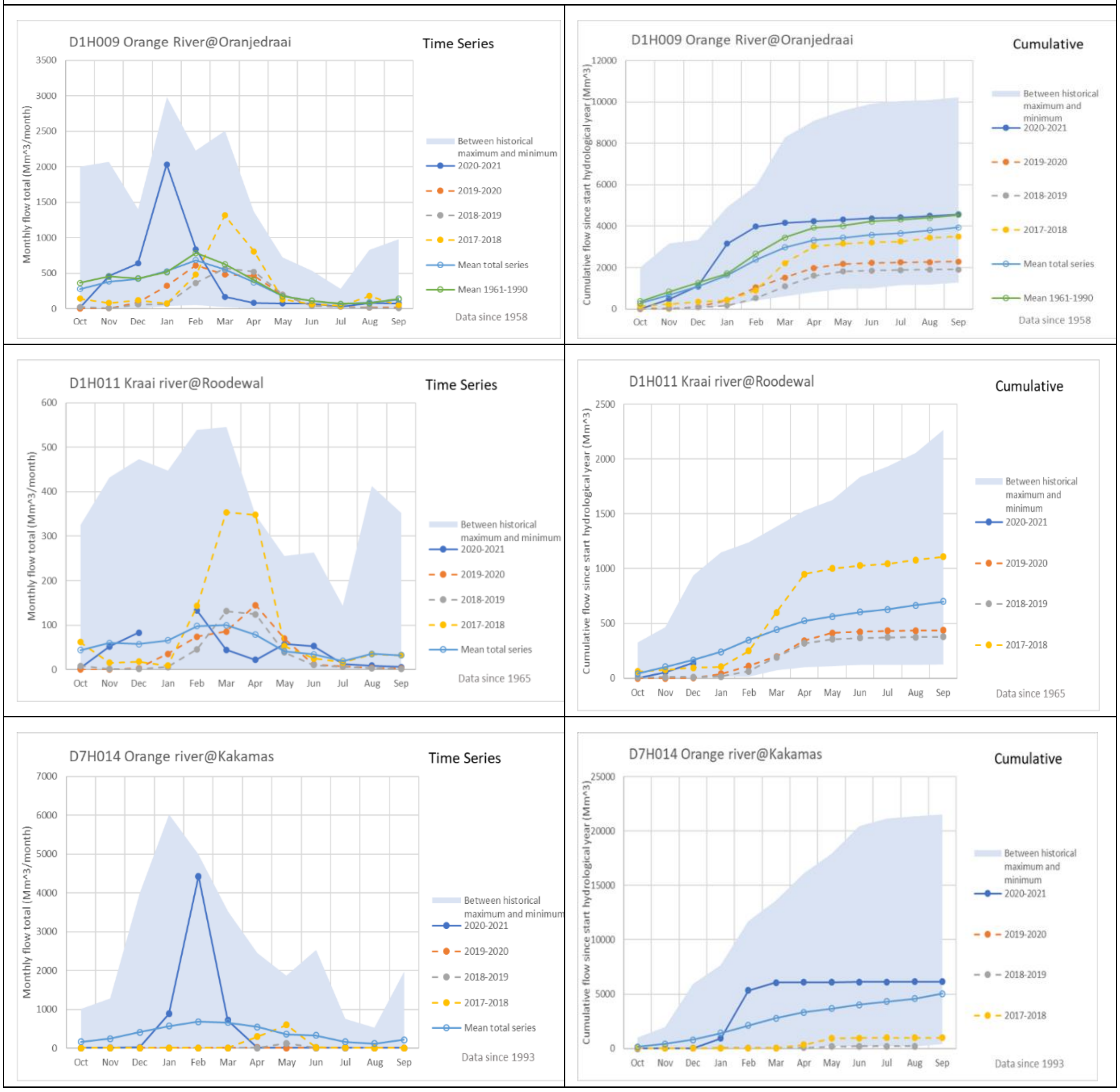
For the lower Orange River at Noordoewer station (0484M01) unfortunately data for the 2020-2021 season have February and March missing, but January was far wetter than the mean, with a flow of 966 Mm^3/month. Vioolsdrif had for the same month 950 Mm^3/month, therefore the contributing flow from Kowiep River, which is a tributary between Vioolsdrif and Noordoewer, was relatively little.

For the Fish River at Ai-Ais (0499M02), which is the main tributary from Namibia to the Orange between Noordoewer and Sendelingsdrif, the peak in flow was in January at 147 Mm^3/month, which is 15% of the flow amount at Noordoewer. The flows in the previous three years were very small, while for 2020-2021 the January flow surpassed the mean for January.

For the Orange River at Sendelingsdrif (0485M02) unfortunately there are no data for 2020-2021, therefore the graph only shows historical records for completeness.

For the Orange-Estuary, given the data of Noordoewer and Ai Ais, it is expected that for the Orange estuary 2020-2021 had better flows than in the previous three years for January to March 2020-2021. The floodplain was inundated to some extent, as will be discussed in Chapter 6.

Flow hydrographs in the basin




Auob River at Stampriet (3124M02)
Time Series
N.B. no data since April 2019
Monthly flow total (Mm^3/month)
Between historical maximum and minimum
2020-2021
2019-2020
2018-2019
2017-2018
Mean total series
Data since 1977
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Auob River at Stampriet (3124M02)
Cumulative
N.B. no data since April 2019
Cumulative flow since start hydrological year (Mm^3)
Data since 1977
Auob River at Gochas (3124M01)
Time Series
N.B. no data for 2020-2021 and recent years
Data since 1973
Auob River at Gochas (3124M01)
Cumulative
N.B. no data for 2020-2021 and recent years
Data since 1973
D8H014 Orange river@Blouputs
Time Series
Data since 2014
D8H014 Orange river@Blouputs
Cumulative
Data since 2014
D8H003 Orange river@Vioolsdrif
Time Series
Data since 1935
D8H003 Orange river@Vioolsdrif
Cumulative
Data since 1935

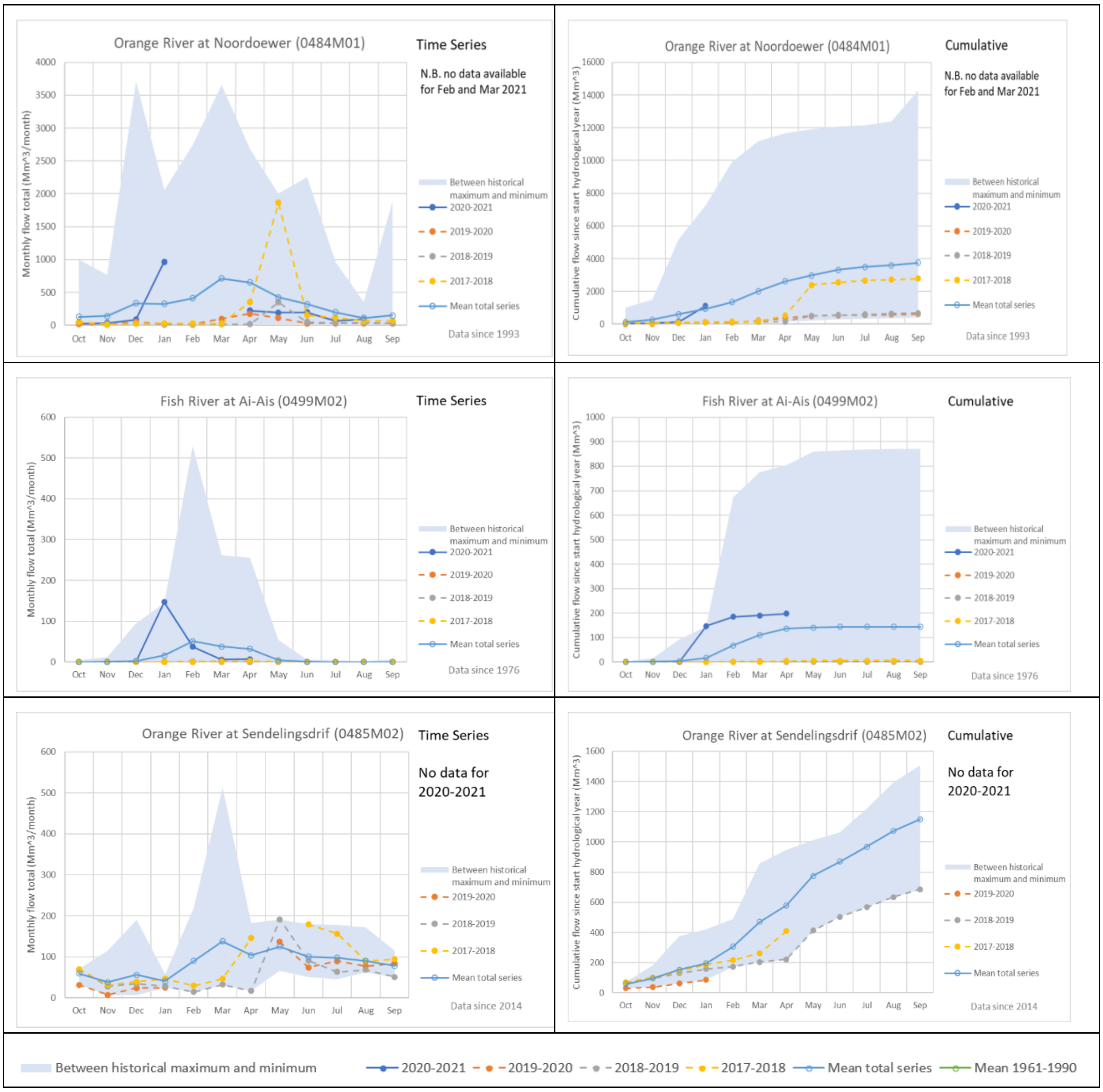


Figure 8: Monthly flow hydrographs at selected river gauges in the basin

4 RESERVOIRS

The storages of the reservoirs at the end of the month for the year 2020-2021 and previous years, and means over the historical series are displayed for the main reservoirs in the Orange-Senqu Basin in Figure 9, while additional data on inflows, outflows and abstractions are displayed in Appendix B. In general, the reservoir storages at the end of the hydrological year were higher than in the previous three years. This is valid for all reservoirs except for Mohale reservoir and Gariep reservoir which also had a good storage end of 2018-2019.

To judge the water management at the reservoirs, one would like to compare the storages and flows with operating rules for those, but these were not made available for this first report.

Lesotho

While both Katse and Mohale reservoirs increased their storage over the year, the storages are far from life full capacity, with Katse being at 71% of the 1950 Mm^3 Life Full Supply Capacity in September 2021 and Mohale being at 36% of 938 Mm^3. Mohale dam transfers also feed Katse reservoir, for transfers from Katse reservoir to the Vaal catchment. The abstractions from Katse dam to the Vaal River system were similar than in previous years, shifting between 50 and 80 Mm^3/year, with a total abstraction of 836 Mm^3 over the whole year (see Chapter 5). Inflows in Mohale distinctly peaked in January, while for Katse it was December and January. Outflows were far below the mean monthly outflows since 2009, which assisted in building up storage. The effect on environmental flows or downstream users cannot be concluded from these data.

South Africa

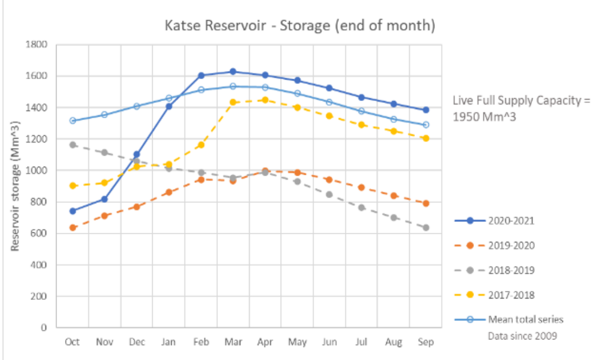
For the Vaal catchment, the Vaal reservoir was full starting from March up to May. Only storage data are available so no conclusion can be drawn on outflows or inflows and abstractions mainly take place downstream of the dam. The Bloemhof reservoir spilled in January and February and remained almost full until the end of the hydrological year. The Douglas weir downstream, has some missing data for February and March, but seems to have been (almost) full as from November. Abstraction data were not available.

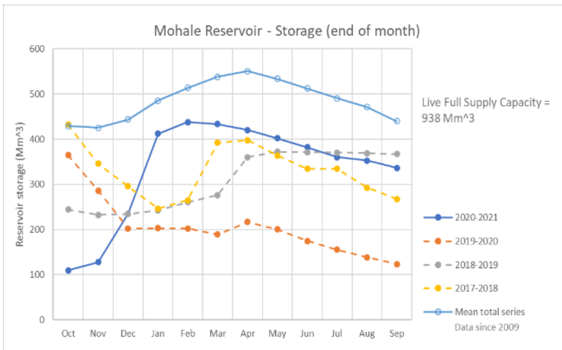
For the main Orange River, the Gariep and Van der Kloof reservoirs are major reservoirs. For both reservoirs for 2020-2021 only unverified storage and outflow data were available. These showed that Gariep reservoir filled mostly in January, earlier than in previous years and earlier than the mean trajectory. Van der Kloof reservoir was full starting from February and spilled in February.

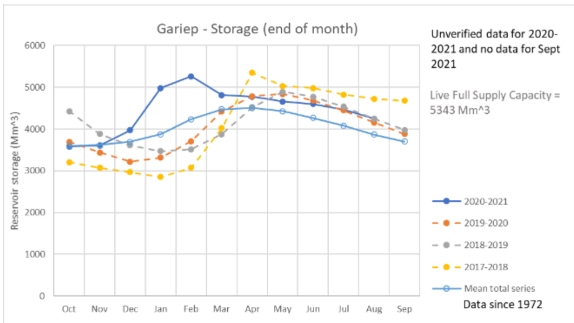
Namibia

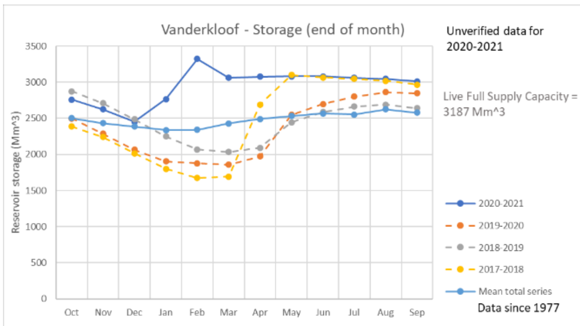
For the Hardap and Naute reservoirs, both in the Fish River catchment but on different tributaries, only storage data were available. Hardap and Naute reservoirs were almost full as from January, having more storage than in the previous three years, although for Naute reservoir there were no data available for August and September. For a third main reservoir in the Fish River catchment, the Neckartal reservoir, there were no data available for this year.

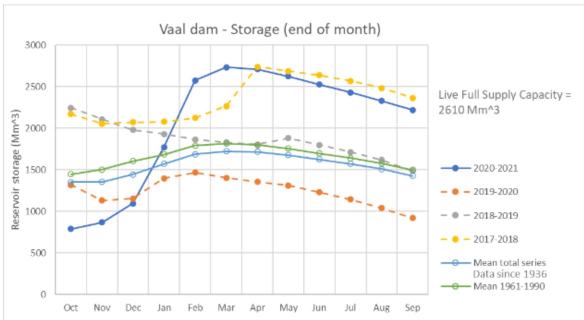
Storage time series for main reservoirs

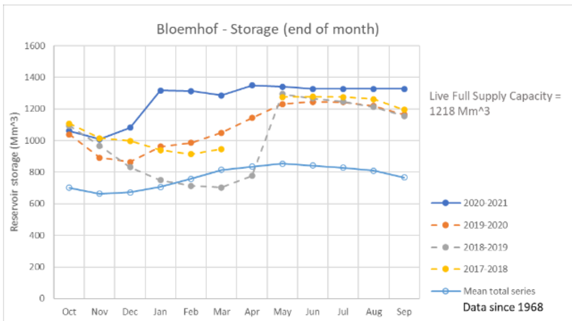


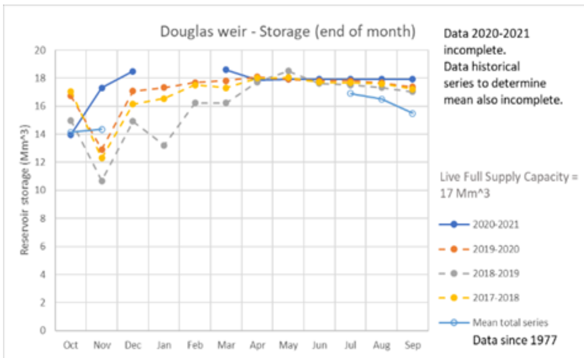


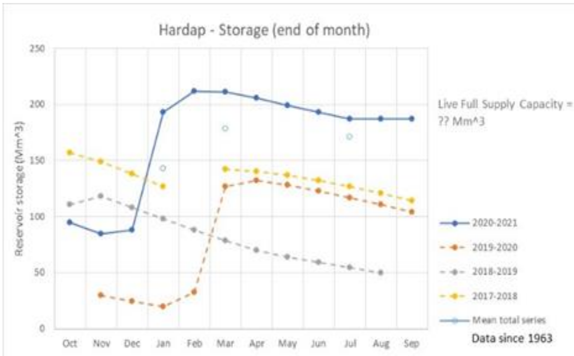












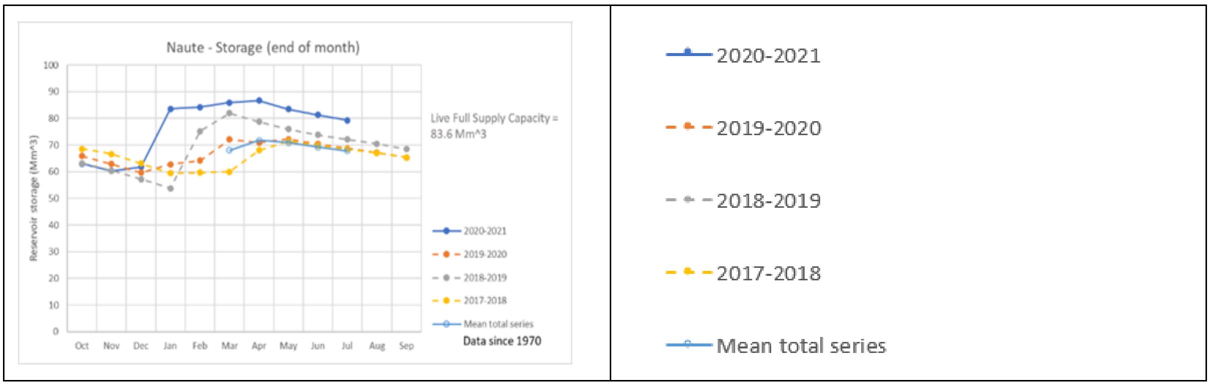


Figure 9: Storage time series for main reservoirs in Orange-Senqu basin.

5 RIVER TRANSFER SCHEMES

Concluding from the main river transfers below, the Orange-Senqu is a net receiver of transfers from other basins. The main transfers within, into and out of the Orange Senqu Basin are shown respectively in Figure 10, Figure 11 and Figure 12.

Internal in the Orange-Senqu Basin, in total about 800 Mm^3 was transferred from the Katse dam to the Vaal catchment with transfers over the months between 50 Mm^3/month and 78 Mm^3/month. This was close to the mean transfers, about 25% more than in 2019-2020, but less than in the two years before.

From the transfers into the Orange-Senqu Basin, the transfer from the Tugela River was most significant. From the Tugela Basin, almost 200 Mm^3 in total was transferred, which was one of the highest transfers on record, and far more than the previous three years. From the Assegaai River catchment, there were very limited transfers and only known for December with 4 Mm^3/month, but data missing for October and November. From the Slang River catchment, no transfer data were available.

Transfers out of the Orange, the transfers to the Fish River catchment were very constant at 0.06 Mm^3/month, which is 0.72 Mm^3 in total for the whole year and insignificant for the water balance of the whole basin.

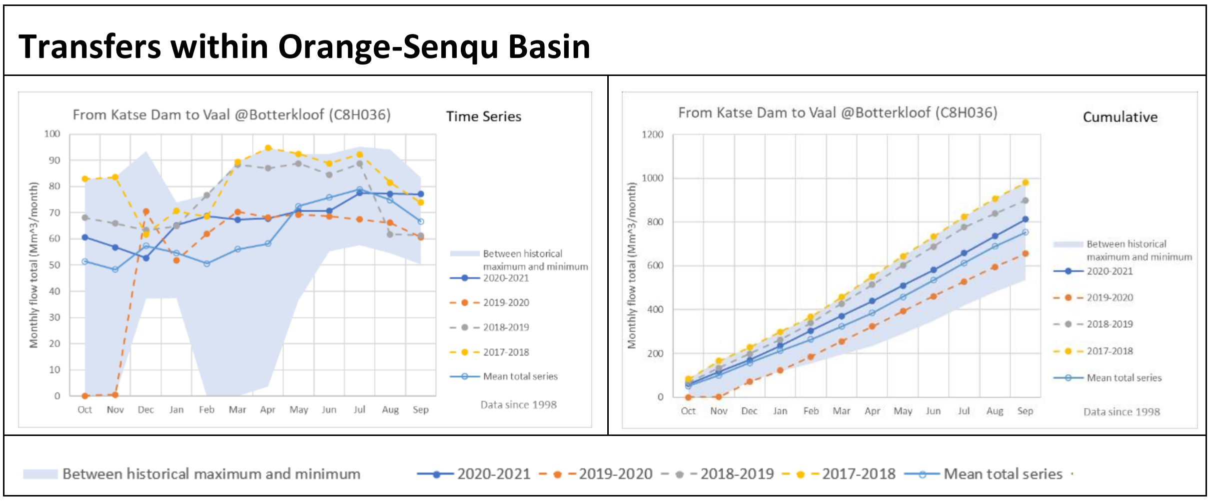
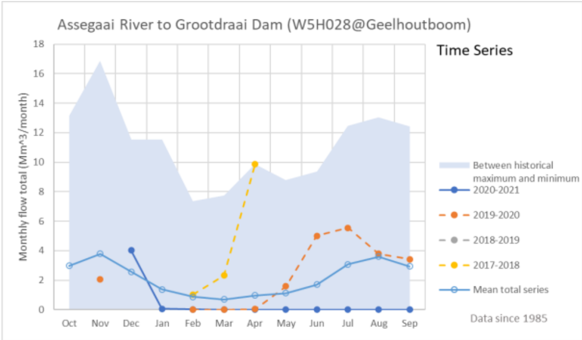
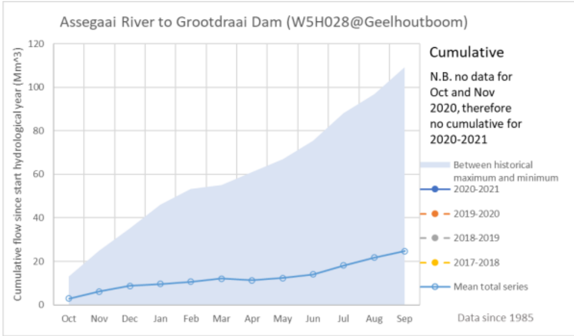


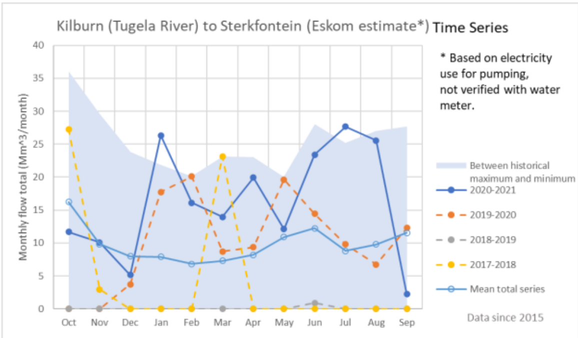
Figure 10: Transfers within the Orange-Senqu Basin

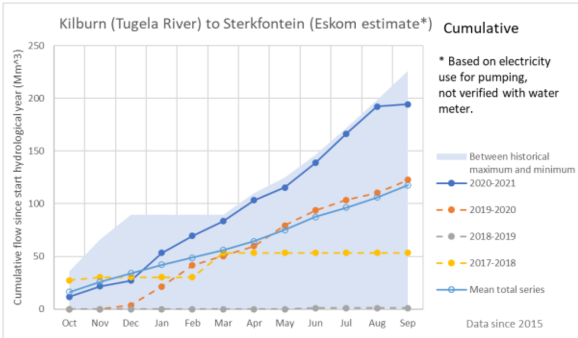
Transfers into Orange-Senqu Basin





Zaaihoek to Grootdraai dam (Slang River) no data received

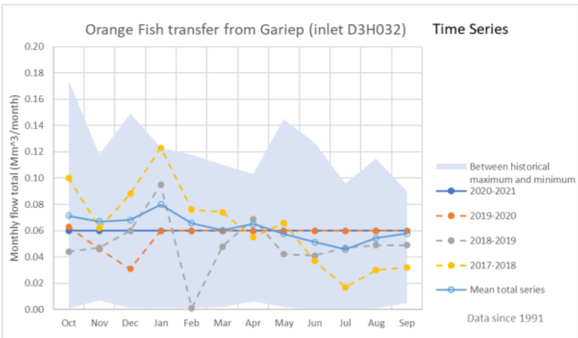


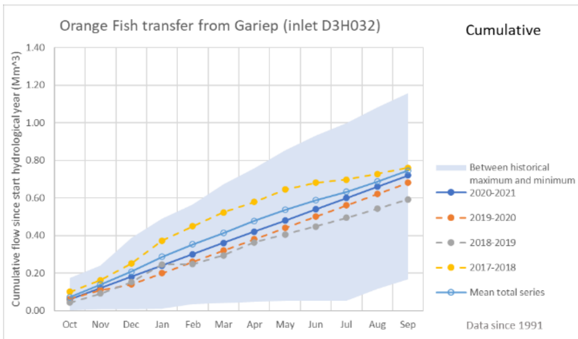


Between historical maximum and minimum — 2020-2021 — 2019-2020 — 2018-2019 — 2017-2018 — Mean total series

Figure 11: Transfers into the Orange-Senqu Basin

Transfers out of Orange-Senqu Basin





Between historical maximum and minimum — 2020-2021 — 2019-2020 — 2018-2019 — 2017-2018 — Mean total series

Figure 12: Transfers out of the Orange-Senqu Basin

6 WATER LEVELS AND FLOODS

To follow the water level impacts of high flows, Figure 13 shows the water level fluctuations at the key river gauges, while Figure 14 compares the 2020-2021 water level fluctuations for each gauge with historically measured water level fluctuations in the past 10 years (or as long as data are available). For many stations, peak water levels were above the rating curves to determine flows.

For the water levels (and thus the flows) it can be concluded that upstream in the catchment, in Oranjedraai, just downstream of the confluence of the Orange and Makhaleng Rivers, and on the Kraai River tributary, the maximum water levels were extreme compared for the previous 10 years of records. Maximum water levels appeared independently in both gauges on 28 January 2021. For the Kraai gauge this was beyond the capacity of the rating curve to derive a flow and more than eight metres higher than the normal water level. While this may seem a lot, the Kraai River catchment is sparsely populated and irrigation schemes along the river seem to be higher than the river itself.

As described before, Van der Kloof dam spilled in February. Bloemhof dam also had high outflows in January and February, with Douglas weir only having data for February to confirm high flows. Downstream at respectively Kakamas, Blouputs, Vioolsdrif and Noordoewer, the peak came later. Noordoewer peaked on 15 February 2021. While no flow was determined in Botswana, the high rainfall there around 5 February might have influenced flows, but most flow is probably from spilling of the upstream reservoirs. In Noordoewer the water levels came about eight metres higher than normal and the fields next to the river might have been affected, although no incident was reported.

The peak water levels measured were not extreme for the past 10 years. Blouputs, which only had data since 2014, did not see such high peak levels since then. The peaks of 2020-2021 almost matched or matched those of 2010-2011 but came a bit later in the season.

The river mouth of the Orange-Senqu is a Ramsar-site downstream of the Ernest Oppenheimer bridge, which is also the extend of the tidal influence (Government of South Africa, 2017). In general, estuaries are important breeding and foraging areas. Not only are there unique species depending on estuaries, also many marine species need well functioning estuaries during some stage in their life cycle. In the Orange-Senqu estuary, the salt marsh component of the system collapsed in the nineties as a result of a combination of impacts, both at and upstream of the estuary (Government of South Africa, 2017), having to do with sediment transport, water quality and the flow regime. Small fresh water floods are required to flush the salt marsh of excess salts. For the 2020-2021 year, Figure 15 shows in red the maximum extent that the floodplains were inundated. The salt marshes on the southern side close to the ocean were hardly inundated.

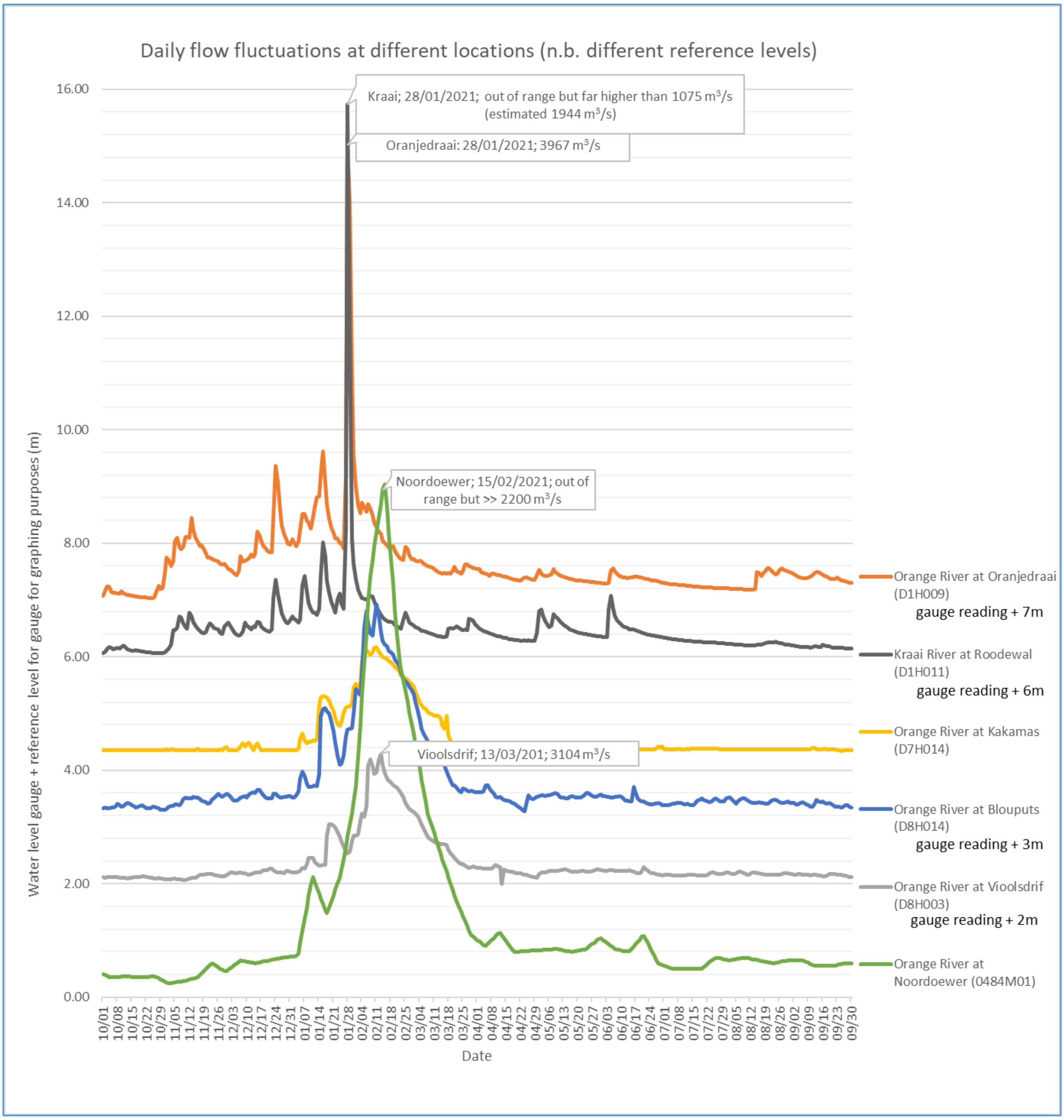
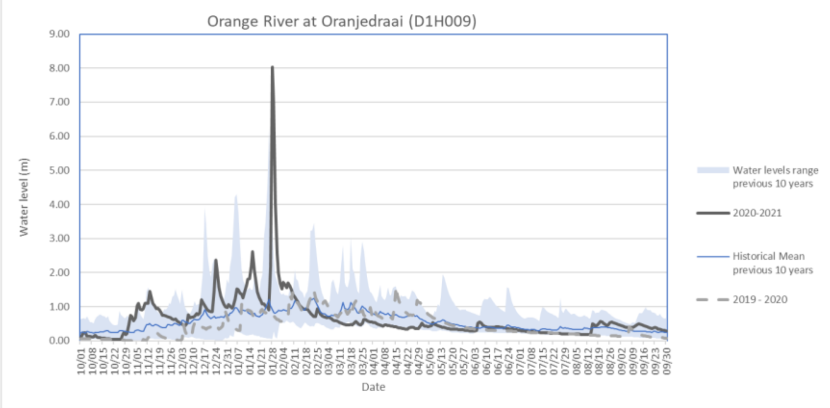
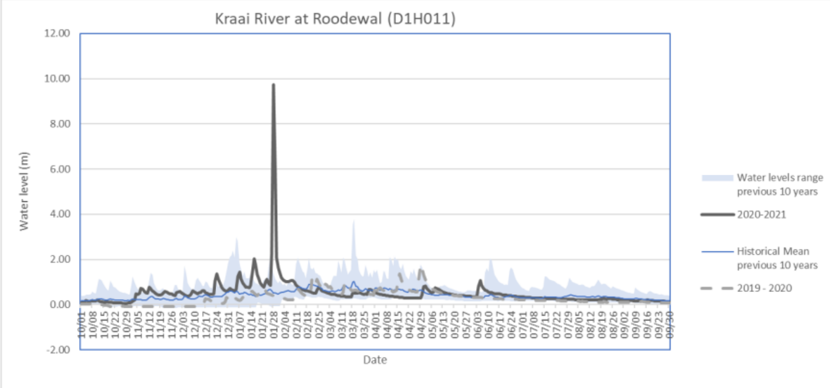
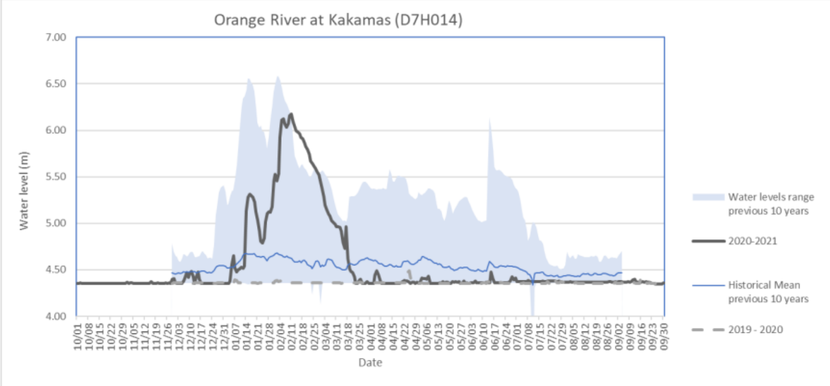


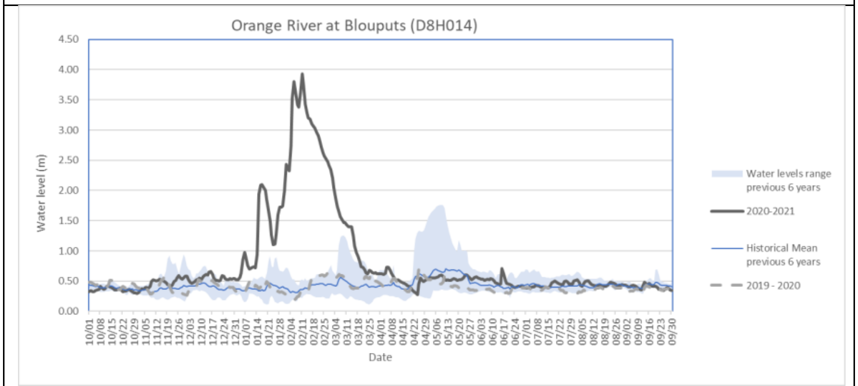
Figure 13: Stage hydrographs in 2020-2021 hydrological year at key river gauges.

Stage hydrographs at different gauging stations









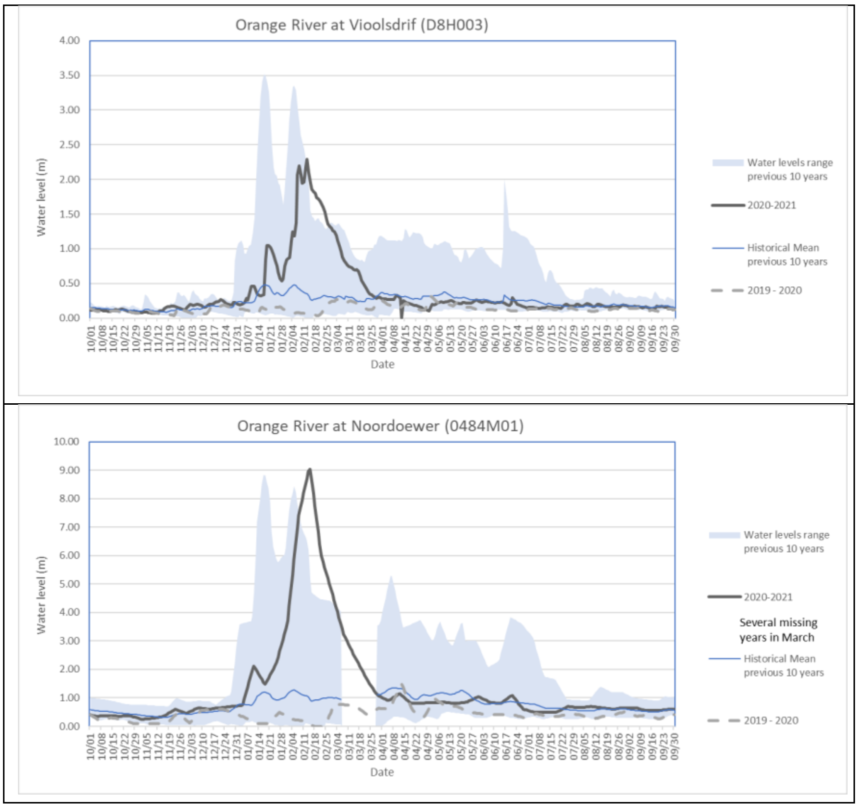


Figure 14: Stage hydrographs at different gauging stations, with comparison with past 10 years

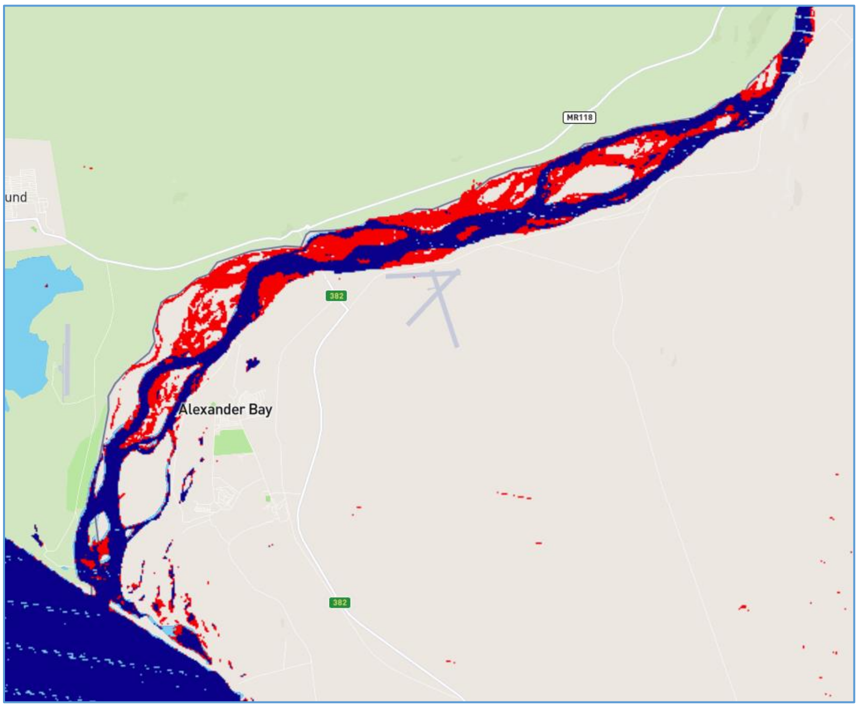


Figure 15: Inundation of floodplain close to river mouth between 19 Feb 2021 and 31 March 2021 in red, as in UNU-INWEH Flood Mapping Tool (2022). (Ernest Oppenheimer bridge is crossing R382)

7 CHALLENGES IN MONITORING AND OBSERVATION

The status of the monitoring and observations is a considerable concern. The gauges chosen for reporting on in this report, are a few key gauges for this synoptic surface water report, as chosen by the SWHC to assess transboundary impacts. More gauges will be necessary for river basin management. As can be seen from the graphs presented in this report, often records are not continuous, in particular in very wet months when the flows surpassed the rating curves. Apart from gauges not measuring flows, it also proofed challenging to obtain verified data months after the end of the hydrological year. Thus, not only the reliability and accuracy are a challenge, also the time it takes to get the data. Furthermore, transparency in the basin also requires transparency on operating rules, which were not made available for this report. It is important to get more insight in how upstream flow releases are influencing the flows downstream, in particular once agreement will be obtained on environmental flow requirements.

While the concerns below are genuine, it needs to be mentioned that all NHSs were very cooperative in trying to provide the data. A quality check on the data was not part of this assignment and thus not done. Remarks per reservoir or river gauge selected are provided in Appendix C.

All four countries lack field work means causing either delays in assessing the quality of the hydrological year data or preventing for any data to be included in this report. For Lesotho already since 2018 no field work has been done by the Ministry of Water. For South Africa, some stations (such as Wilgerdraai on the boundary of Lesotho) have been disbanded and others have some delay in verification of data. For Botswana, the two river gauges cannot be used as a rating curve was not made, due to lack of field work. For Namibia there has been a challenge in visiting stations, resulting in Auob River stations and Neckartal dam data not having been incorporated in this report.

Additionally, it proved very cumbersome to get data of the flows of the transfer schemes, while these are managed flows in and out of basins and one would expect records to be kept of those. For some stations, the flows were derived from pumping electricity used, rather than from water measurements.

Also, quite some of the gauges could not measure the peak flows of 2020-2021, in particular in February 2021, due to their rating curves not being calibrated for such high flows. As high flows are rare, and field work during peak flows is difficult, a rating curve could also be assessed by modelling rather than fieldwork, but nevertheless field work during high flows would considerably improve estimates of flows.

For many of the reservoirs, there was no full water balance available, and in terms of flows in particular inflow records were lacking (as shown in Appendix B). Evaporation pan data were not obtained.

Thus, all four countries face challenges in observations and monitoring which will need attention.

8 CONCLUSION

The hydrological year 2020-2021 was wetter than previous years, with major flows in February partly as a result of cyclone Eloise. Gariep reservoir already started spilling in January, and most of the other reservoirs in the Vaal and in the Orange spilled in February. However, the Lesotho reservoirs Katse and Mohale did not reach capacity. Transfers were quite normal, except for transfers from the Tugela reservoir which was relatively high compared to previous years.

The status of the monitoring network is a concern. Apart from gauge data not being available, the time from then end of the hydrological year until verification of the data was considerable.

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APPENDIX A: OVERVIEWS OF BASIN

The maps below are from earlier publications of ORASECOM, for readers to orientate themselves in the basin. Copied from ORASECOM (2012) which has many more detailed schematics.

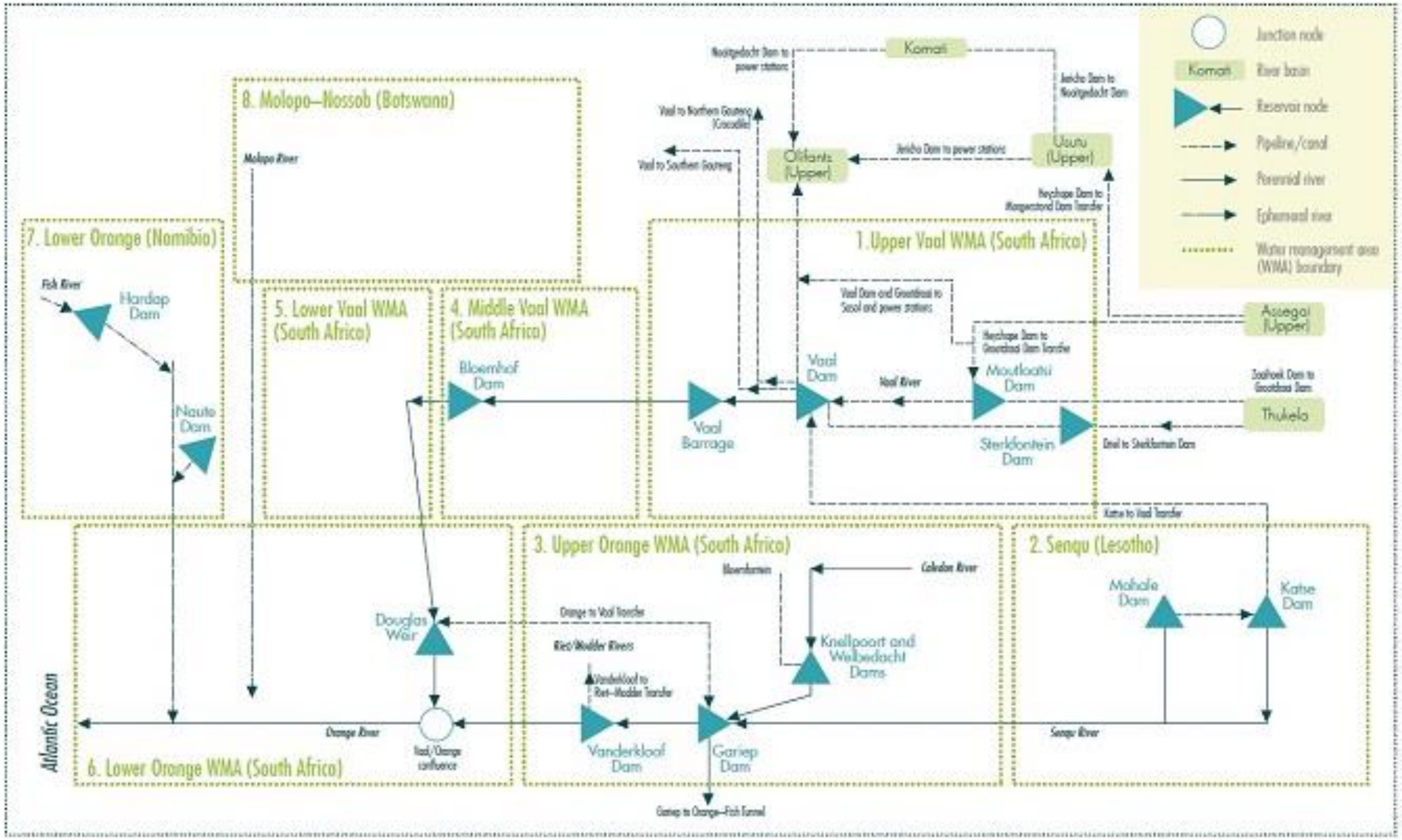


Figure 16: Integrated schematic of Orange-Senqu Basin as in ORASECOM (2012)

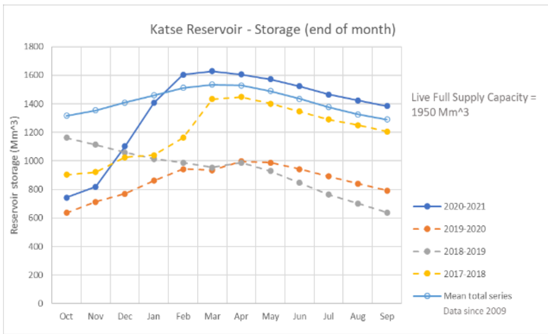
Figure 17:: Map of Orange-Senqu Basin as in ORASECOM (2012)

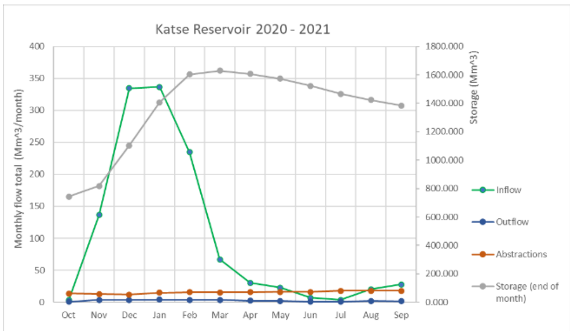
APPENDIX B: OVERVIEWS OF RESERVOIR WATER BALANCES

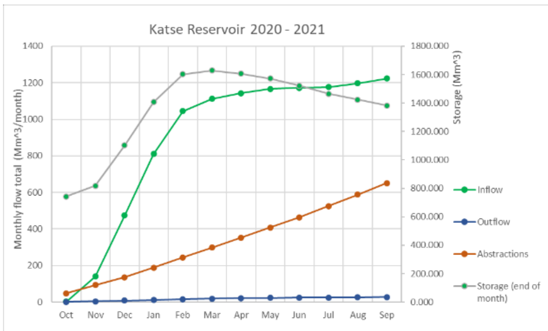
In this Appendix the other data available for the reservoirs are shown.

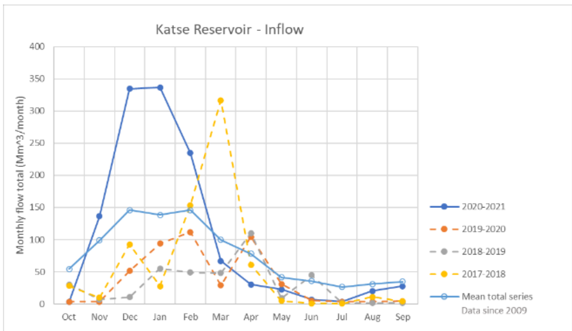
Katse Reservoir (Lesotho)

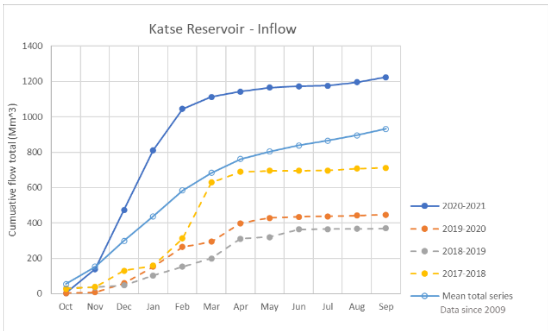
The Katse reservoir is on the Senqu River and receives transfers from Mohale Reservoir which is not accounted for in the inflow graph. From Katse, water is transferred to the Vaal catchment in South Africa.

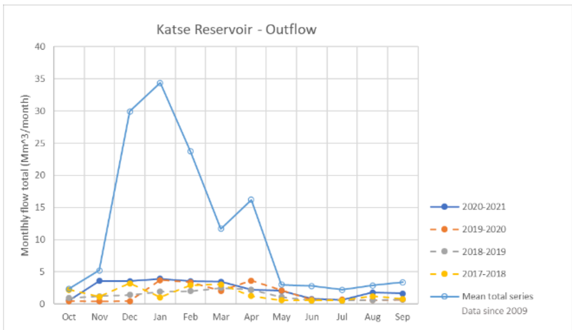


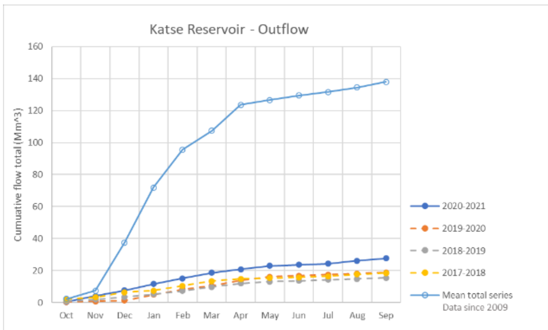












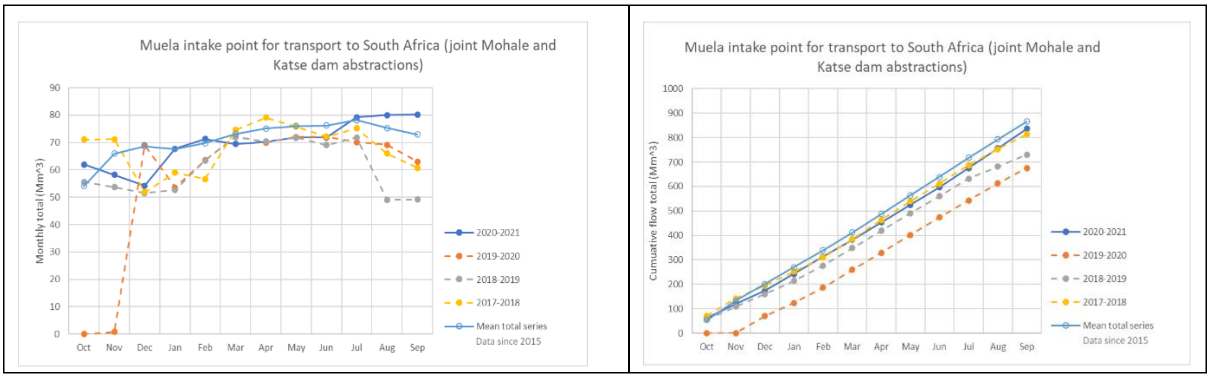
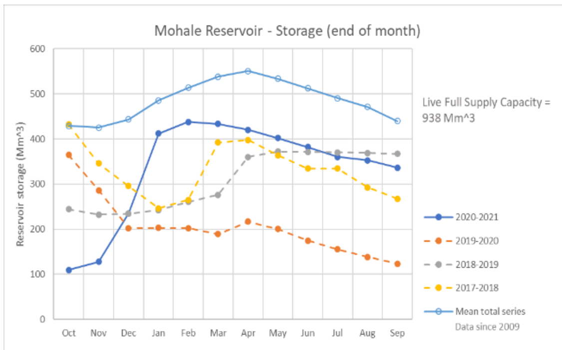
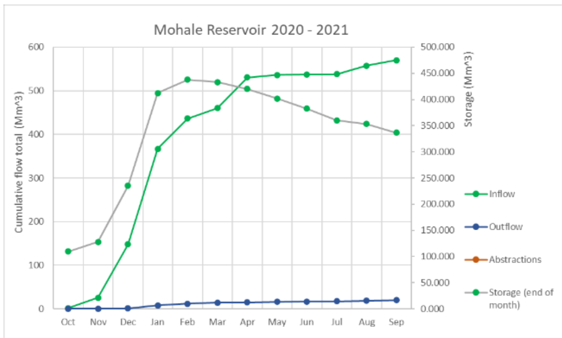


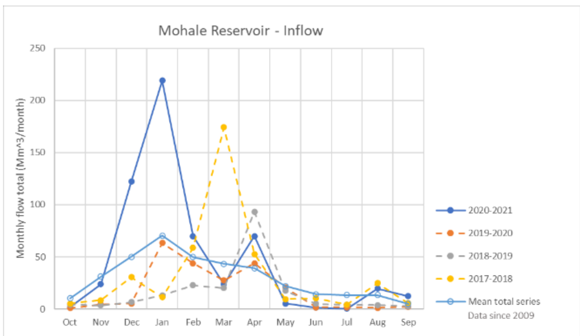
Figure 18: Katse Reservoir data

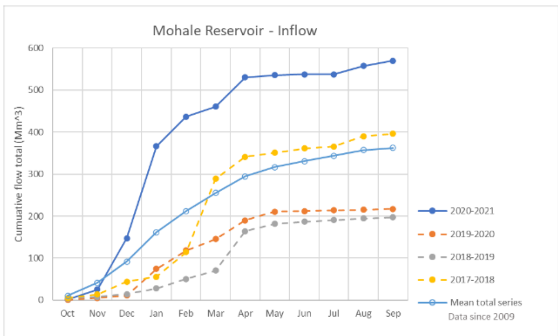
Mohale Reservoir (Lesotho)

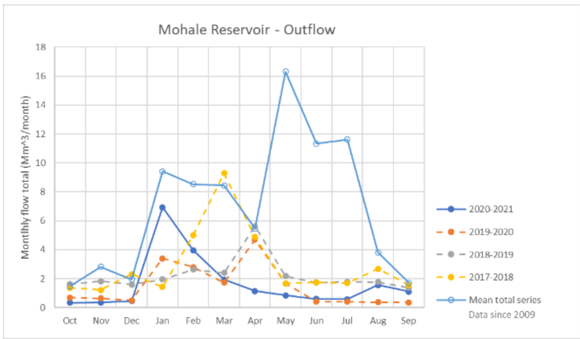
Mohale Reservoir is transferring water to Katse dam and feeds the Senqu River.

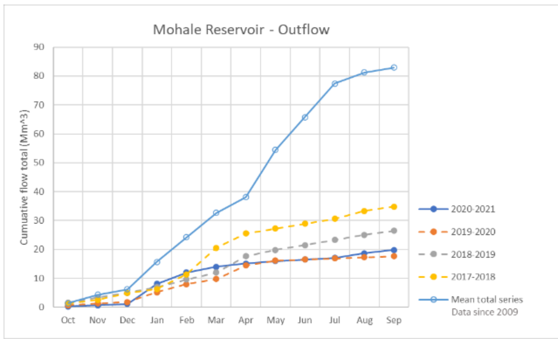










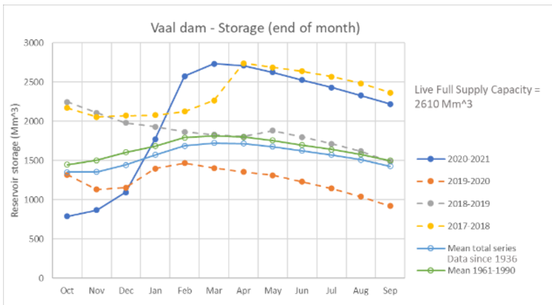


Abstraction data for the transfer to Katse Reservoir were not provided.

Figure 19: Mohale Reservoir data

Vaal Reservoir (South Africa)

Vaal Reservoir is in the Upper Vaal water management area and receives inflows coming from the upstream Grootdraai and Sterkfontein Reservoirs, which are partly fed by transfers from Thukela River and for Grootdraai, also from Assegaai River. Upstream of the Vaal dam also the transfer from Katse comes in.

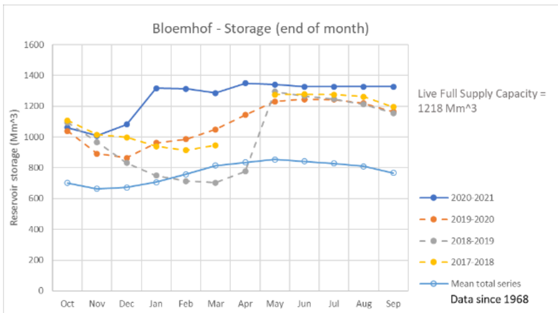


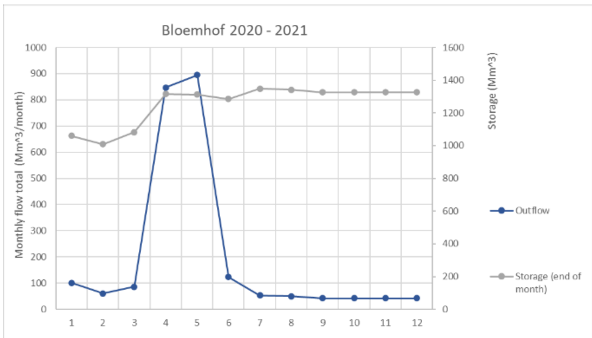
For 2020-2021 only storage records were made available, therefore no separate graphs for 2020-2021 are presented here, as this information is also in graph above.

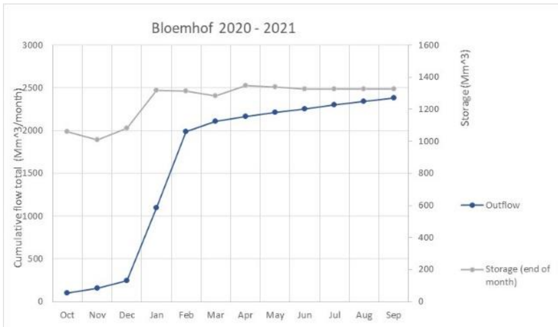
Figure 20: Vaal Reservoir data

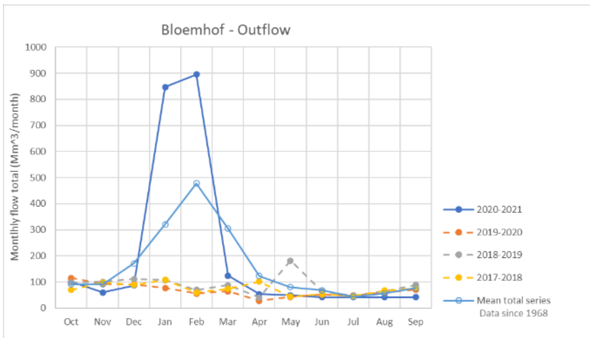
Bloemhof Reservoir (South Africa)

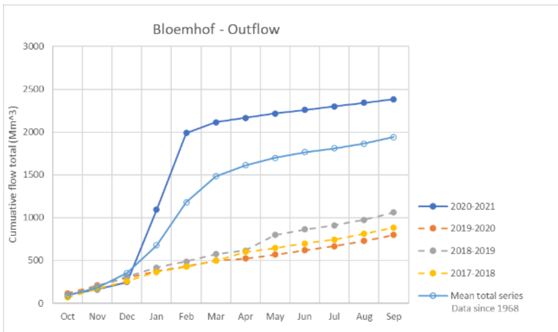
Bloemhof reservoir is in the Middle Vaal water management area.









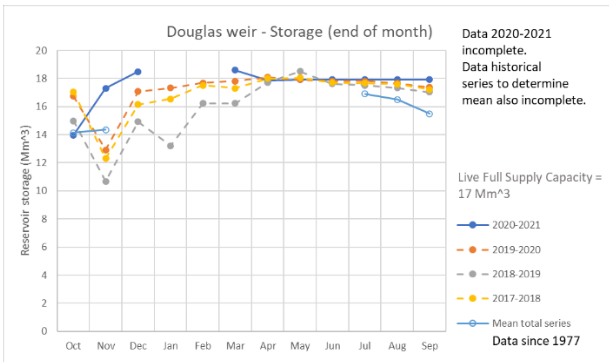


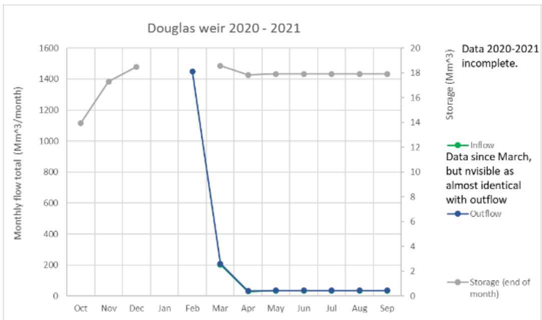
No inflow data were provided. Abstraction does not take place directly from the reservoir.

Figure 21: Bloemhof Reservoir data

Douglas Weir (South Africa)

Douglas Weir is in the Lower Orange water management area. It is fed by the Vaal River downstream of Bloemhof Reservoir.



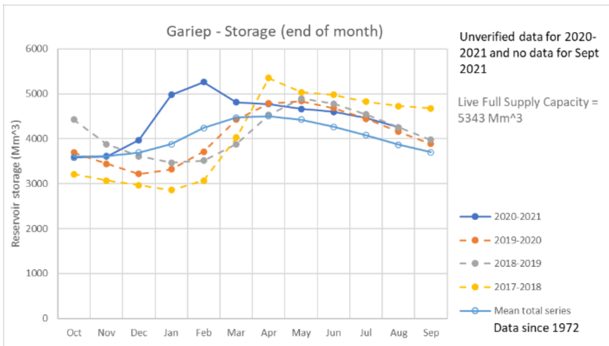


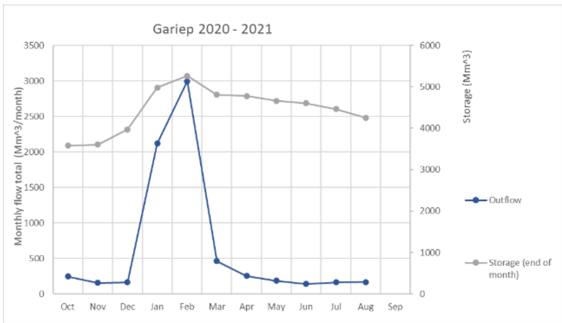
Due to lack of data, no further graphs for Douglas Weir.

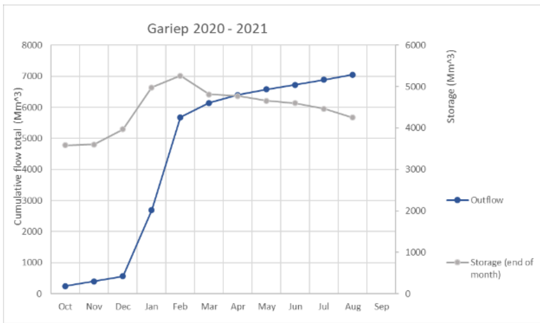
Figure 22: Douglas Reservoir data

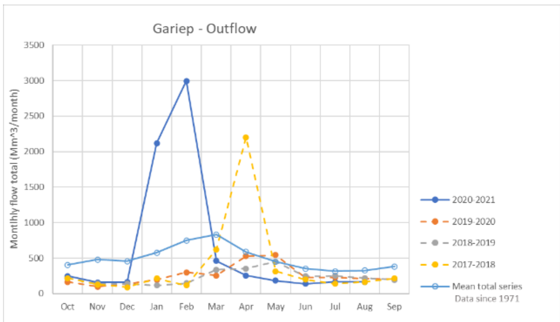
Gariep Reservoir (South Africa)

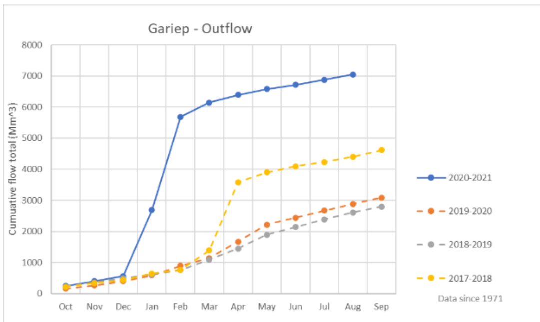
Gariep Reservoir is in the Upper Orange water management area, downstream of Mohale, Katse, Knellpoort and Welbedacht dams. Transfers from Gariep go to the Fish River.









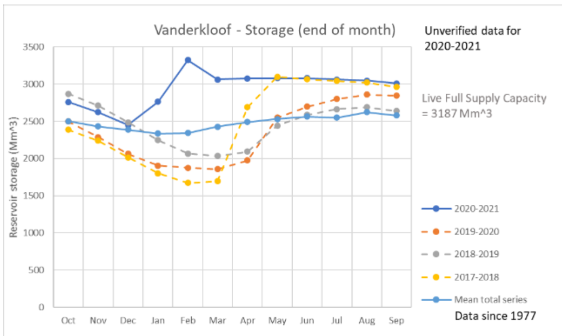


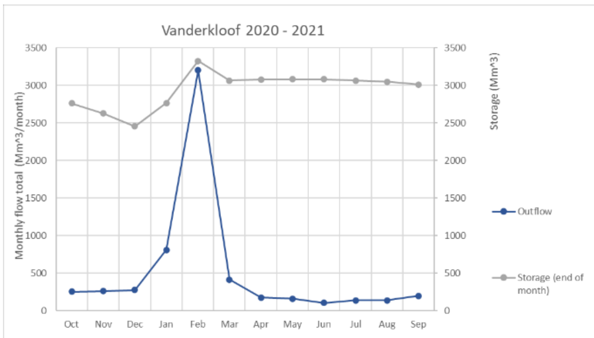
No inflow data available. No major abstraction in reservoir itself.

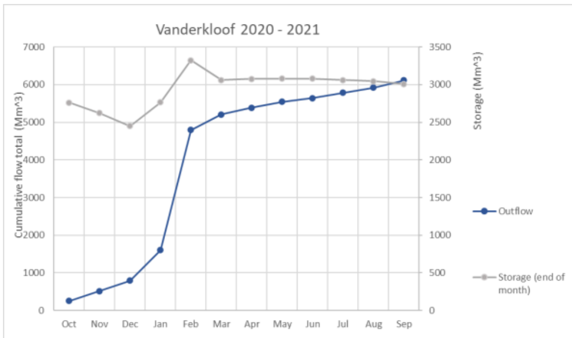
Figure 23: Gariep Reservoir data

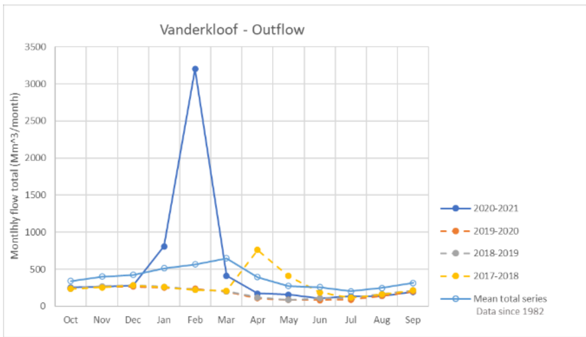
Van der Kloof Reservoir (South Africa)

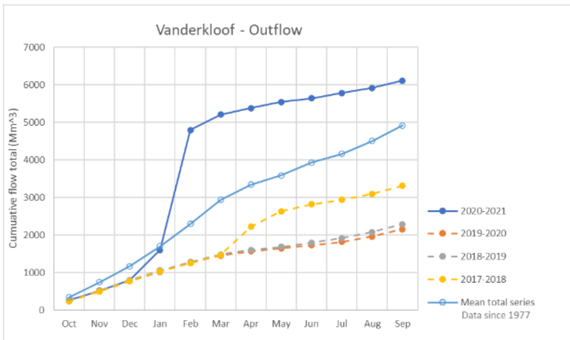
Van der Kloof Reservoir is in the Upper Orange water management area, downstream of Gariep Reservoir.









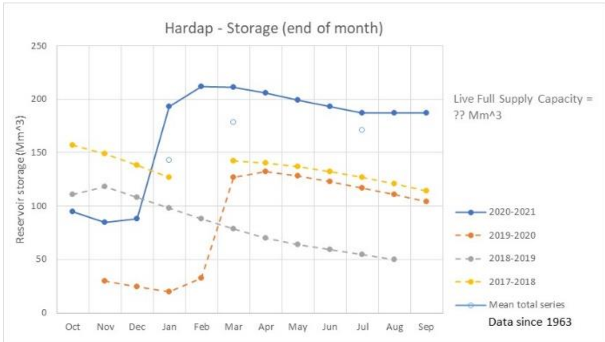


No inflow data available. No major abstraction in reservoir itself.

Figure 24: Van der Kloof Reservoir data

Hardap Reservoir (Namibia)

Hardap Reservoir is on a tributary of the upper Fish River.

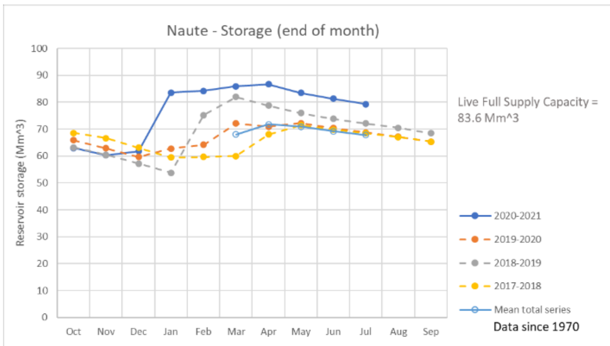


For Hardap Reservoir only storage records are available.

Figure 25: Hardap Reservoir data

Naute Reservoir (Namibia)

Naute Reservoir is on a tributary of the Fish River.



For Naute Reservoir only storage records are available.

Figure 26: Naute Reservoir data

Neckartal Reservoir data were not available for 2020-2021.

APPENDIX C: SELECTION OF GAUGES AND STATUS OF GAUGES CONSULTED

The table below gives an overview of the gauges selected by the SWHC for reporting in this first annual hydrological report. Quality checks on rating curves and data have not been done. The description and judgement are based on the length and reliability of the record only. The order of the gauges is as per the order of this report.

For the selection of gauges or locations to be included in this synoptic hydrological report, a long list of stations was made using the following criteria. But the final decision on whether these were relevant and had data, the SWHC vetted the selection of the locations also keeping in mind that the report had to be synoptic (short), thus not all stations that made the individual criteria made it in this selection. The criteria were:

- Crucial according to Transboundary Diagnostic Analysis (ORASECOM, 2014)
- Crucial according to the interviews / workshops with the individual Member States representatives from the NHSs
- Added as a result of the SWHC meeting of 18 October 2021
- Reported on in Namibia annual report (last version 2015-2016)
- Reported on in South African annual report (last version 2019-2020)
- Reported on in Lesotho Highlands Development Authority in most recent Instream Flow Requirements report 2015-2016.
- Relevant to determine Instream Flow Requirements according to Louw and Koekemoer (2010)
- Monitored real time in surface water monitoring system of South Africa (https://www.dws.gov.za/Hydrology/Daily/Default.aspx)
- Gauges used in Haasbroek et al. (2011) where it is recommended that “it is of the utmost importance that at least the stations used for this analysis be maintained to ensure ongoing monitoring”

The excel-sheet with scoring on the separate criteria Is provided to SWHC separately.

Legend of colour coding for remarks about monthly data received
Data record suitable for reporting
Data challenges, but still able to display 2020-2021.
Data record not available for use in 2020-2021 report.

Type	Country	Code	Description	Type	Remarks about monthly data received	2020-2021 missing	2020-2021 not complete but partly there	Recent three years not complete	Many gaps / impossible values in historical data	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
RIVER FLOWS											
	Lesotho	CG70	Mohokare basin - West (not official description)	RIV	Data not available since 2018.	1				-29.63098333	27.06088523
	Lesotho	MG21	Makhaleng	RIV	Data not available since 2018.	1				-30.08991869	27.43312371
	Lesotho	SG3	Senqu	RIV	Data not available since 2018.	1				-30.3652473	27.59023354
	South Africa	D1H022	Wilgerdraai	RIV	* Data for 2020-2021 not available and also not for future years.	1				-29.61670505	27.06580502
	South Africa	D1H009	Orange River @ Oranjedraai	RIV	Data long (since 1958) and almost complete.	1				-30.33638	27.35861
	South Africa	D1H011	Kraai River @ Roodewal	RIV	Complete data set			1	1	-30.83058628	26.92066523
	South Africa	D7H014	Orange River @ Kakamas South Neusberg	RIV	Complete data set			1	1	-28.77350321	20.74398098
	South Africa	D8H014	Orange River at Blouputs	RIV	* February monthly data missing for 2021 due to beyond range of rating curve. Data since 2014.					-28.51324501	20.18724943
	Namibia	0480M01	Orange River at Blouputs	RIV	* Monthly & daily data February 2021 missing, due to beyond range of rating curve.		1			-28.51324501	20.18724943
	South Africa	D8H003	Orange River @ Vioolsdrif	RIV	* Complete data set.			1	1	-28.76125532	17.72904695
	Namibia	3124M02	Stampriet on Auob River	RIV	* Monthly record 2020-2021 missing and part of 2019-2020 * Daily water level data missing since 13 April 2020	1		1		-24.33118611	18.42743056
	Namibia	3124M01	Gochas on Auob River	RIV	* Monthly record ok. * Daily water level data missing since 13 April 2020		1			-25.01657778	18.88509444
	Namibia	0484M01	Orange River at Noordoewer	RIV	* For monthly data February and September 2021 missing.		1			-28.72253589	17.60821183

Type	Country	Code	Description	Type	Remarks about monthly data received	2020-2021 missing	2020-2021 not complete but partly there	Recent three years not complete	Many gaps / impossible values in historical data	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
					* For daily water level data, almost complete, upto 26 September 2021						
	Namibia	0499M02	Ai-Ais on Fish River	RIV	* Monthly data upto April 2021, daily upto 7 May 2021		1			-27.920376	17.48709841
	Namibia	0485M02	Orange River at Sendelingsdrif	RIV	* Monthly data 2020/2021 missing. * Daily water level data 2020/2021 missing	1	1			-28.12503623	16.89008624
	Botswana	Lepurung	Lepurung (data not reported on but available)	RIV	Data not available as still to make rating curve. Installed after Cyclone Dineo in 2017.	1				-25.75485092	24.98356699
	Botswana	Bray	Bray (data not reported on but available)	RIV	Data not available as still to make rating curve. Installed after Cyclone Dineo in 2017.	1				-25.46235633	23.70515221
RESERVOIRS											
	Lesotho	Katse dam	Katse dam	RES	* Storage, abstraction and inflow data available. Outflow not.					-29.33718427	28.50613051
	Lesotho	Mohale dam	Mohale dam	RES	* Storage, abstraction and inflow data available. Outflow and transfer to Katse dam not.					-29.4580212	28.0963004
	South Africa	D3R002 for storage	Orange River @ Gariep Dam	RES	* Only storage data and outflow data available for 2020-2021. Verified data would only be available end of February 2022		1			-30.62323998	25.50678001
	South Africa	D3H013	Orange River downstream Gariep Dam	RES (out-flow)	* Good record from 1973, but for 2020-2021 August and September still missing.					-30.62323998	25.50678001
	South Africa	D3R003	Orange River @ Vanderkloof Dam	RES	* Only storage data and outflow data available for 2020-2021. Verified data would only be available end of February 2022		1			-29.99149	24.73189
	South Africa	D3H012	Orange River downstream VanderKloof Dam	RES (out-flow)	* Good record since 1981						

Type	Country	Code	Description	Type	Remarks about monthly data received	2020-2021 missing	2020-2021 not complete but partly there	Recent three years not complete	Many gaps / impossible values in historical data	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
	South Africa	C1H001	Vaal River @ Langverwyl (Grootdraai releases)	RES (out-flow)	Data not available since 1993.	1				-26.94244	29.26388
	South Africa	C1R001	Vaal River @ Vaal Dam	RES	* Inflow & outflow data missing, in particular of recent years and 2020-2021 recent year. * Some inflow data, which are supposed to be good quality, have negative values * No abstractions available (they happen at Vaal barrage downstream)	1		1		-26.88234	28.11607
	South Africa	C2H003	Vaal River @ Elandsfontein (Vaal dam releases)	RES (out-flow)	Data not available.	1				-26.82022	28.0633
	South Africa	C9R002	Vaal River @ Bloemhof Dam	RES	* Some inflow data are negative, and mostly missing for recent years.		1			-27.66922	25.61657
	South Africa	C9R003	Vaal River @ Douglas Weir	RES	* Storage data missing for first part of 2020-2021 season * Outflow data missing for 2020-2021 season and recent years * Inflow data incomplete for recent years including 2020-2021 and historic years		1	1	1	-29.04404	23.83518
	Namibia	0497R01	Naute Dam	RES	* Inflow and outflow data not available for most of 2020-2021 * Storage data only available until July 2021		1			-26.9319643	17.93791561
	Namibia	Unknown	Neckartal Dam	RES	Data not available for 2020-2021	1				-26.72096718	17.80045062
	Namibia	0492R02	Hardap Dam	RES	* Inflow and outflow not available for most of 2020-2021 season. * Storage data only available until July 2021		1			-24.49950113	17.85848495
TRANSFERS											

Type	Country	Code	Description	Type	Remarks about monthly data received	2020-2021 missing	2020-2021 not complete but partly there	Recent three years not complete	Many gaps / impossible values in historical data	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
	South Africa	C8H036	Katse-Vaal tunnel inlet @Botterkloof	TRANSFER INTERNAL	* Only data of 2020-2021. Missing historical data.			1	1	-29.1727569	28.48297033
	South Africa	W5H028	Assegaai to Grootdraai @Geelhoutboom	TRANSFER IN	* Only data of 2020-2021. Missing historical data. (26:54:32 30:15:56)			1	1		
	South Africa	Unknown	Zaaihoek Dam to Grootdraai Dam	TRANSFER IN	* Data not received for 2020-2021.	1				-26.91053046	29.30774029
	South Africa	Electricity estimate	Driel to Sterkfontein Dam (Kilburn)	TRANSFER IN	* No data available from DWS. Estimates received on Kilburn to Sterkfontein from Eskom based on sales figures of electricity.	1				-28.47304489	29.02971539
	South Africa	D3H032	Orange-Fish tunnel inlet from Gariep	TRANSFER OUT	Complete data set					-30.69080338	25.76276584