May 2024

MONTHLY STATE OF WATER BULLETIN

WATER IS LIFE - SANITATION IS DIGNITY

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

Overview

South Africa experiences winter rainfall in the western parts of the country and summer rainfall, which covers a significant portion of the eastern part of the country. In the Western Cape, the Winter rainfall season has commenced, with the southwestern tip of the country experiencing a Mediterranean climate with hot summers and cool, wet winters.

At the end of May 2024, the national dam levels were at **85.5%** of Full Supply Capacity (FSC). This level is lower than last year, where the national storage was at **93.3%** of FSC. Approximately **22%** of the dams nationally were **above 100% of FSC** (either full or spilling)**, 67%** were between **50 and 100%** of FSC, **10%** were between 10 and 50% of FSC, and at least **1%** were below 10% of FSC (critically low levels).

The most recent 24-month Standardised Precipitation Index revealed that the Namakwa District in the Northern Cape Province, the Thabo Mafutsanyane District in the Free State, the Sarah Baartman District in the Eastern Cape, and the Capricorn District in Limpopo were among the districts that experienced a severe drought. While a number of other districts, such as the Zululand District in KwaZulu-Natal, Gert Sibande District in Mpumalanga, Waterberg and Sekhukhune Districts in Limpopo, Ekurhuleni and Sedibeng Districts in Gauteng and the City of Cape Town in Western Cape only experienced moderate drought.

The Department has several strategic importance points for surface water monitoring. These strategic gauging stations contain long-term data which was used in this report to assess the deviation of total annual streamflow volume in the 2022/23 Hydrological Year from the long-term median (1980-2010). Most strategic points demonstrated a significant increase in the total annual flow volume in the 2022/23 HY compared to the 2021/22 HY. This can be attributed to well above-normal rainfall received over extensive parts of central South Africa due to ENSO's El Niño state.

Rainfall

The monthly rainfall distribution during the current hydrological year for the summer and winter seasons is presented in Figure 1 and Figure 2, respectively. May 2024 was dry and mild for most parts of the country over summer and winter rainfall regions. The country is currently in a weak El Niño-Southern Oscillation (ENSO), predicted to rapidly decline into a neutral state by mid-to-end of winter. However, as the summer has ended, minimal influence from the current El Niño event is expected. In May, 50-100 mm rainfall was observed over isolated parts of the KwaZulu-Natal, Western Cape, and Eastern Cape Provinces.

The monthly rainfall anomalies expressed as a percentage of normal rainfall for the summer season and the beginning of the winter season are presented in Figure 3 and Figure 4, respectively. Above-normal rainfalls were observed in isolated parts of the Western Cape, Eastern Cape, and KwaZulu-Natal Provinces. The South African Weather Service (SAWS) multi-model rainfall forecast has indicated mostly below-normal rainfall over most parts of the country during the June-July-August 2024 (JJA), July-August-September 2024 (JAS), and August-September-October (ASO) forecast periods (Figure 5). In JAS, only the northern parts of Mpumalanga are expected to receive slightly above-normal rainfall, while the southwestern parts of the country, which normally receive significant rainfall during the early winter season, are expected to receive mostly below-normal rainfall during this period. Moreover, minimum and maximum temperatures are expected to be mostly above-normal countrywide.

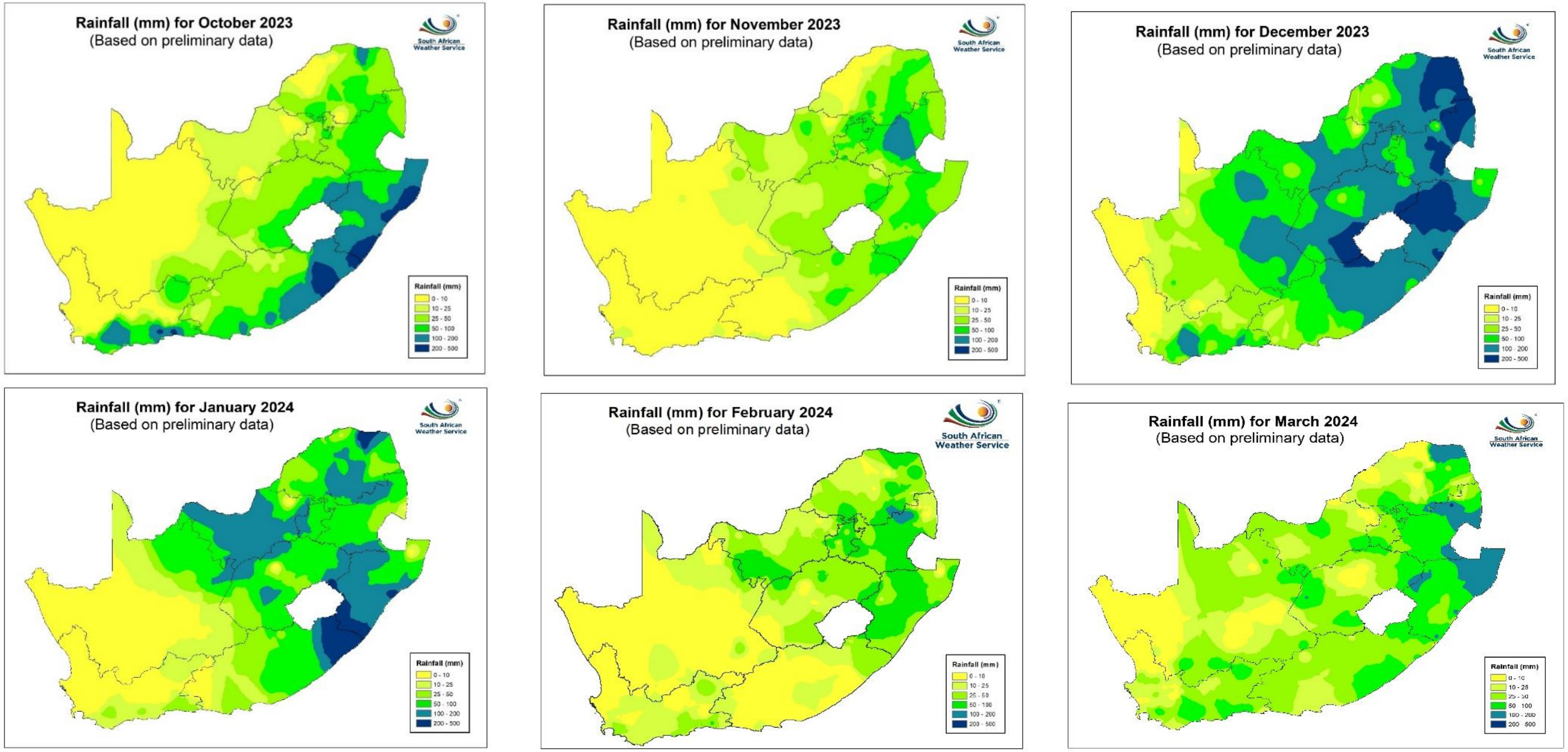


Figure 1: Summer season monthly rainfall distribution for October 2023 to March 2024 (Source: SAWS https://www.weathersa.co.za/home/historicalrain)

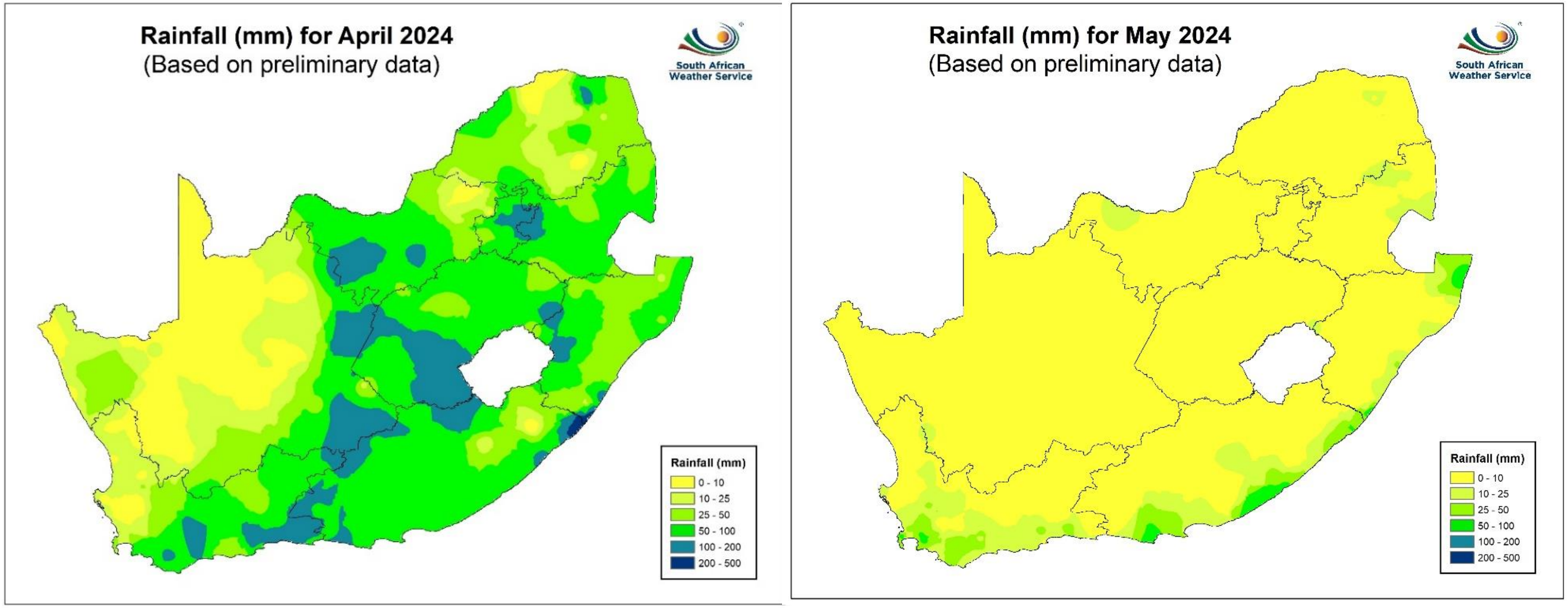


Figure 2: Winter season monthly rainfall distribution for April to May 2024 (Source: SAWS https://www.weathersa.co.za/home/historicalrain)

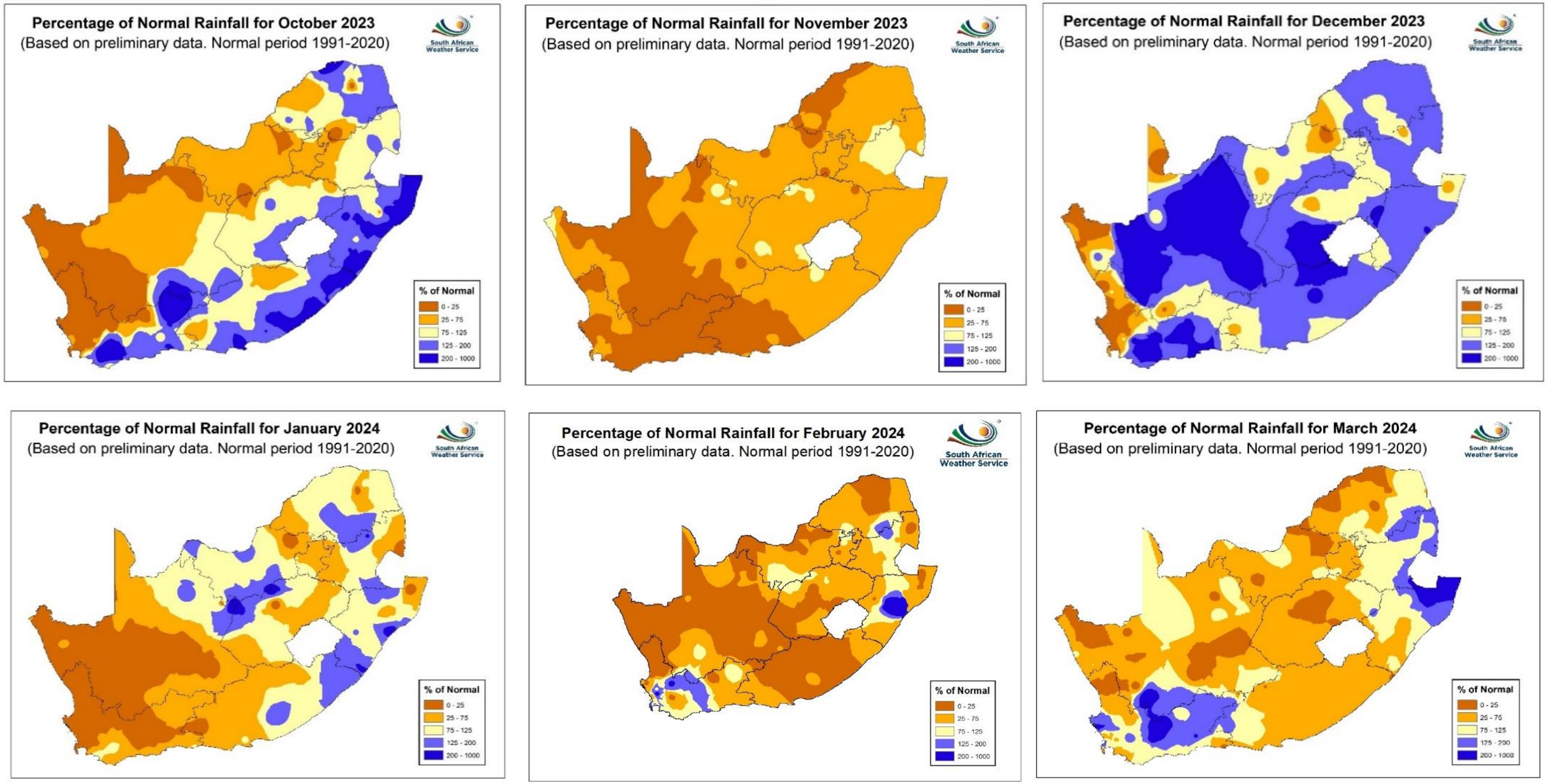
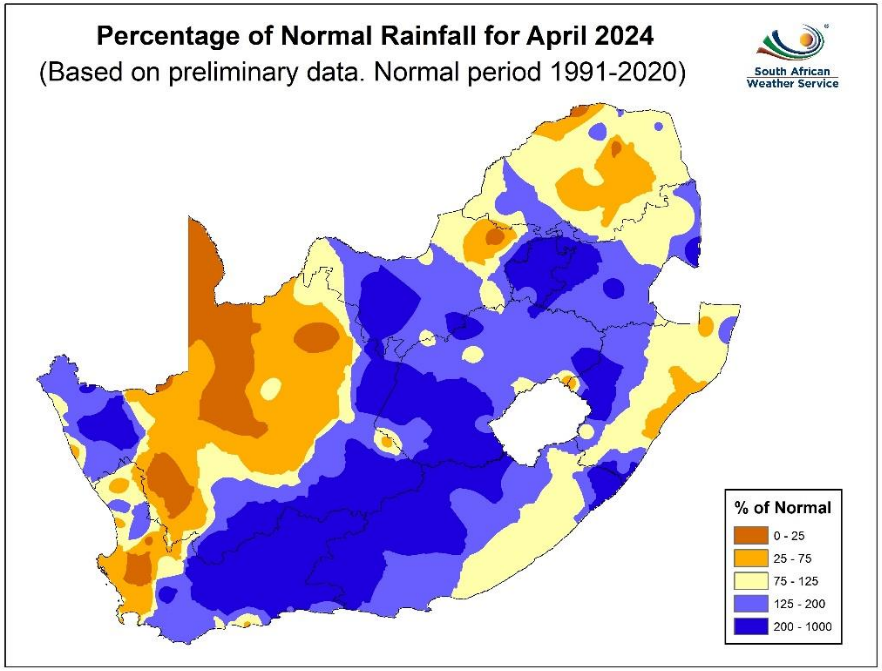


Figure 3: Summer season Percentage of normal rainfall for October 2023 to March 2024. Blue shades are indicative of above-normal rain, and the darker yellow shades of below-normal rainfall (Source: SAWS https://www.weathersa.co.za/home/historicalrain)



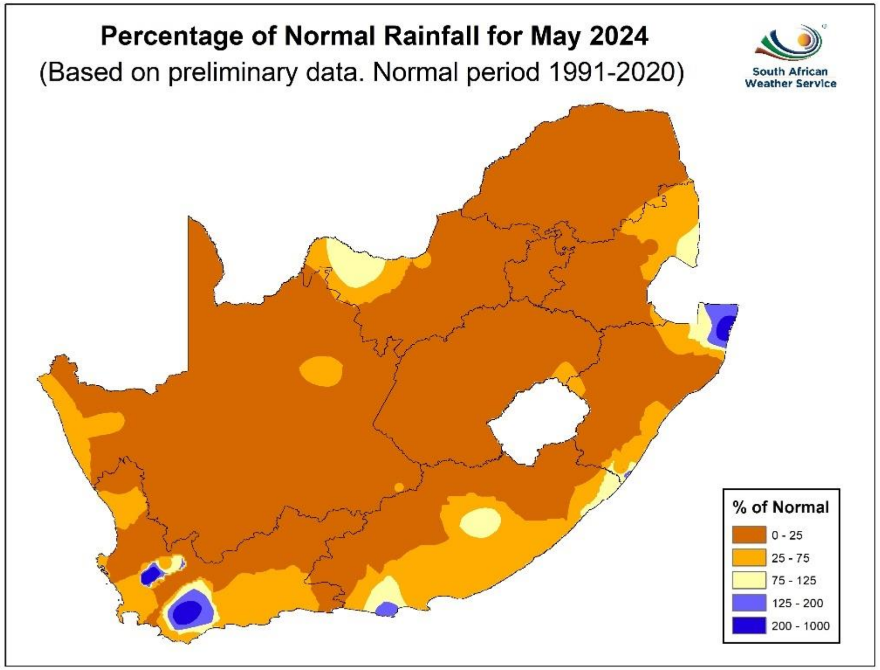


Figure 4: Summer season Percentage of normal rainfall for April to May 2024. Blue shades are indicative of above-normal rain, and the darker yellow shades of below-normal rainfall (Source: SAWS https://www.weathersa.co.za/home/historicalrain)

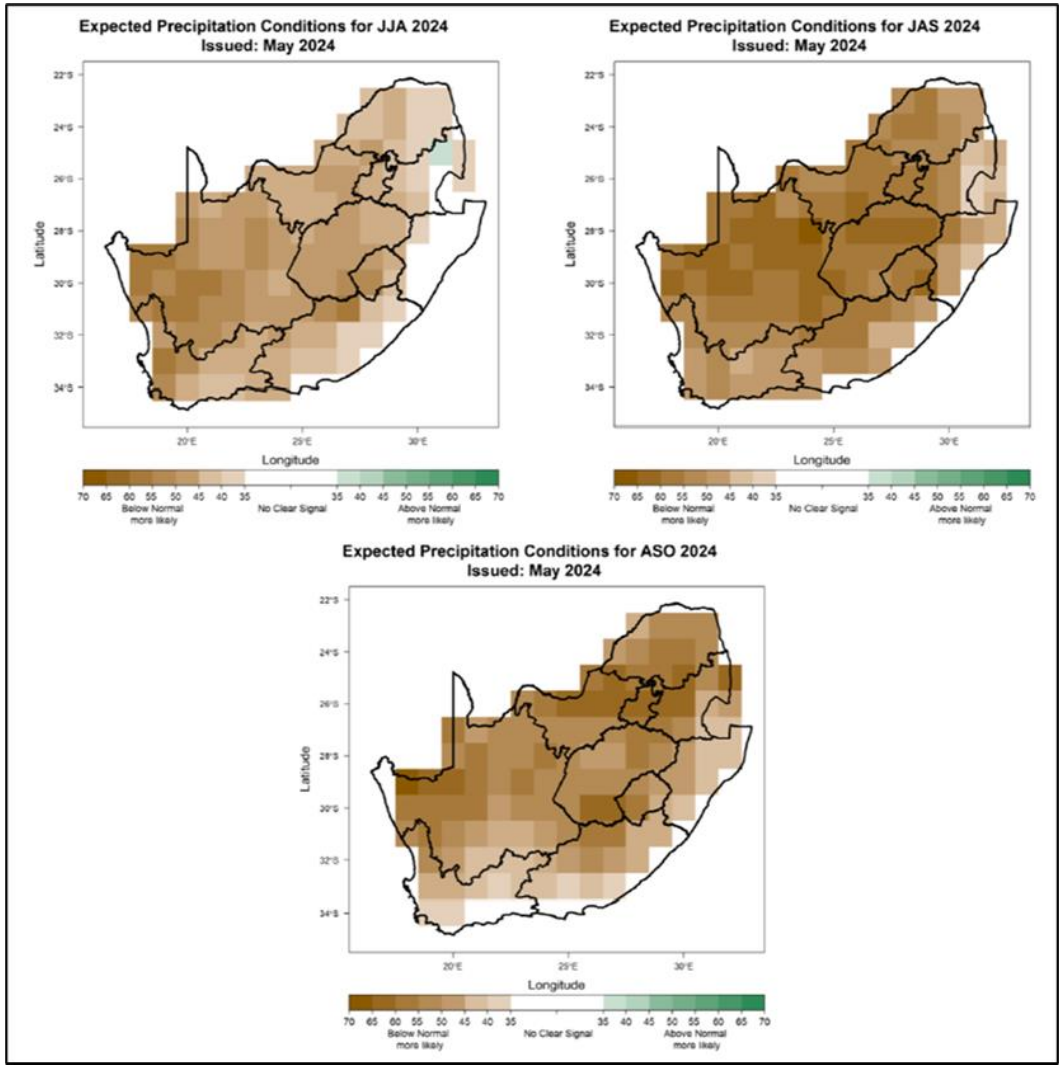


Figure 5: June-July-August 2024 (JJA; top left), July-August-September 2024 (JAS; top right), August-September-October 2024 (ASO; bottom) seasonal precipitation prediction. Maps indicate the highest probability of the above-normal and below-normal categories (Source: SAWS)

National Dam Storage

The national dam's water storage for the previous four years and the trend from October for the hydrological year 2023/24 are presented in Figure 6 below. At the end of May 2024, the national dam levels were at **85.5%** of Full Supply Capacity (FSC). This level is lower than last year, at the same time of reporting when national storage was at **93.3%** of FSC. Approximately **22%** of the national dams were **above 100% of FSC** (either full or spilling)**, 67%** were between 50 and 100% of FSC, **10%** were between 10 and 50% of FSC, and at least **1%** were below 10% of FSC (critically low).

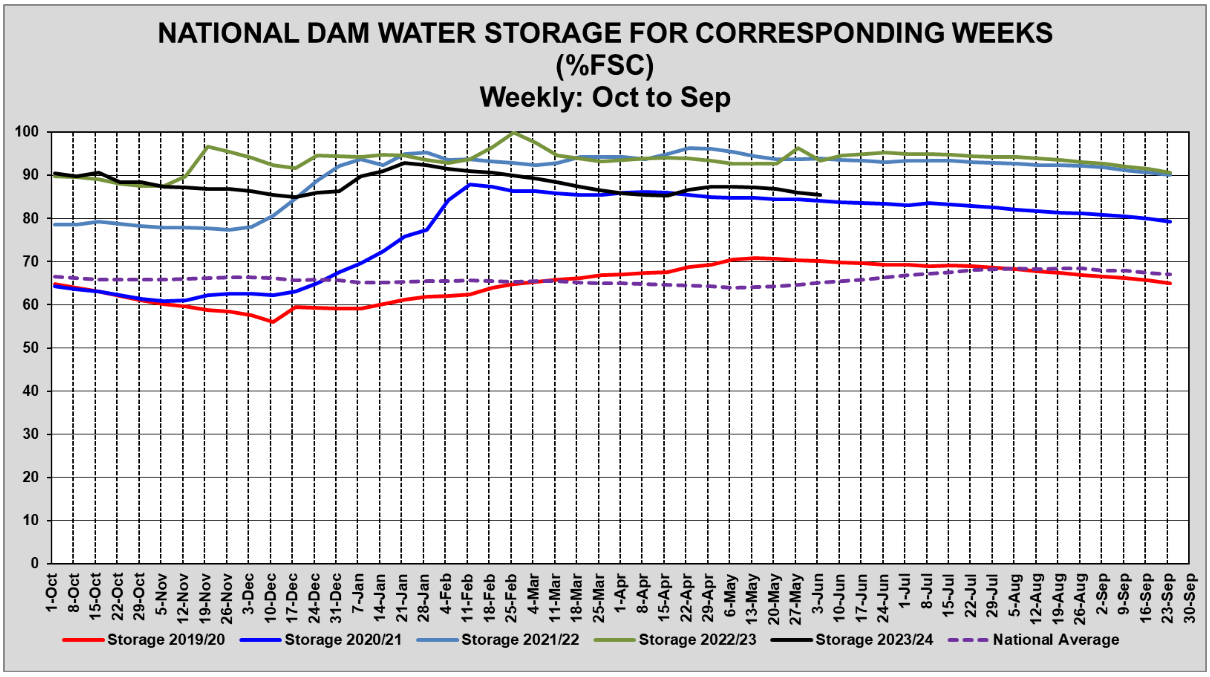


Figure 6: National Dam Storage on 27 May 2024

The comparison of the country's five largest dam storage %FSC for May 2023 and May 2024 is presented in Table 1. Due to the drier and warmer conditions experienced this summer compared to 2023, only Pongolapoort Dam, out of the five largest dams by volume, has a positive change at +0.7%, while the Vaal Dam storage levels have declined by -39.5%.

Table 1: Storage Levels comparison for the Five Largest storage Dams (by volume) to last year

Reservoir	River	Province/Country	27 May 2023 (%FSC)	27 May 2024 (%FSC)	% Change (-/+)
Gariep Dam	Orange River	Free State	96.1	82.6	-13.5
Vanderkloof Dam	Orange River	Free State	99.6	99.1	-9.5
Sterkfontein Dam	Nuwejaarspruit River	Free State	101.5	99.5	-2
Vaal Dam	Vaal River	Free State	96.8	57.3	-39.5
Pongolapoort Dam	Phongolo River	KwaZulu-Natal	85.4	86.1	+0.7

The spatial distribution of the dams with a classified range of their storage levels on 27 May 2024 is presented in Figure 7. An observation can be made that most of the dams across the country are at storage levels of between 50-100% of FSC. The Middle-Letaba Dam in Limpopo Province remains the only dam at critical levels, as given in Table 2 below.

Table 2: Dams below 10% of Full Supply Capacity compared to last year

Reservoir	River	Province/Country	27 May 2023 (%FSC)	27 May 2024 (%FSC)	% Change (-/+)
Middle-Letaba Dam	Middel-Letaba River	Limpopo	6.1	1.7	-4.4

Figure 8 presents the 24-month Standardised Precipitation Index (SPI) for April 2024, indicating that several District Municipalities have experienced droughts in the previous 24 months. The Namakwa District in the Northern Cape Province, the Thabo Mafutsanyane District in the Free State, the Sarah Baartman District in the Eastern Cape, and the Capricorn District in Limpopo were among the districts that experienced a severe drought. Moreover, other districts such as the Zululand District in KwaZulu-Natal, Gert Sibande District in Mpumalanga, Waterberg and Sekhukhune Districts in Limpopo, Ekurhuleni and Sedibeng Districts in Gauteng and the City of Cape Town in Western Cape only experienced moderate drought. The persistent below-normal rainfall in these districts is the cause of the drought conditions there.

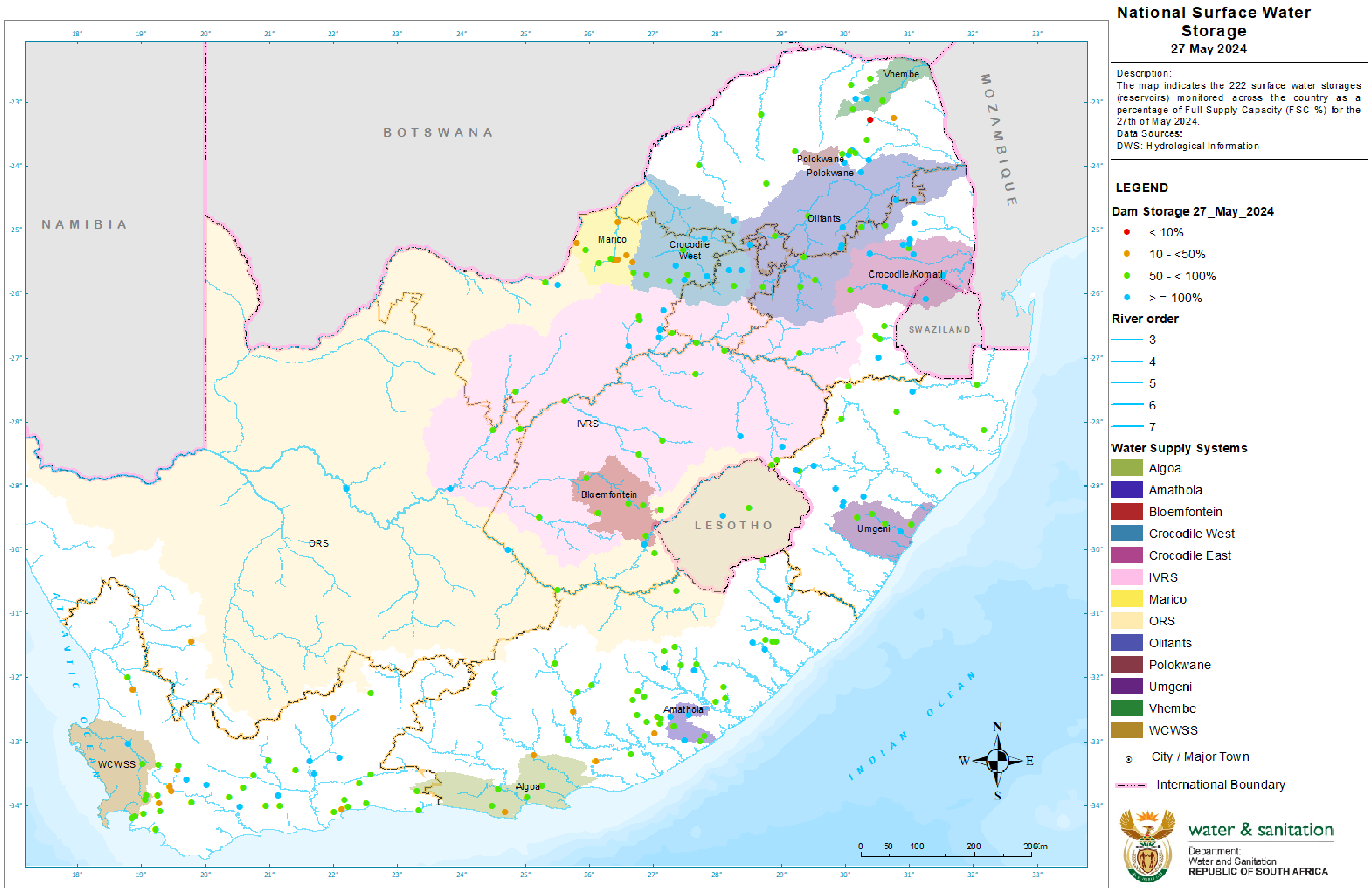


Figure 7: Surface Water Storage Levels - May 2024

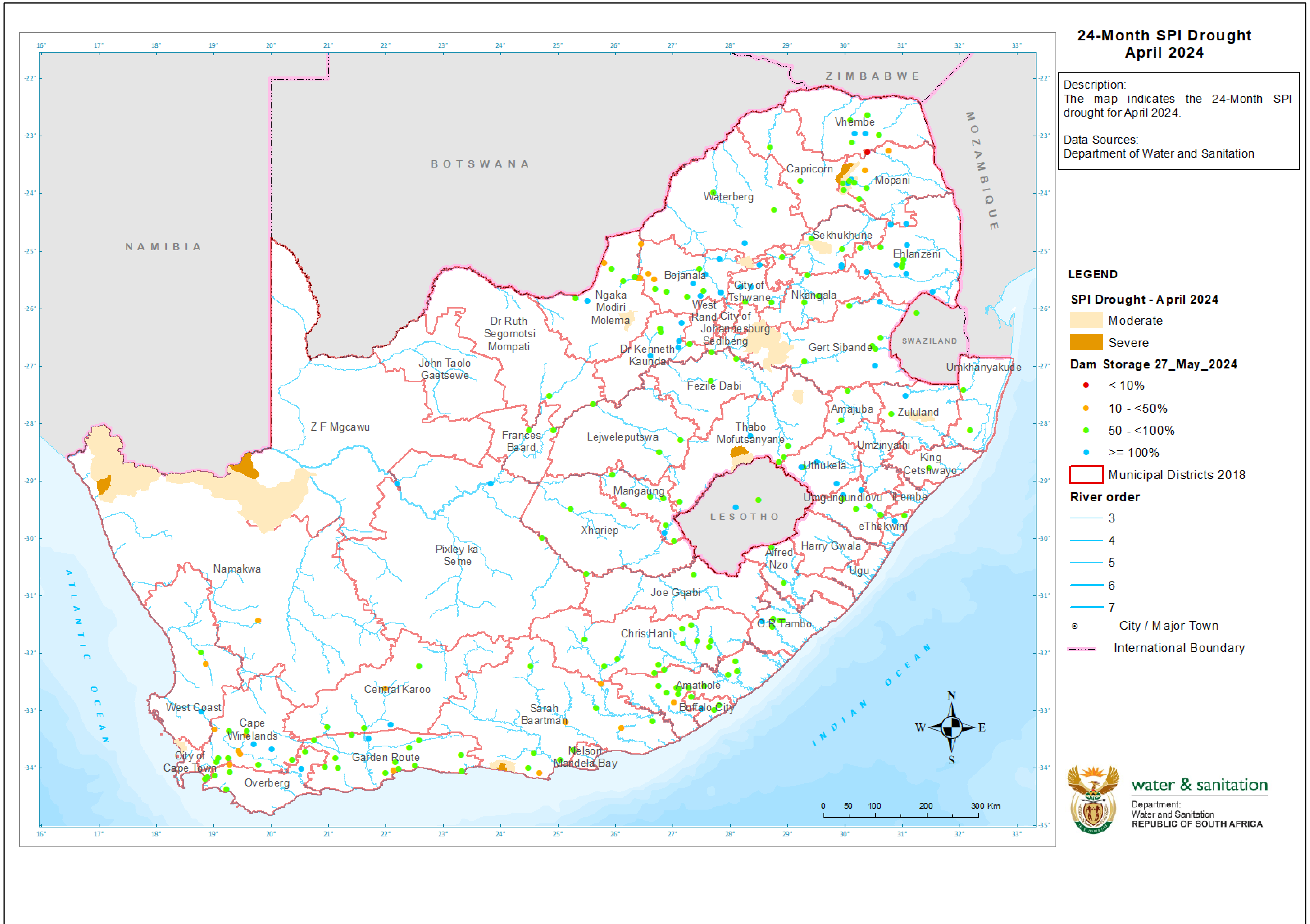


Figure 8: 24-month Standardised Precipitation Index (SPI) and dam levels

Figure 9 compares the storage levels per Province and international areas for May 2024 to the same time last year. Seven of the nine provinces presented a decline in dam storage levels compared to the previous year. The two provinces with increased dam storage levels were the Eastern Cape (+7.5% of FSC) and Western Cape (+7.6% of FSC), while the highest decline was in the Free State Cape (-11.3% of FSC).

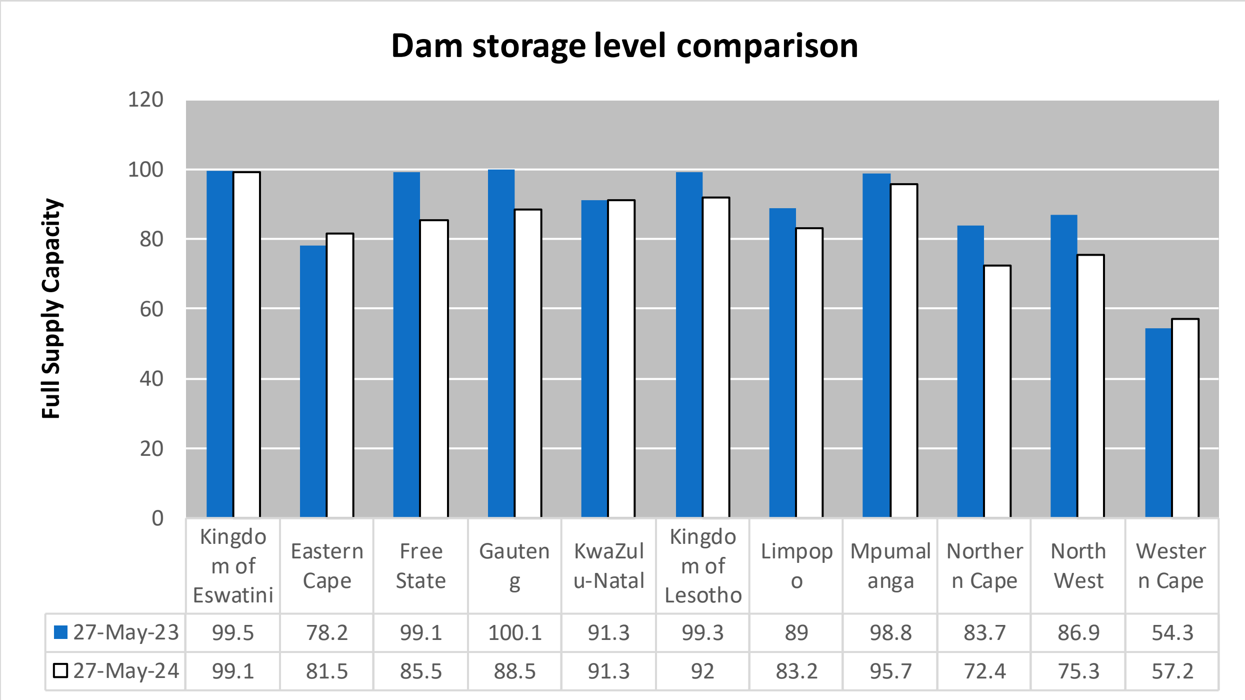


Figure 9: Water Storage Levels May 2023 vs. May 2024

District Municipalities

The year-on-year comparison of water storage levels per District Municipality (DM) is presented in Figure 10. Sarah Baartman DM, Garden Route DM, Central Karoo DM, and Namakwa DM experienced a significant increase (>20%) in dam storage levels compared to last year. In contrast, Ngaka Modiri DM, Fezile Dabi DM, and Sedibeng DM experienced significant declines (>-20%) in dam levels compared to last year.

The dam storage levels in water supply systems (WSSs) and applicable restrictions are presented in Table 3. The Algoa WSS decision date was changed from 1 June to 1 November, and a new annual operating analysis for the decision date was performed, resulting in an update of water restrictions which were effected from 1 November 2023 to 31 October 2024. However, these restrictions are yet to be gazetted.

Due to infrastructure limitations, permanent restrictions are applicable for the Polokwane and Bloemfontein WSSs.

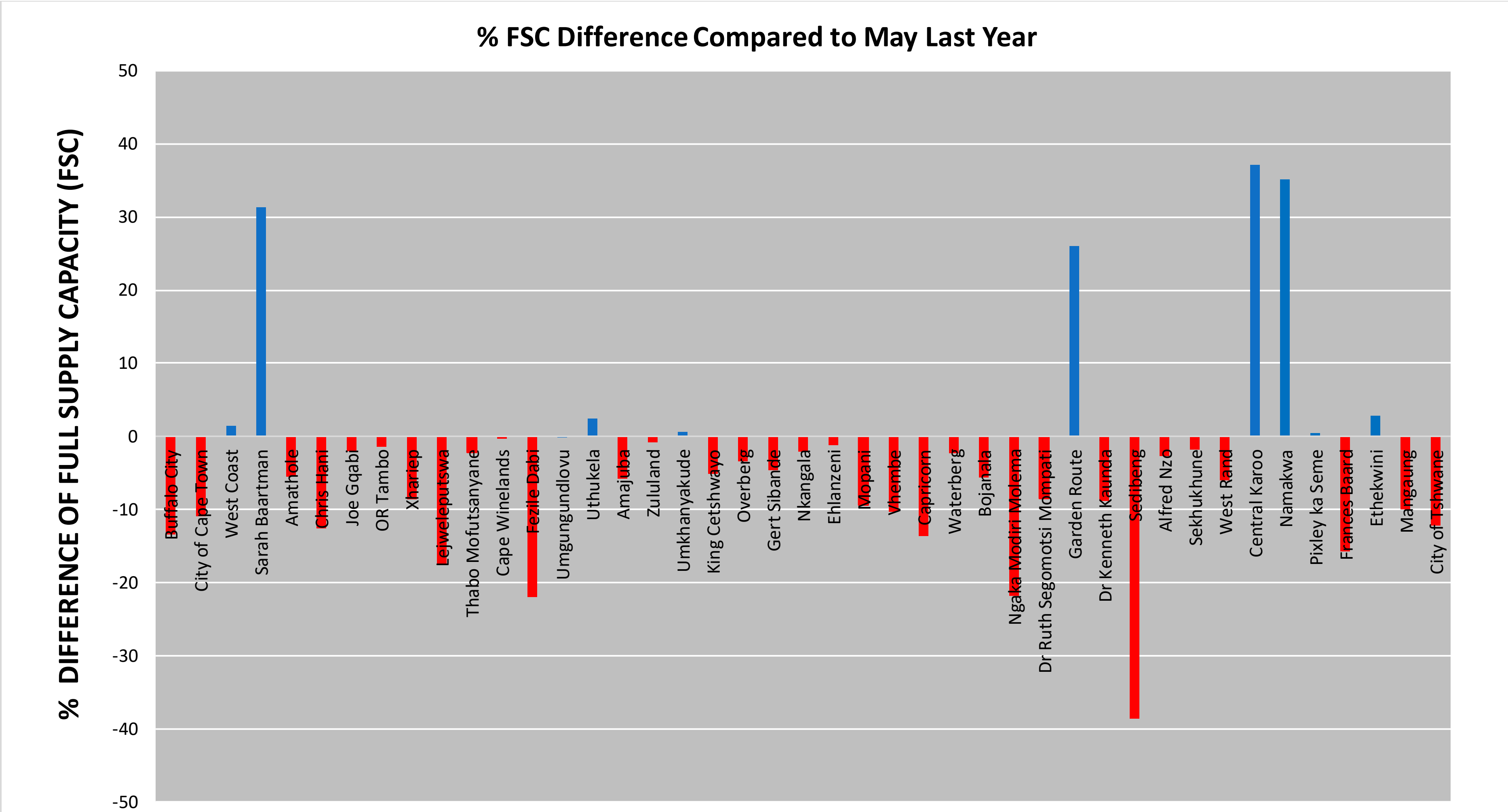


Figure 10: Difference in Water Storage Levels per District Municipality May 2023 vs May 2024

Table 3: Water Supply Systems storage levels

Water Supply Systems/clusters	Capacity in $10^6 m^3$	27 May 2023 (% FSC)	20 May 2024 (%FSC)	27 May 2024 (% FSC)	System Description
Algoa System	282	20.3	71.2	71	The following 5 dams serve the Nelson Mandela Bay Metro, Sarah Baartman (SB) DM, Kouga LM and Gamtoos Irrigation: Kromrivier Dam, Impofu Dam, Kouga Dam, Loerie Dam, Groendal Dam
Amathole System	241	101.1	93.6	92.8	The following 6 dams serve Bisho & Buffalo City, East London: Laing Dam, Rooikrans Dam, Bridle Drift Dam, Nahoon Dam, Gubu Dam, Wriggleswade Dam
Klipplaat System	57	100.2	93.3	93.2	The following 3 dams serve Queenstown (Chris Hani DM, Enoch Ngijima LM): Boesmanskrantz Dam, Waterdown Dam, Oxkraal Dam
Luvuvhu	225	101.5	99.6	95.7	The following 3 dams serve Thohoyandou etc: Albasini Dam, Vondo Dam, Nandoni Dam
Bloemfontein	219	98.6	89.8	89.7	The following 4 dams serve Bloemfontein, Botshabelo and Thaba Nchu: Rustfontein Dam, Groothoek Dam, Welbedacht Dam, Knellpoort Dam
Butterworth System	14	100.1	90.6	90	Xilinxa Dam and Gcuwa weirs serve Butterworth
Integrated Vaal River System	10 546	100.1	86.1	85.6	The following 14 dams serve Gauteng, Sasol, and Eskom: Vaal Dam, Grootdraai Dam, Sterkfontein Dam, Bloemhof Dam, Katse Dam, Mohale Dam, Woodstock Dam, Zaaihoek Dam, Jericho Dam, Westoe Dam, Morgenstond Dam, Heyshope Dam, Nooitgedacht Dam, Vygeboom Dam
Polokwane	254.27	102.1	99.6	98.9	The following 2 dams serve Polokwane: Flag Boshielo Dam, Ebenezer Dam
Crocodile West	444	98.6	96.4	96.5	The following 7 dams serve Tshwane up to Rustenburg: Hartbeespoort Dam, Rietvlei Dam, Bospoort Dam, Roodeplaat Dam, Klipvoor Dam, Vaalkop Dam, Roodekopjes Dam
uMgeni System	923	98.8	99.3	98.6	The following 5 dams serve Ethekwini, iLembe & Msunduzi: Midmar Dam, Nagle Dam, Albert Falls Dam, Inanda Dam, Spring Grove Dam
Cape Town System	889	62.6	59.5	59	The following 6 dams serve the City of Cape Town: Voelvlei Dam, Wemmershoek Dam, Berg River Dam, Steenbras-Lower Dam, Steenbras-Upper Dam, Theewaterskloof Dam
Crocodile East	159	100.4	100.2	100.1	Kwena Dam supplies Nelspruit, KaNyamazane, Matsulu, Malelane and Komatipoort areas and surroundings

Water Supply Systems/clusters	Capacity in $10^6 m^3$	27 May 2023 (% FSC)	20 May 2024 (%FSC)	27 May 2024 (% FSC)	System Description
Orange	7 996	97.4	89.3	89	The following two dams service parts of the Free State, Northern and Eastern Cape provinces: Gariep Dam, Vanderkloof Dam
uMhlathuze	301	100.8	96.3	95.7	Goedertrouw Dam supplies Richards Bay, Empangeni small towns surrounding rural areas, industries and irrigators, supported by lakes and transfer from Thukela River

Table 4: Water Supply Systems with Restrictions

Water Supply Systems/clusters	Restrictions
Algoa	The decision date was changed from 1 June to 1 November, therefore new AOA was conducted, and water restrictions were imposed as from 1 November 2023, Urban (Domestic and Industrial) = 5%, Irrigation = 15% for Kouga Subsystem and Urban (Domestic and Industrial) = 40%, Irrigation = 50% for the Kromme Subsystem, these are yet to be gazetted
Bloemfontein	A 15% restriction has been recommended on Domestic and Industrial water supply when the system drops below 95%, notice is yet to be gazetted
Polokwane	20% restrictions on Domestic and Industrial

Overview of Annual Streamflow Anomaly at Strategic Points

The Department has several surface water monitoring points of strategic importance (outlet of catchments, importance of international obligations, and reporting of Sustainable Development Goals). These strategic gauging stations contain long-term data which was used in this report to assess the deviation of total annual streamflow volume in the 2022/23 Hydrological Year (HY), from the long-term median (1980-2010). Figure 11 presents a streamflow anomaly map that shows the deviation of annual streamflow in the 2022/23 HY from the long-term median (median period of 1981-2010), whereas Figure 12 depicts the streamflow deviation for the 2021/22 HY.

Most strategic points demonstrated a significant increase in the total annual flow volume in the 2022/23 HY compared to the previous year. This can be attributed to well above-normal rainfall received over extensive parts of central South Africa as a result of ENSO's El Niño phase, which is associated with above-normal rainfall in the majority of summer rainfall regions. Only three strategic stations were below normal, compared to five in 2021/22 HY, with one being extremely below normal (Figure 11). One of the highlights was a station in the Olifants WMA (B7H007 - Olifants River at Oxford) that has improved from below normal to above normal in the 2022/23 HY. Water from this station flows into Mozambique, and the total annual volume recorded at this station in the 2022/23 HY was 2601 MCM, the highest ever recorded.

The flow station D8H014, which is located on the Orange River and flows into Namibia, maintained its extremely above-normal flow status from the 2021/22 HY. A detailed streamflow analysis for this station indicated that both this station and the one above (D7H005- Orange River at Upington) had good flows in the last 2020/21 and 2021/22 HYs, after 9 years of low flows. Overall, all rivers in the Integrated Vaal River System improved or maintained a significantly higher than long-term median pattern, except for C9H003 (Vaal River at Riverton), which was above normal and regressed to below normal in the 2022/23 HY (Figure 11 and Figure 12).

Notably, the streamflow at a station in the Pongola-Mtavuma WMA V5H002 (Tugela River at Mandeni) was again flagged as being below normal in 2022/23 HY, but this was an improvement over the much lower levels reported in 2021/22 (Figure 12). A comprehensive streamflow analysis for this station revealed that the flow at this station has been below normal since the 2014/15 hydrological year. Two stations (L7H006- Groot River at Grootrivierspoort and Q9H018- Fish River at Matomela's Location) in the Mzimvubu-Tsitsikamma WMA improved significantly from below normal to above normal in the 2022/23 HY, which can be associated with above-normal summer rainfall that caused flooding in some areas of the Eastern Cape.

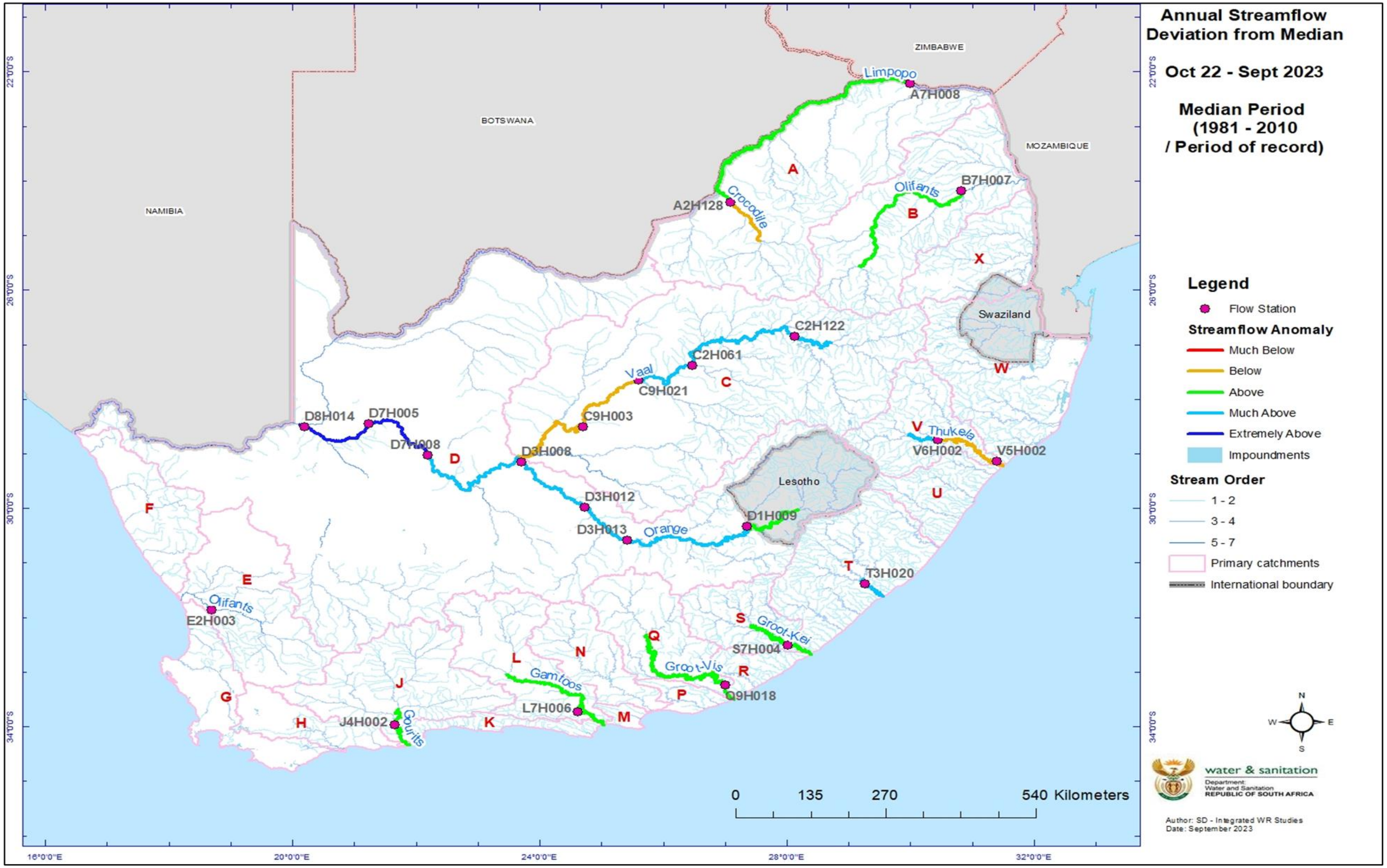


Figure 11: Annual Streamflow Anomaly for Strategic River Flow Monitoring Stations as of September 2023

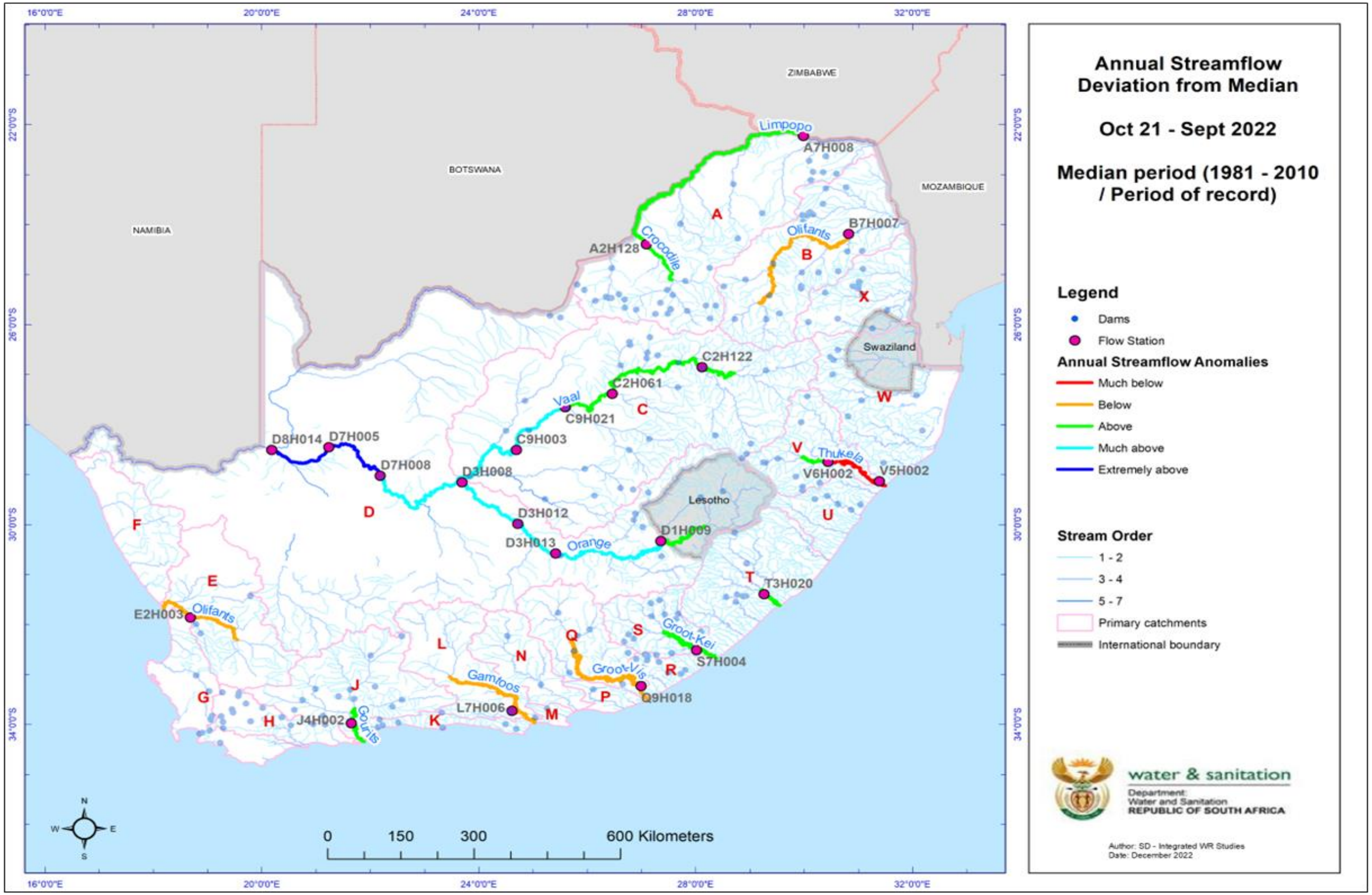


Figure 12: Annual Streamflow Anomaly for Strategic River Flow Monitoring Stations for the 2021/22 HY

Water Quality Parameters Explained (a continuation from the April 2024 bulletin)

Water quality refers to the condition and characteristics of water that determine its fitness for various uses and the health of aquatic ecosystems. It encompasses water's chemical, physical, and biological properties and the presence of contaminants and pollutants. Water quality in natural water bodies such as lakes, rivers, and oceans can be affected by several factors. These factors include natural processes like weathering, erosion, and biological interactions, as well as human activities such as industrial discharges, agricultural runoff, and improper waste disposal. Contaminants commonly found in water include organic and inorganic substances, pathogens, heavy metals, pesticides, and nutrients like nitrogen and phosphorus. Assessing water quality is essential for understanding aquatic ecosystems' health, identifying pollution sources, and developing effective management strategies.

PART B: MACRO CHEMICAL WATER QUALITY PARAMETERS

Macro chemical parameters commonly investigated to establish water quality include pH, acidity, alkalinity, hardness, dissolved oxygen, chemical oxygen demand, biochemical oxygen demand, nitrogen compounds, phosphorus compounds, fluoride, sulphate, and chloride.

pH

pH stands for the **p**otential of **H**ydrogen since pH is effectively a measure of the concentration of hydrogen ions (H^+/protons) in a substance. pH measures how acidic or alkaline/basic a solution is, with a numeric scale ranging from 0-14, with 7.0 being neutral, <7.0 acidic, and >7.0 being alkaline or indicating a base (Figure 13). Acidic water contains extra hydrogen ions (H+), and basic water contains extra hydroxyl (OH^-) ions. When measuring the pH of a solution, the solution's temperature is also measured since pH varies with temperature. The pH level of a solution is inversely proportional to the temperature. The reason for this is that molecular vibrations rise when the temperature increases within a solution, resulting in ionisation and hydrogen ions (H^+) formation. The more hydrogen ions in a solution, the more acidic it becomes. Therefore, the pH level decreases as temperature increases in a solution. (https://www.fondriest.com/environmental-measurements/parameters/water-quality/)

Figure 13: The pH scale (AtlasScientific, 2021)

Typical pH levels in water

The pH levels can change from different water inputs, such as runoff from land, groundwater, and even water draining from forest areas where weak organic acids and organic matter can alter pH levels (AtlasScientific, 2022). Typical pH levels in different water systems that are used to compare unusual pH ranges:

Drinking water: 7.0 - 8.5
Surface water (streams): 6.5 - 8.5
Groundwater: 6.0 – 8.5
Seawater: 8.1

Factors that influence the Water pH

Natural Factors:

- Limestone (calcium carbonate, $CaCO_3$) naturally buffers water against pH fluctuations in watersheds (drainage basins). Drainage basins that lack limestone are vulnerable to acid rain or mine drainage due to the lack of buffering capacity.
- Decomposing plants add acidity to the soil and often surrounding streams and rivers.
- Groundwater travels through soils, so if the soils have a high or low pH level, the pH of the water can change.
- Rainfall – natural and unpolluted rain and snowfall have a pH between 5.0 and 6.0. However, when rain falls through the atmosphere, it picks up CO_2 to form a weaker acid.

Anthropogenic Factors:

- Acid rain caused by burning fossil fuels
- Increased atmospheric carbon dioxide (CO_2) levels can lower the pH of water, as CO_2 is very soluble in water, forming weak carbonic acid (H_2CO_3)
- Directly dumping industrial pollutants (point-source pollution) into the water can decrease the pH.
- Mining can produce acidic runoff by exposing rocks to rainwater.

There are two methods available for the determination of pH: colorimetric and electrochemical methods. Colorimetric methods use pH indicators and pH litmus test papers, while electrochemical methods use pH meters consisting of metal electrodes, glass electrodes and semiconductor sensors. The use of electrodes allows hydrogen ions in a solution to flow past a selective barrier (commonly constructed of special glass), resulting in a detectable potential difference proportional to the pH of the solution (AtlasScientific, 2021).

ACIDITY

Acidity is a measure of acids in water. It is caused by the presence of carbon dioxide (which, when dissolved in water forms carbonic acid,); mineral acids/inorganic acids such as hydrochloric acid (HCl), nitric acid (HNO_3) and sulphuric acid (H_2SO_4); and hydrolysed salts such as iron and aluminum sulphates. Acidity can influence many processes such as biological activities, chemical reactions, and corrosion.

The level of acidity is determined by titration methods. Treatment of acidic waters involves the use of a neutralising filter containing ground limestone or magnesium oxide (MgO).

ALKALINITY

Alkalinity is a measure of water's ability to neutralize acids. It is known as the buffering capacity of water, or the ability of water to resist a change in pH when acid is added (https://za.hach.com/parameters/alkalinity). The three primary alkali ions that contribute to alkalinity are bicarbonate (HCO_3^-), carbonate (CO_3^{2-}) and hydroxide (OH^-). Alkalinity results primarily from dissolving limestone or dolomite (magnesium carbonate, $MgCO_3$) minerals in the aquifer. It is usually expressed in terms of mg/L of $CaCO_3$.

Alkalinity is measured in the laboratory using a UV-VIS Spectrophotometric method. Troublesome amounts of alkalinity can be removed by reverse osmosis technology or by using a mineral acid such as hydrochloric acid to neutralize the alkalinity of water. This process converts the bicarbonates and carbonates present into carbonic acid.

HARDNESS

Calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions cause the greatest portion of hardness in naturally occurring waters and are primarily caused by water slowly dissolving rocks that contain calcium and magnesium. These ions are present as bicarbonates, sulphates, chlorides and nitrates. There are no health concerns associated with drinking hard water. However, it is often undesirable because it can cause lime buildup (scaling) in pipes, difficulty in producing lather with soap, and causes a buildup of soap scum and greying of white laundry over time. Generally, groundwater is harder than surface water (http://dx.doi.org/10.5772/intechopen.89657).

Laboratory testing for the hardness in water is performed using titration methods. Hardness in water can be removed by adding sodium carbonate (Na_2CO_3) which reacts with the dissolved salts of calcium and magnesium to form insoluble carbonates that can be removed by filtration, resulting in a softening of water.

DISSOLVED OXYGEN

Dissolved oxygen (DO) measures the amount of gaseous oxygen in water. Healthy waters that can support life must contain dissolved oxygen. A low level of dissolved oxygen in water is a sign of contamination and is an important factor in determining water quality, pollution control, and treatment processes. Factors that contribute to the concentration of DO in water are atmospheric pressure, temperature, depth of water, salinity, and bioactivity of microorganisms. Depletion of dissolved oxygen in water supplies can encourage the microbial reduction of nitrate to Nitrite and sulphate to sulphide (https://za.hach.com/parameters/dissolved-oxygen).

Why monitor Dissolved Oxygen?

Measuring dissolved oxygen in water and treating it to maintain proper levels is crucial in various water treatment applications. While dissolved oxygen is necessary to support life and treatment processes, it can also be harmful, causing oxidation that damages equipment and compromises products. Dissolved oxygen affects:

- **Quality:** The DO concentration determines the quality of source water. Without enough DO, the water turns foul and unhealthy, affecting the quality of the environment, drinking water, and other products.

Regulatory Compliance: To comply with regulations, wastewater often must have specific levels of dissolved oxygen (DO) before it can be discharged into a water body such as a stream, lake, or river. Adequate dissolved oxygen is crucial for supporting aquatic life in healthy waters, and for instance, fish cannot survive in water with a dissolved oxygen level of less than 5mg/L

- **Process Control:** The level of dissolved oxygen (DO) is crucial for managing the biological treatment of wastewater and the biofiltration process in producing drinking water. In certain industrial settings, such as power generation, any presence of DO is harmful to steam generation and must be eliminated, with its levels requiring close control.

Dissolved oxygen is measured by using a calibrated dissolved oxygen sensor or probe directly in the water. The probe measures the amount of oxygen that crosses a permeable or semi-permeable membrane into the sensor. Once the oxygen is inside the sensor, a chemical reduction reaction produces an electrical signal, which is then read by the dissolved oxygen probe.

CHEMICAL OXYGEN DEMAND

When treated wastewater is released into the environment, it can cause pollution by introducing organic substances into receiving water. Chemical oxygen demand (COD) refers to the amount of dissolved oxygen needed to oxidise organic materials, such as diesel and petroleum. Processes that require COD monitoring are municipal and industrial wastewater treatment. Elevated levels of COD in wastewater indicate high concentrations of organic compounds that can deplete the water's dissolved oxygen, which can have adverse environmental and regulatory effects. COD is an essential measurement for assessing the short-term impact of wastewater on the oxygen levels in receiving waters (https://za.hach.com/parameters/cod).

The laboratory method to analyse water samples for COD is conducted via a UV-VIS Spectrophotometric procedure.

BIOCHEMICAL OXYGEN DEMAND

Biochemical oxygen demand (BOD), is an important parameter in water treatment. It represents the amount of oxygen bacteria and other microorganisms consume while they decompose organic matter under aerobic conditions at a specified temperature. BOD is used to gauge the short-term impact wastewater effluents will have on the oxygen levels of receiving water.

COD versus BOD

COD and BOD measurements estimate the pollution (organic loading) in a water sample. However, COD measures the amount of oxygen required to chemically break down organic pollutants, while BOD indicates the amount of oxygen needed to break down organic pollutants biologically with microorganisms (https://za.hach.com/parameters/bod).

NITROGEN

There are four forms of nitrogen in water and wastewater:

- organic nitrogen (amino acids, fatty acids, aromatic compounds etc.)
- ammonia nitrogen/ammonium ion (NH_3 / NH_4^+)
- nitrite nitrogen (NO_2^-)
- nitrate nitrogen (NO_3^{2-})

Nitrogen in various forms plays a crucial role in water quality. Ammonia, Nitrite, and nitrate serve as essential nutrients for plants and animals, but excessive nitrogen can have harmful effects. In bodies of water, high concentrations of nitrogen can cause depletion of DO and thus negatively affect aquatic life. Drinking water containing excess nitrogen from ammonia or nitrate can pose public health risks. Furthermore, changes in nitrite concentrations in drinking water distribution systems can indicate the onset of nitrification, which compromises water quality. In wastewater treatment, high concentrations of ammonia and elevated pH can be toxic to sludge digestion microbes (https://za.hach.com/parameters/nitrogen).

Macro-nitrogen determinants are important water quality parameters.

Total Nitrogen

Total nitrogen is the sum of all the different forms of nitrogen present in the water, including ammonia, organically bonded nitrogen (Total Kjeldahl Nitrogen), nitrite, and nitrate. Total nitrogen methods measure nitrogen loads on influent streams, at intermediate stages of water treatment for sludge, and on effluent to gauge overall treatment plant efficiency. A laboratory method to determine the nitrogen content in water involves the conversion of organic and inorganic nitrogen to nitrate, which is then analysed by UV-VIS Spectrophotometry.

Total Kjeldahl Nitrogen

The term Total Kjeldahl Nitrogen refers to the combination of ammonia and organic nitrogen. It does not include nitrite-nitrogen or nitrate-nitrogen. The laboratory method for analysing water samples for Total Kjeldahl Nitrogen involves digesting the sample with concentrated sulphuric acid to convert the components of organic and biological origin to ammonium sulphate, followed by analysis by UV-VIS Spectrophotometry. The biological wastewater treatment process for removing organic nitrogen involves nitrification and denitrification steps.

Ammonia & Ammonium

Ammonia is formed naturally as a product of the microbiological decay of nitrogenous organic matter (animal and plant protein). It is also produced for use in fertilizers and in the production of plastics, pharmaceuticals, and other chemicals. Ammonia in groundwater is due to normal microbiological processes. However, the presence of ammonia nitrogen in surface water usually indicates domestic pollution. Excess ammonia can damage vegetation and is toxic to aquatic life, especially at elevated pH and temperature levels.

Ammonia and ammonium have a pH and temperature-dependent relationship. The chemical equation that drives the relationship between ammonia and ammonium is:
$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$
When the pH is low, the equilibrium is driven to the right, and when the pH is high, the equilibrium is driven to the left. Ammonia is used as both a reagent and as a measurement parameter in several areas of water and wastewater treatment. During the chlorination disinfection process, ammonia is combined with chlorine to treat drinking water and maintain a longer-lasting residual in distribution systems (https://za.hach.com/parameters/ammonia).

Ammonia is widely monitored in wastewater nitrification and denitrification processes. Ammonia and Ammonium are measured by UV-VIS Spectrophotometry. A common wastewater treatment process decreases the pH, thus driving the formation of ammonium ions, which can be readily removed by reverse osmosis.

Total Oxidisable Nitrogen (Nitrate + Nitrite)

The term refers to the sum of the nitrite and nitrate content. Nitrites readily oxidize to nitrates and are not often found in surface waters. When concentrations are adequately monitored and maintained, Nitrite and nitrate play an important role in many industrial and municipal water-quality monitoring programs:

- Nitrites are often used as corrosion inhibitors in industrial process water and cooling towers.
- The food industry uses nitrite compounds as preservatives
- Many granular commercial fertilizers contain nitrogen in the form of nitrates.

Excessive nitrite and nitrate concentrations can negatively affect water treatment processes and pose health risks:

- High levels of nitrate in water may indicate biological wastes or runoff from heavily fertilized fields
- Nitrate-rich effluents discharged into receiving waters can degrade water quality by encouraging the excessive growth of algae
- Drinking waters containing excessive amounts of nitrates at the 10 mg/L level can cause infant methemoglobinemia (blue babies). (https://za.hach.com/parameters/nitrate)

Nitrate and nitrite in water samples are measured using UV-VIS spectrostometry or ion chromatography methods. Treatment processes to reduce the level of nitrate are achieved by biological denitrification (reduction of nitrate to molecular nitrogen) for surface waters and ion exchange for groundwaters.

PHOSPHATES

Phosphates are chemical compounds containing phosphorus. Phosphorus is a non-metallic element necessary for life and is found in rock as inorganic phosphates. Due to its high reactivity, phosphorus does not naturally exist as a free element. Complex organisms such as plants and animals need phosphorus because phosphates are a component of DNA (Deoxyribonucleic acid), RNA (Ribonucleic acid), ATP (Adenosine triphosphate), and phospholipids. Phosphorus is mined for use in detergents, pesticides, nerve agents, and fertilizers. There are three forms of phosphates:

- **Orthophosphates** - orthophosphate (PO_4^{3-}) is the soluble form of phosphate and is a naturally occurring ion in water, arising from the weathering of geologic phosphate material and plant decomposition
- **Condensed phosphates/polyphosphates** - condensed phosphates are multiple orthophosphate molecules "condensed" together
- **Organic phosphates** include phosphate ester compounds such as trimethyl phosphate and organophosphorus pesticides.

Human-induced forms of phosphate are fertiliser, agricultural and urban runoff, sewage, and faulty or overloaded septic systems. High levels of phosphates in source water can accelerate types of algae and plant growth, leading to eutrophication and algae blooms. When this occurs, fish and aquatic life are robbed of oxygen, resulting in large fish kills and destroyed habitats. Municipal water treatment systems commonly add phosphates to drinking water to prevent the release of metals in drinking water: orthophosphate is used for lead and copper control while polyphosphates sequester (bind to) iron and manganese to prevent discoloured water by controlling corrosion in drinking water distribution systems (https://za.hach.com/parameters/phosphorus).

The standard laboratory method for determining phosphate in water is by UV-VIS Spectrophotometry. Samples for Total Phosphate require acid oxidation (using sulphuric acid) under pressure to convert organic phosphorus to orthophosphate, before analysis by UV-VIS Spectrophotometry (so the Total Phosphorus represents the sum of all the phosphorus present: orthophosphate, condensed phosphates, and organic phosphorus). Chemical precipitation of phosphate using metal salts such as aluminium sulphate, iron sulphate and calcium sulphate is the most common method used for phosphorus removal to meet effluent concentrations below 1.0 mg/L. The solid precipitate is then removed by filtration.

FLUORIDE

Fluorine is a gas at room temperature and is a common element that is widely distributed in Earth's crust and exists in the form of fluorides in several minerals, such as fluorspar (calcium fluoride, CaF_2), cryolite (sodium hexafluoroaluminate Na_3AlF_6), and fluorapatite [calcium fluorophosphate, $Ca_5(PO_4)_3F$]. Traces of fluorides are present in many waters, with higher concentrations often found in groundwater (WHO, 2011). In dentistry, healthcare providers use fluoride to strengthen teeth and reduce the risk of cavities. Fluoride can also be added to table salt or drinking water to help prevent dental cavities. The dosages added to drinking water typically range between **0.5 and 1 mg/L** (WHO, 2011). Fluoride ions are always present in the final water, whether from natural sources or artificial fluoridation. Adverse effects of fluoride are dental fluorosis (discolouration of the teeth enamel) and skeletal fluorosis (a long-term bone disease).

Laboratory analyses of fluoride in water are based on a UV-VIS Spectrophotometric or a Selective Ion Electrode method. Treatment technologies for fluoride removal range from simple techniques such as adsorption on activated alumina (aluminium oxide, Al_2O_3), carbon, bone charcoal and synthetic ion exchange resins to advanced treatment processes such as reverse osmosis (a membrane filtration process).

SULPHATES

Sulphate ions are found in natural water and wastewater. Common sulphates found in water are sodium, potassium, and magnesium sulphates. High concentrations of sulphate in natural water are usually caused by the leaching of natural deposits of Glauber's salt (sodium sulphate decahydrate, $Na_2SO_4.10H_2O$) and Epsom salt (magnesium sulphate, $MgSO_4$). Sulphates in wastewater originate from mine drainage; sewage infiltration, industries such as paper mills, textile mills, tanneries and synthetic detergents; and fertilisers. The ingestion of drinking water containing high sulphate levels leads to gastrointestinal effects (WHO, 2011).

Laboratory methods to analyse sulphate in water range from Ion Chromatography to UV-VIS Spectrophotometric methods. Treatment systems to remove sulphate from drinking water include reverse osmosis, distillation and ion exchange processes.

CHLORIDES

Chloride is a naturally occurring ion found in the Earth's crust, with table salt (sodium chloride, NaCl), potassium chloride (KCl), and magnesium chloride ($MgCl_2$) being the most common. Chlorides enter surface water from several sources, including chloride-containing rock, agricultural runoff (e.g. from the use of organochlorine pesticides), and wastewater. The sodium part of table salt has been connected to kidney and heart diseases (http://dx.doi.org/10.5772/intechopen.89657).

Laboratory methods to analyse chloride in water range from titration methods to UV-VIS Spectrophotometric methods. Removing chloride in water and wastewater involves reverse osmosis, anion exchange and distillation techniques.

Table 5: Guidelines for Drinking Water Quality according to SANS 241: 2015: 2

Physical Parameter	Standard Limit
pH	≥5 to ≤9.7
Nitrate	≤11
Nitrite	≤0.9
Nitrate + Nitrite	≤1
Ammonia	≤1.5
Fluoride, mg/L	≤1.5
Phosphate, mg/L	≤1*
Sulphate, mg/L	≤500
Chloride, mg/L	≤300

*World Health Organisation, 2011

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Glossary

Term	Definition
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
ENSO	El Niño-Southern Oscillation
FSC	Full Storage Capacity
HY	Hydrological Year
pH	Potential of Hydrogen
SPI	Standardized Precipitation Index (SPI) is a widely used index to characterise meteorological drought on a range of timescales. On short timescales, the SPI is closely related to soil moisture, while at longer timescales, the SPI can be related to groundwater and reservoir storage
SDG	Sustainable Development Goal
WMA	Water Management Area
Water Supply System	A typical town/city water supply system consists of a gravity or pumping-based transmission and distribution system from a local or distant water source with needed water treatment system

References

AtlasScientific (2021), Why is pH important? DOI: https://atlas-scientific.com/blog/why-is-ph-important/

AtlasScientific (2022), How does pH affect water quality? DOI: https://atlas-scientific.com/blog/how-does-ph-affect-water-quality/

Biochemical oxygen demand DOI: https://za.hach.com/parameters/bod

Chemical oxygen demand DOI: https://za.hach.com/parameters/cod

Dissolved oxygen DOI: https://za.hach.com/parameters/dissolved-oxygen

Dissolved oxygen DOI: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/dissolved-oxygen

Guidelines for Drinking Water Quality. World Health Organization. 2011 (4th edition).

How does pH affect water quality? DOI: https://atlas-scientific.com/blog/how-does-ph-affect-water-quality/

Nitrate DOI: https://za.hach.com/parameters/nitrate

Phosphorus DOI: https://za.hach.com/parameters/phosphorus

Resource Quality Information Services Inorganic Laboratory Methods Manual. Revision 10, 2023.

SANS 241-1:2015 Drinking Water Standard Edition 2: General requirements for the competence of testing and calibration laboratories.

Water Quality DOI: https://www.fondriest.com/environmental-measurements/parameters/water-quality/water-temperature/

Water Quality Parameters DOI: http://dx.doi.org/10.5772/intechopen.89657