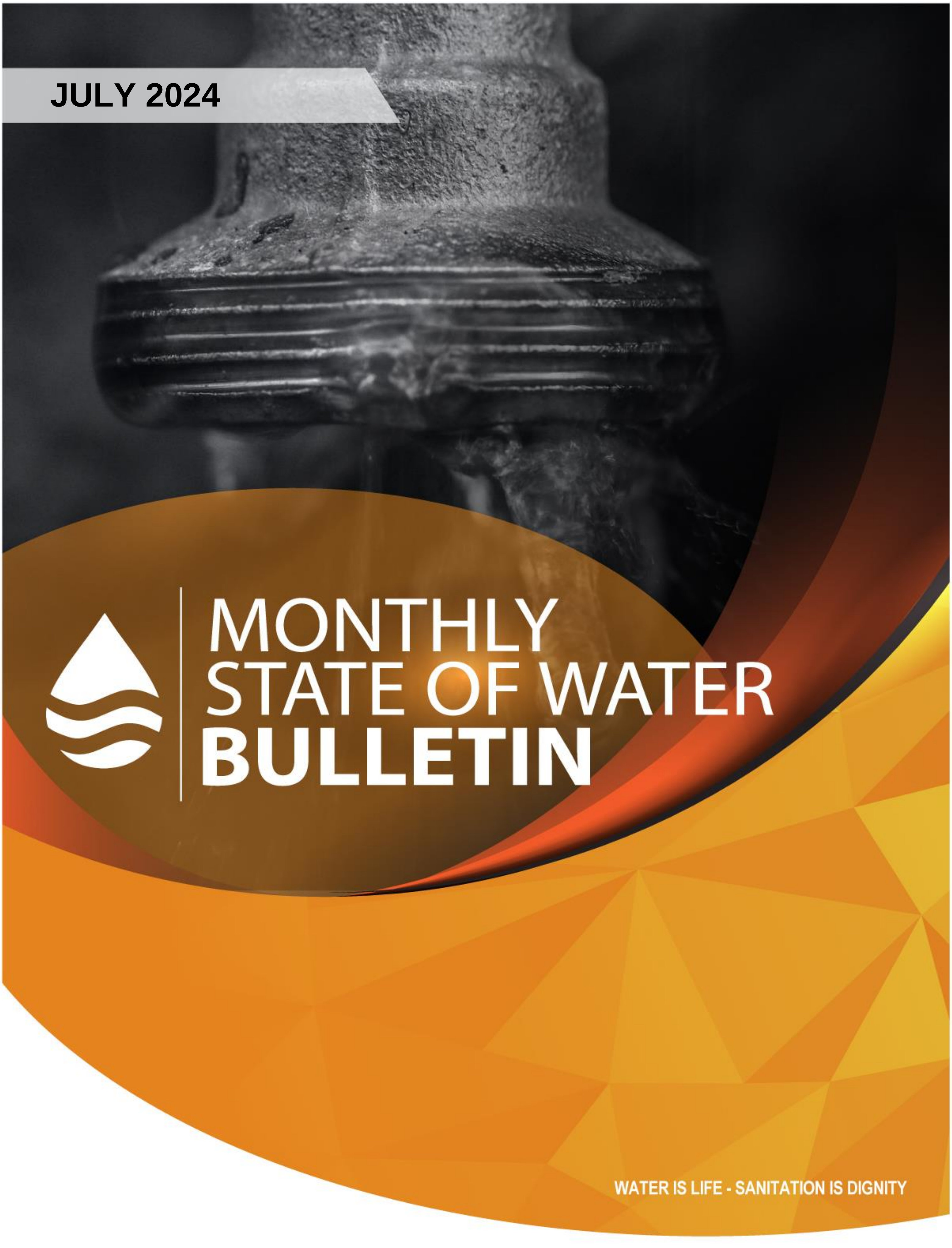
JULY 2024



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 southwestern parts of the country and summer rainfall in the eastern part of the country. The southwestern tip of the country has a Mediterranean climate with hot summers and cool, wet winters. 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.

At the end of July 2024, the national dam levels were at **84.5%** of Full Supply Capacity (FSC) lower than last year by 9.5%. Approximately **24%** of the national dams were **above 100% of FSC** (either full or spilling)**, 64%** 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).

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, the Capricorn and the Mopani Districts in Limpopo were among the districts that had some areas experiencing severe drought. Other Districts such as the Zululand District in KwaZulu-Natal, Gert Sibande District in Mpumalanga, Bojanala and Ngaka Modiri Districts in North West, Sekhukhune Districts in Limpopo, Ekurhuleni and Sedibeng Districts in Gauteng and the City of Cape Town in Western Cape only experienced moderate drought.

In July, the Western Cape experienced an onslaught of cold fronts, with heavy rainfall, strong winds, and snow occurring week after week, resulting in flooding, burst river banks, infrastructure damage, and displaced people throughout the province. An analysis of rainfall data from South African Weather Service (SAWS) stations revealed that the Cape Town (Oranjezicht) rainfall station received 317.6 mm of rain in July 2024, far exceeding the long-term average of 128.0 mm for this month. This significant total not only exceeded the historical average but also represents the highest monthly rainfall recorded in July since comprehensive records began in 1960.

Rainfall

The country is currently in a neutral El Niño-Southern Oscillation (ENSO), however, current SAWS predictions are mixed in whether it will weaken towards a La Niña state during our next summer season. The monthly rainfall distribution during the current hydrological year for the summer and winter seasons is presented in Figure 1 and Figure 2, respectively. Winter rainfall regions received good rainfall during the month of July 2024. Meanwhile, the summer rainfall regions experienced insignificant rainfall in July as expected. However, rainfall ranging from 50-100 mm was received over isolated parts of the Northern Cape and KwaZulu-Natal 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 rainfall was received in isolated parts of the Western Cape, Free State, and Northwest 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 August-September-October (ASO), September-October-November (SON), and October-November-December (OND) 2024 , while there are indications of above-normal rainfall over most of the summer rainfall areas during October-November-December (OND)forecast periods (Figure 5). However, there is an exception for the Limpopo region which still indicates below-normal rainfall that can be expected going into the early summer period. Moreover, minimum and maximum temperatures are expected to be mostly above-normal countrywide.

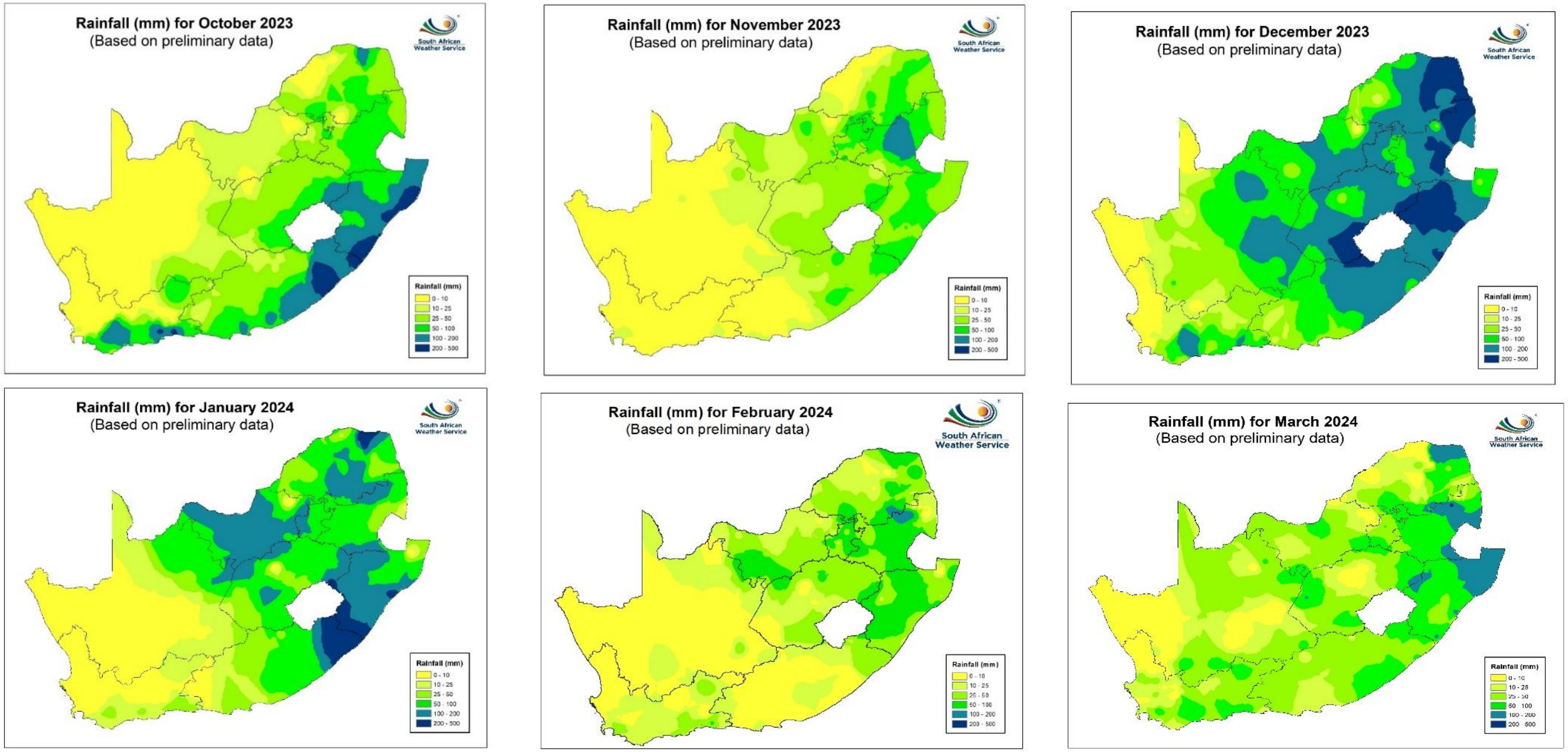


Figure 1: Summer season monthly rainfall distribution for October 2023 to March 2024 (Source: SAWS https://www.weathersa.co.za/home/historicalrain)

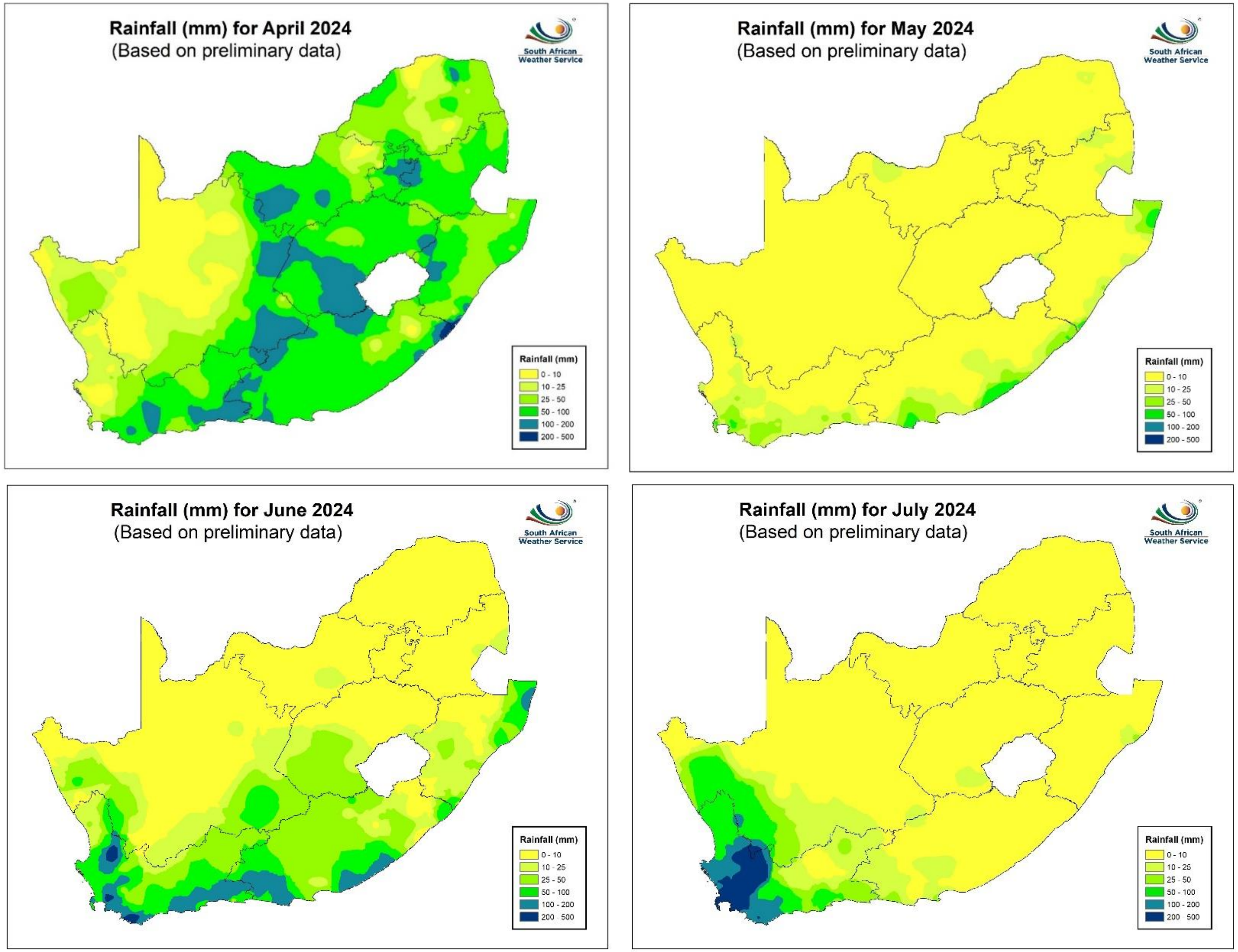


Figure 2: Winter season monthly rainfall distribution for April to July 2024 (Source: SAWS https://www.weathersa.co.za/home/historicalrain)

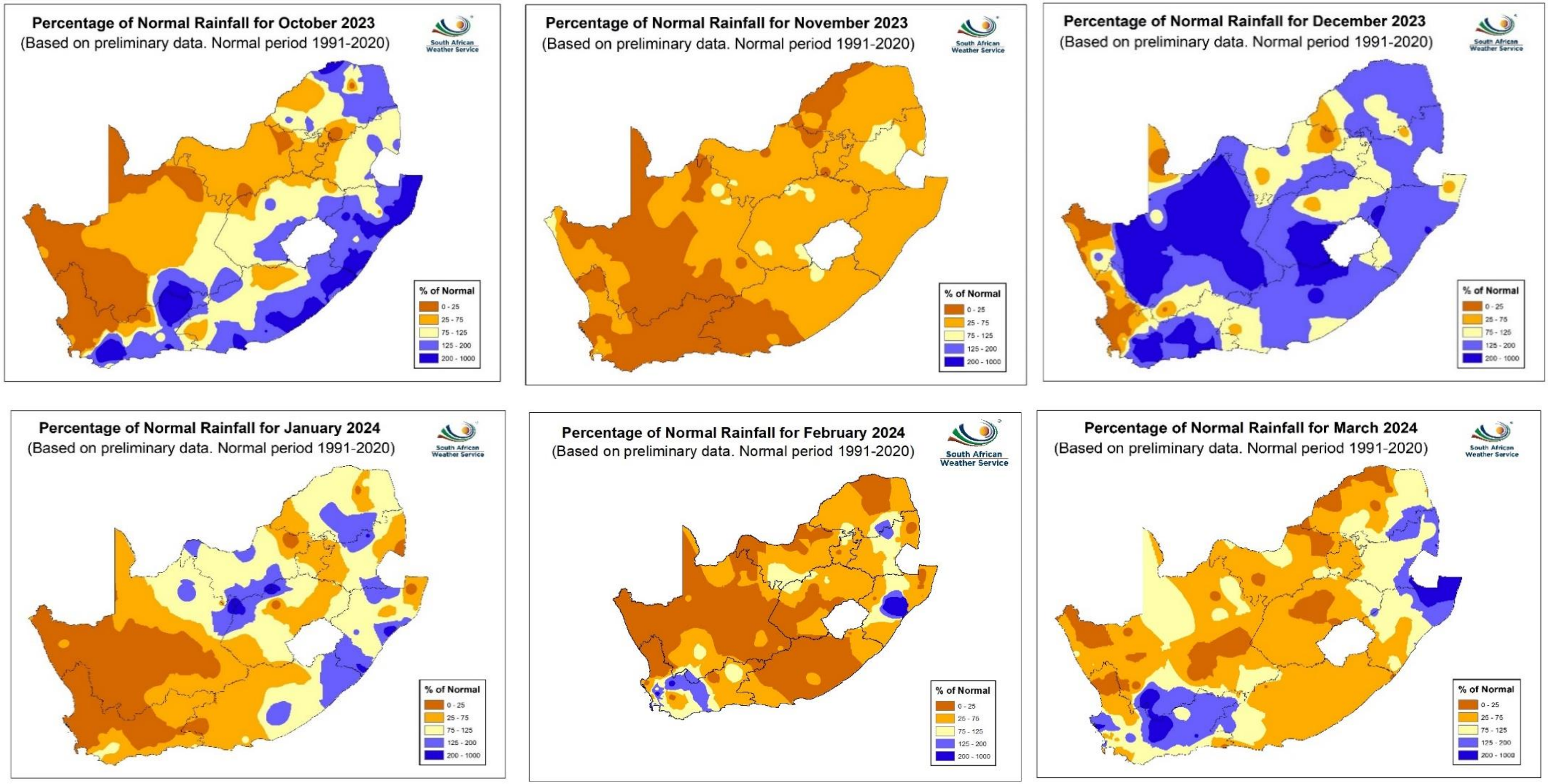


Figure 3: Summer season Percentage of normal rainfall for October 2023 to March 2024. Blue shades are indicative of above-normal rain, and the darker yellow shades of below-normal rainfall (Source: SAWS https://www.weathersa.co.za/home/historicalrain)

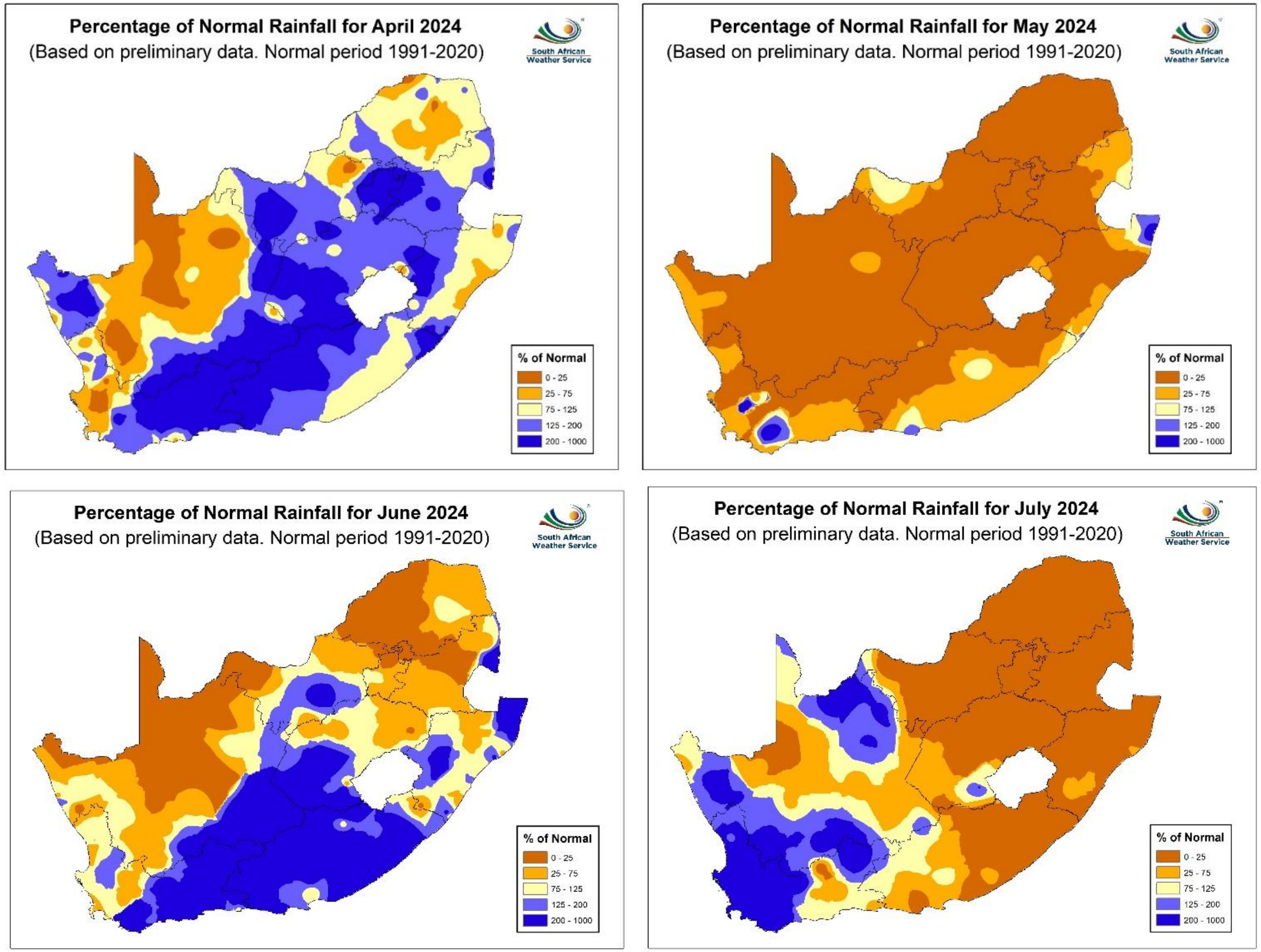


Figure 4: Summer season percentage of normal rainfall for April to July 2024. Blue shades are indicative of above-normal rain, and the darker yellow shades of below-normal rainfall (Source: SAWS https://www.weathersa.co.za/home/historicalrain)

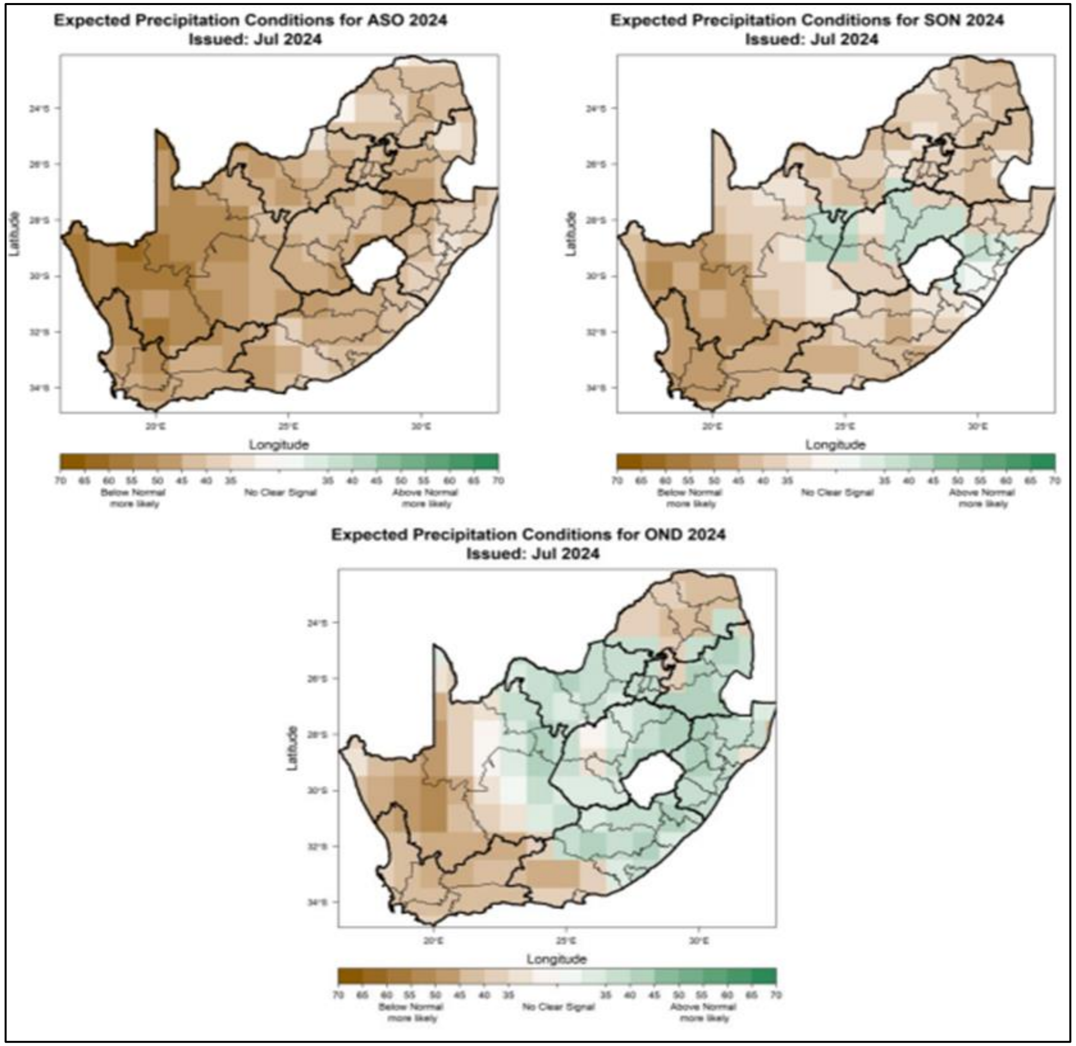


Figure 5: August-September-October 2024 (ASO; top left), September-October-November 2024 (SON; top right), October-November-December 2024 (OND; bottom); seasonal precipitation prediction. Maps indicate the highest probability of the above-normal and below-normal categories (Source: SAWS)

National Dam Storage

The national dam's water storage trends for the previous four hydrological years and the trend for the current hydrological year (2023/24) are presented in Figure 6 below. At the end of July 2024, the national dam levels were at **84.5%** of Full Supply Capacity (FSC). This level is lower than last year, at the same time of reporting when national storage was **94%** of FSC. Approximately **24%** of the national dams were **above 100% of FSC** (either full or spilling)**, 64%** 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).

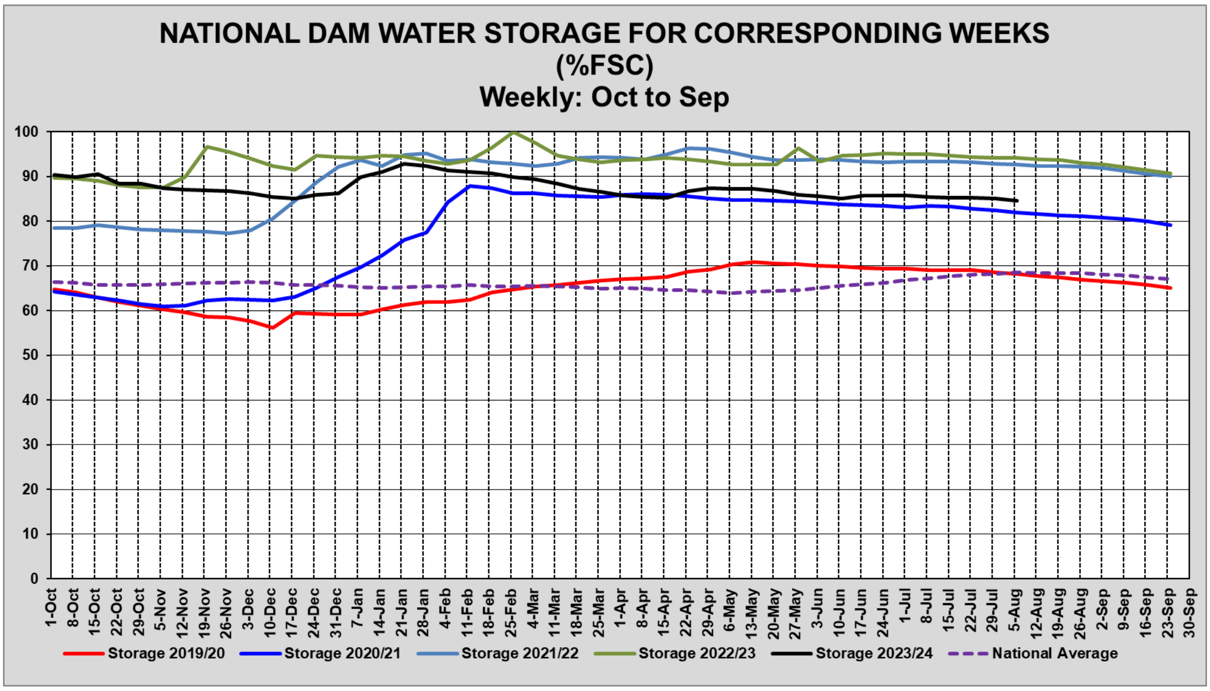


Figure 6: National Dam Storage on 29 July 2024

The comparison between July 2023 and July 2024 of the country's five largest dam storage %FSC is presented in Table 1. Due to the drier and warmer conditions experienced this summer compared to 2023, Gariep Dam and Sterkfontein Dam storage levels have declined by -40.4%, and -18.1% respectively.

The Middle-Letaba and Glen Alpine Dams in Limpopo Province remain the only dams at critical levels, as given in Table 2.

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

Reservoir	River	Province/Country	29 July 2023 (%FSC)	29 July 2024 (%FSC)	% Change (-/+)
Gariep Dam	Orange River	Free State	97.1	79	-18.1
Vanderkloof Dam	Orange River	Free State	99.7	98.9	-0.8
Sterkfontein Dam	Nuwejaarspruit River	Free State	100.1	98.5	-1.6
Vaal Dam	Vaal River	Free State	90.1	49.7	-40.4
Pongolapoort Dam	Phongolo River	KwaZulu-Natal	85	84.3	-0.7

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

Reservoir	River	Province/Country	29 July 2023 (%FSC)	29 July 2024 (%FSC)	% Change (-/+)
Middle-Letaba Dam	Middel-Letaba River	Limpopo	4.5	1.2	-3.3
Glen Alpine Dam	Mogalakwena River	Limpopo	94.2	5	-89.2

The spatial distribution of the dams with a classified range of their storage levels on 29 July 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.

Figure 8 presents the 24-month Standardised Precipitation Index (SPI) for June 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, the Capricorn and the Mopani Districts in Limpopo were among the districts that had some areas experiencing severe drought. Moreover, districts such as the Zululand District in KwaZulu-Natal, Gert Sibande District in Mpumalanga, Bojanala and Ngaka Modiri Districts in North West, 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.

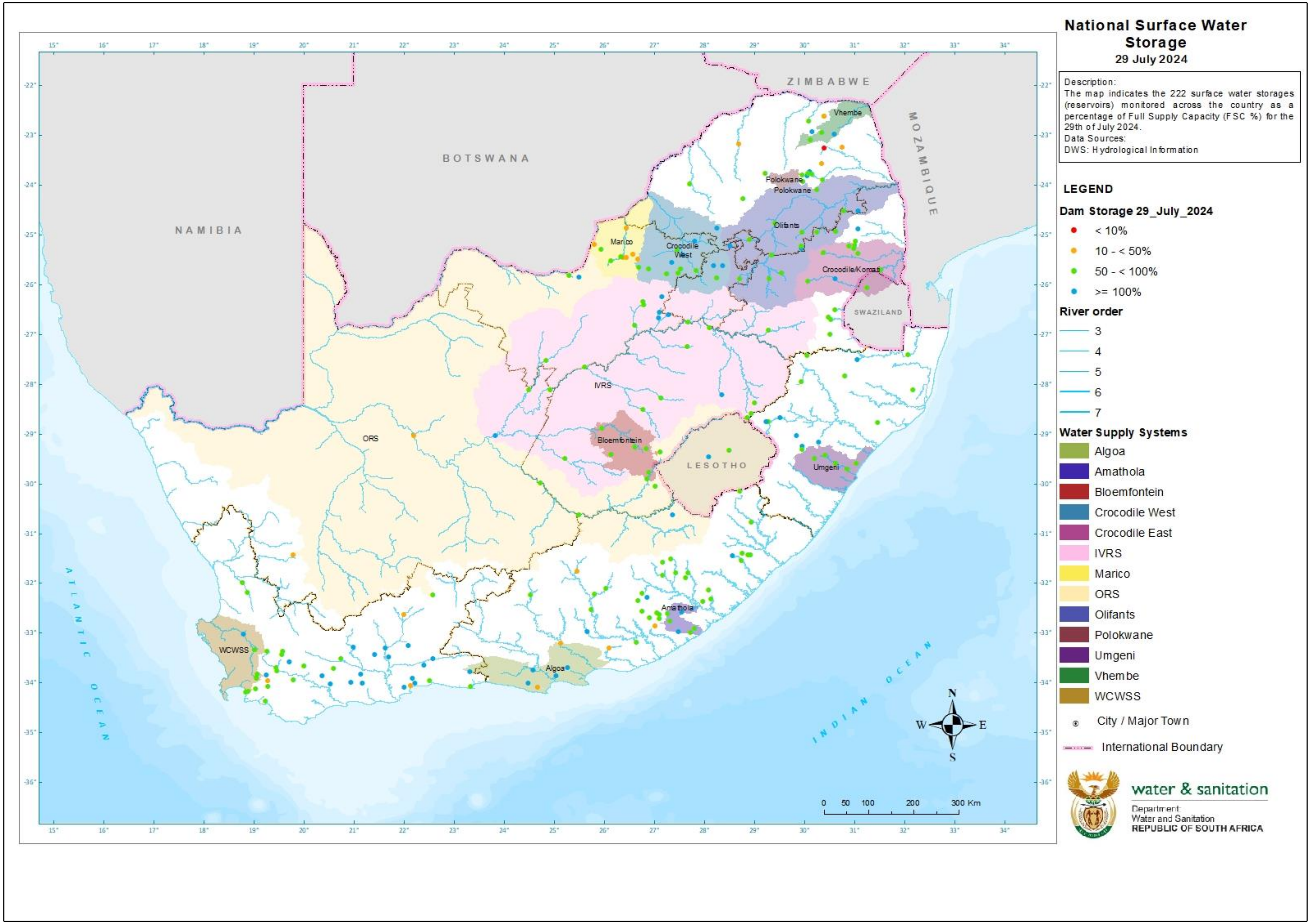


Figure 7: Surface Water Storage Levels - July 2024

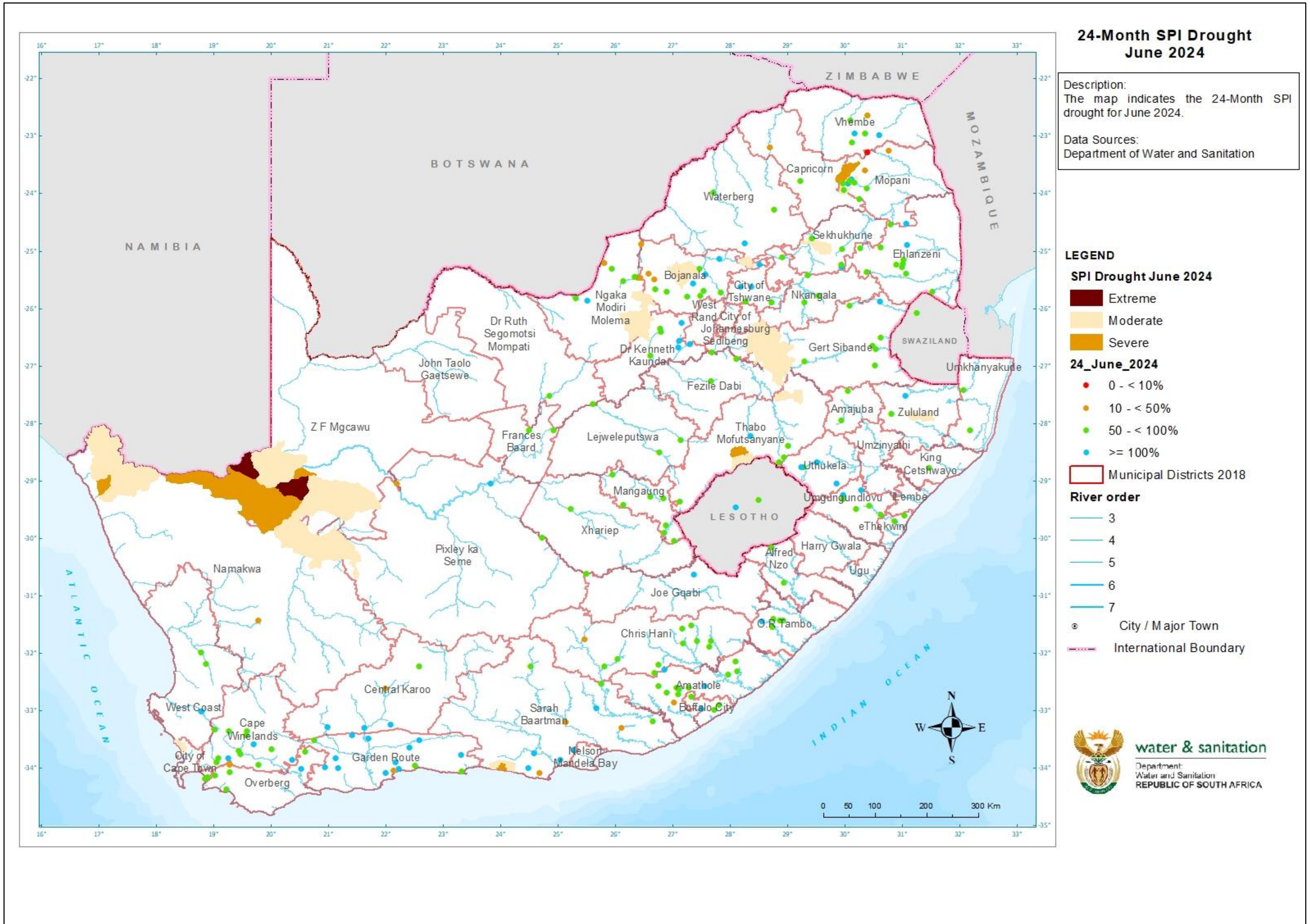
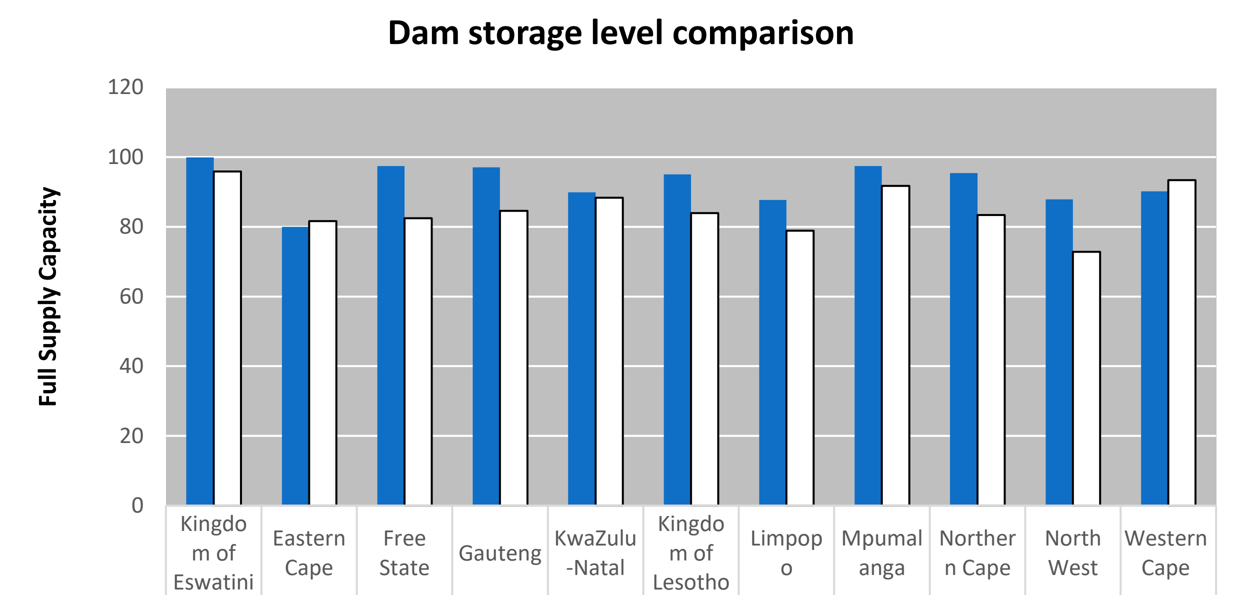


Figure 8: 24-month Standardised Precipitation Index (SPI) and dam levels

The comparison of the storage levels per Province and international areas for July 2024 to the same time last year is presented in Figure 9. Seven of the nine provinces are showing a decline in dam storage levels compared to the previous year. The province with increased dam storage levels was the Western Cape (+3.2% of FSC), while the highest decline was in the Northwest (-15.1% of FSC).



	Kingdom of Eswatini	Eastern Cape	Free State	Gauteng	KwaZulu-Natal	Kingdom of Lesotho	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape
29-Jul-23	99.9	80	97.4	97.1	89.9	95	87.7	97.4	95.4	87.9	90.2
29-Jul-24	95.9	81.6	82.5	84.6	88.3	83.9	78.9	91.7	83.4	72.8	93.4

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

District Municipalities

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

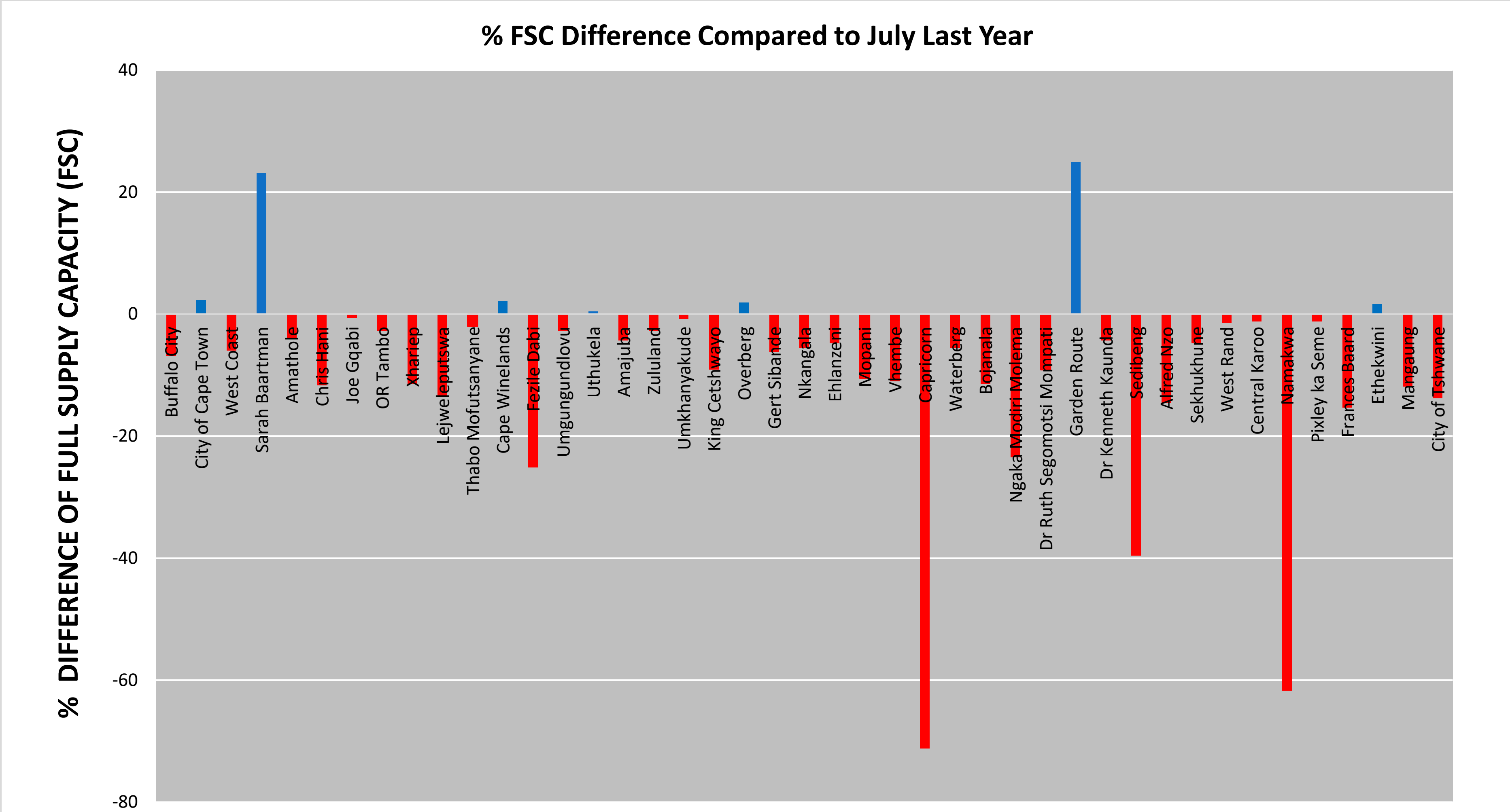


Figure 10: Comparison of water storage levels per District Municipality July 2023 vs July 2024

Table 3: Water Supply Systems storage levels

Water Supply Systems/clusters	Capacity in 10^6m^3	29 July 2023 (% FSC)	22 July 2024 (%FSC)	29 July 2024 (% FSC)	System Description
Algoa System	282	38.5	77.7	77.6	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	100.8	97.2	95.9	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	100.5	97.2	97.1	The following 3 dams serve Queenstown (Chris Hani DM, Enoch Ngijima LM): Boesmanskrantz Dam, Waterdown Dam, Oxkraal Dam
Luvuvhu	225	101.1	96.9	96.4	The following 3 dams serve Thohoyandou etc: Albasini Dam, Vondo Dam, Nandoni Dam
Bloemfontein	219	97.9	86.3	85.7	The following 4 dams serve Bloemfontein, Botshabelo and Thaba Nchu: Rustfontein Dam, Groothoek Dam, Welbedacht Dam, Knellpoort Dam
Butterworth System	14	99.4	81.2	79	Xilinxa Dam and Gcuwa weirs serve Butterworth
Integrated Vaal River System	10 546	96	81.5	81	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	100.8	93.5	92.8	The following 2 dams serve Polokwane: Flag Boshielo Dam, Ebenezer Dam
Crocodile West	444	100.4	93.7	93.6	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	94.4	92.7	91.9	The following 5 dams serve Ethekwini, iLembe & Msunduzi: Midmar Dam, Nagle Dam, Albert Falls Dam, Inanda Dam, Spring Grove Dam
Cape Town System	889	99	99.6	100.4	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	100.1	96.7	95.2	Kwena Dam supplies Nelspruit, KaNyamazane, Matsulu, Malelane and Komatipoort areas and surroundings

Water Supply Systems/clusters	Capacity in 10^6m^3	29 July 2023 (% FSC)	22 July 2024 (%FSC)	29 July 2024 (% FSC)	System Description
Orange	7 996	98.1	87.6	86.7	The following two dams service parts of the Free State, Northern and Eastern Cape provinces: Gariep Dam, Vanderkloof Dam
uMhlathuze	301	101.3	92.5	92.2	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, Gazzetted on 26 April 2024 (Notice No. 50569)
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

Extreme Weather Events – July 2024

In July, the Western Cape experienced an onslaught of cold fronts, with heavy rainfall, strong winds, and snow occurring week after week, resulting in flooding, burst river banks, infrastructure damage, and displaced people throughout the province. The South African Weather Service has declared July 2024 as Cape Town's wettest July since 1960. An analysis of rainfall data from South African Weather Service (SAWS, 2024c) stations revealed that the Cape Town (Oranjezicht) rainfall station received 317.6 mm of rain in July 2024, far exceeding the long-term average of 128.0 mm for this month. This significant total not only exceeded the historical average but also represents the highest monthly rainfall recorded in July since comprehensive records began in 1960 (SAWS,2024c).

Mid-latitude cyclone / Cold Front(s)

The South African Weather Service (SAWS, 2024a) issued a severe weather warning on 05 July 2024, for heavy rainfall that could affect the western and central parts of the country beginning Sunday, 07 July 2024, and the eastern parts beginning Monday, 08 July 2024. The rainfall was caused by a series of intense cold fronts that hit the Western Cape shores that week (Figure 11). The weather service predicted heavy 24-hour rainfall, with accumulations ranging from 70 to 100 mm in the Western Cape's western regions (Figure 12) (SAWS,2024a). The first cold front left the country on Tuesday morning (09 July 2024), while another approached the Western Cape. Cold fronts with heavy rain and strong winds frequently affect Cape Town and other areas of South Africa's southwest coast during the winter months in the middle of the year. However, it is unusual for multiple cold fronts to strike in such a short period of time.

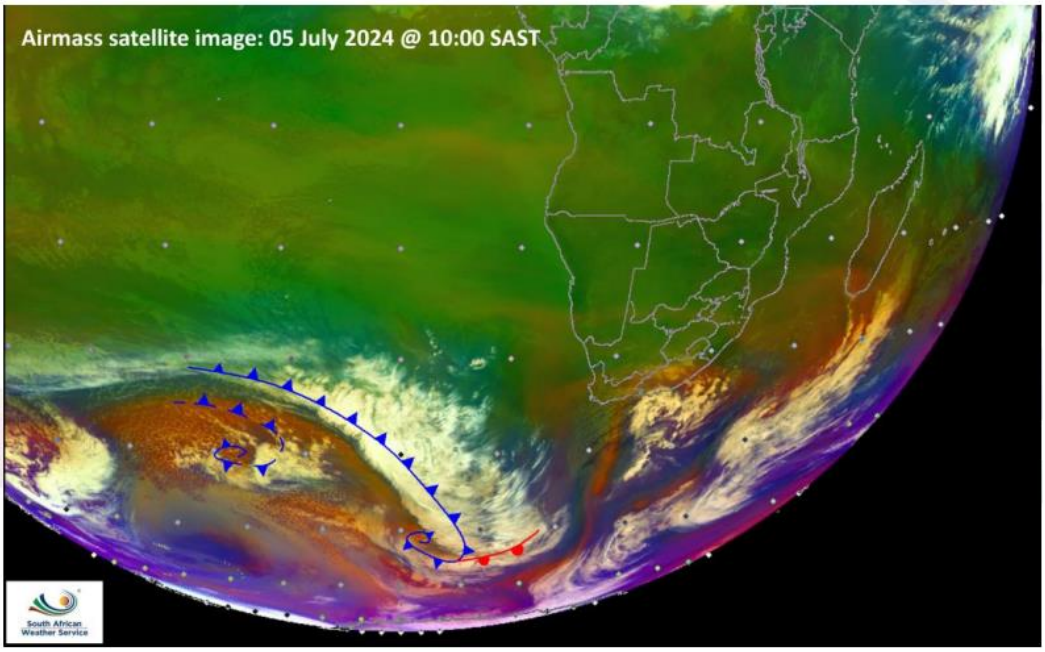


Figure 11: airmass RGB satellite image indicating the cold front movement to the west of South Africa on Friday, 5 July 2024. (Source: SAWS,2024).

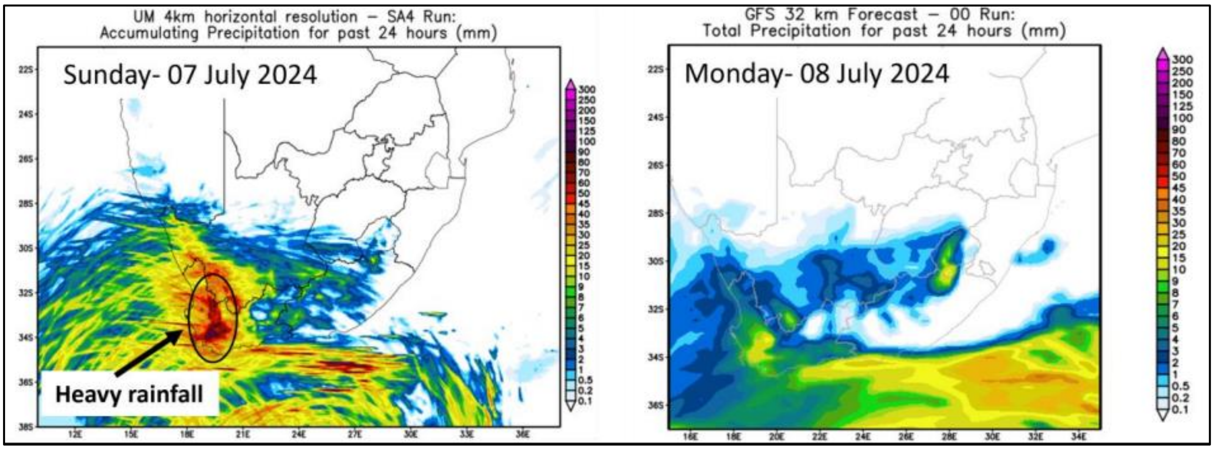


Figure 12: 24-hour rainfall accumulation (in mm) for Sunday (left) according to the Unified model and Monday (right) according to the GFS model. (Source: SAWS, 2024a)

Snow

On July 7, 2024, widespread snow fell over the Western Cape mountains, the Northern Cape's western and southern high ground, and the Eastern Cape mountains. Western Cape Government (2024) also reported light snowfall that reached Prieska in the Northern Cape. The snowfall was caused by a cold front and upper air trough that passed over the provinces, lowering freezing temperatures. Figure 13 depicts the areas that received snow, with disruptive snowfall occurring in parts of the Western and Northern Cape provinces.

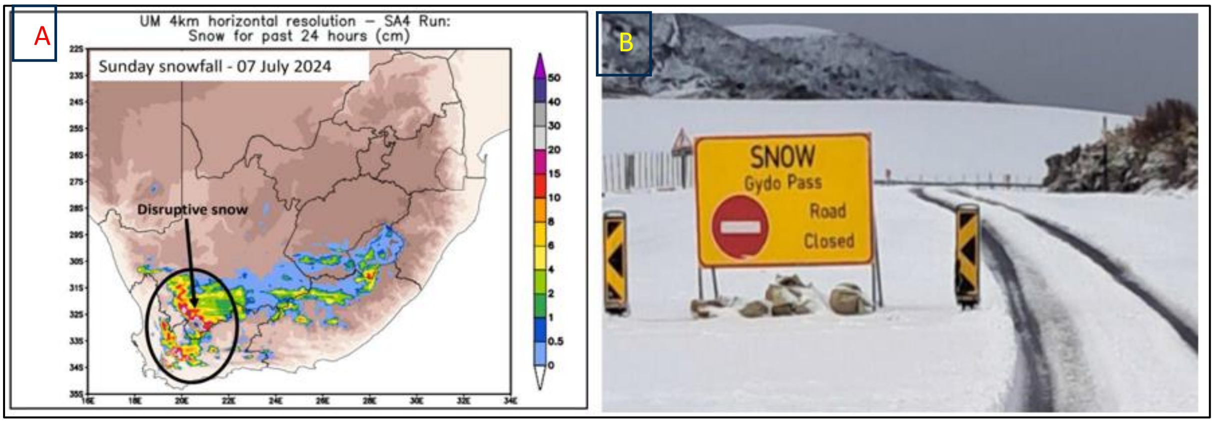


Figure 13: (a) 24-hour snowfall accumulation (in cm) for Sunday, 7 July 2024 (Source: SAWS); (b) 8 July 2024 - Snowfall in the areas surrounding Ceres as cold fronts continue to hit the Western Cape. (Source: Western Cape Government,2024)

Storm surge

On 07- 08 July, 2024, the Western Cape, as well as some parts of the Northern and Eastern Cape provinces, experienced a storm surge. An intense cold front/mid-latitude cyclone caused a significant drop in atmospheric pressure and strong winds, resulting in high waves and storm surge along South Africa's west and south-east coastlines. High waves of up to 10 meters were observed in the affected areas (SAWS,2024b). Figure 14 shows high waves on Cape Town beaches.

> *"A storm surge is an abnormal rise of seawater, over and above predicted astronomical tides, generated by a storm or intense weather system. A surge can be either positive (storm surge) or negative (negative storm surge)" (SAWS,2024b)*

Figure 14: (a) Huge waves break off Sea Point on July 08, 2024 in Cape Town (b) waves hit the coast at Blouberg, Cape Town on 08 July 2024. (Source: Gallo Images)

The aforementioned weather conditions resulted in floods and extensive infrastructure damage throughout the Western Cape Province, including the Overberg and Cape Winelands, with significant financial consequences. The floods had far-reaching economic and social consequences; many people in impoverished informal settlements on the outskirts of Cape Town were left homeless, and provincial disaster management services were forced to evacuate some people in the agricultural area of Citrusdal and parts of the wine-growing region surrounding Stellenbosch. On July 15, 2024, the Western Cape Government reported that approximately 158 000 people had been affected,the majority of whom lived in the City of Cape Town, and that approximately 47 000 structures had been damaged, Figure 15 depicts some of the damage caused by floods in the Western Cape.

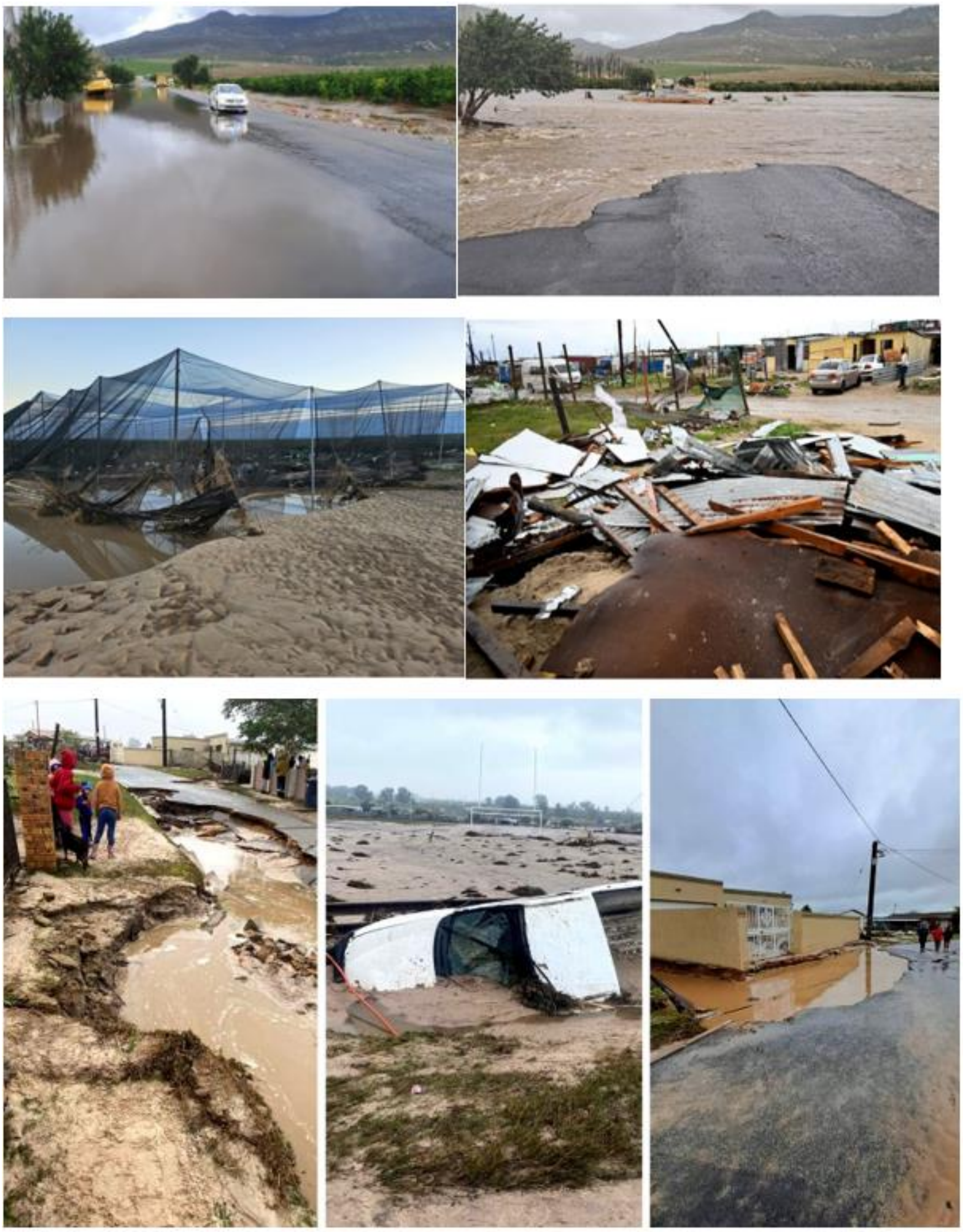


Figure 15: Destruction caused by extreme weather conditions in Western Cape (Source: Independent Newspaper)

Vaal Dam Operating Rules and its Interlinkages With Other Dams In the System

Vaal River System Operational Considerations

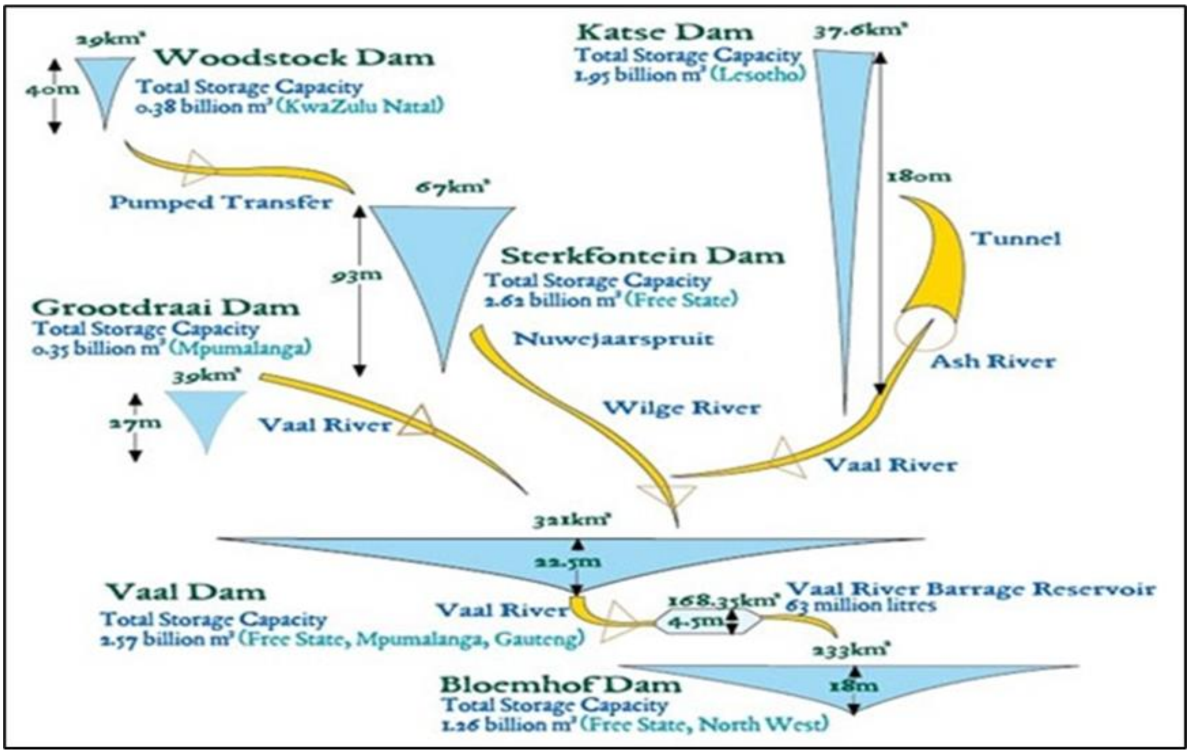


Figure 16 shows Water Sources of the Vaal River System

The Vaal dam serves mostly Gauteng, some of Eskom power stations, and major economic areas in Mpumalanga, Free State, and the Northern Cape. The Vaal Dam is part of the Integrated Vaal River System (IVRS) this means that, its operation is influenced by the state of the other dams within the system and not operated in isolation.

The Vaal Dam storage was at 49.8% of its Full Supply Capacity (FSC) by 29 July 2024, and it has decreased to an unsettling 48.1% by 12 August 2024. This time last year, the Vaal Dam was at 88.6% of its FSC. According to the latest system performance report by DWS, 2024 the dam storage was tracking the worst sequence storage projection. According to records, the lowest dam's storage was 28.3% of FSC in November 2020,

Transfer Links (2024-2025)
The Vlakfontein canal system from Grootdraai Dam is located between Standerton and Secunda, it serves as an important strategic connection by providing water to two of the country's largest energy and petrochemical suppliers in the country: Eskom and Sasol, respectively. These are classified as strategic water users. Throughout the operating year of 2024-2025, the canal will be operated as 6 weeks dry period and 2 weeks wet period with an available capacity of 6.65m3/s, this means that the canal will not be operated at full capacity (DWS,2024).

The Vaal River Eastern Subsystem Augmentation Programme (VRESAP) which abstracts water directly from the Vaal Dam will be utilized as a result of the Vlakfontein Canal closure to transfer up to a maximum available capacity of (2.9m^3/s) during the Vlakfontein Rehabilitation to keep Trichardsfontein (Eskom balancing dam) and Bossiespruit Dams (Sasol Secunda balancing dam) full during dry periods at Vlakfontein refer to **Figure 17**. This is anticipated to put additional strain to the Vaal Dam.

Additional to this, the Lesotho Highlands tunnel is scheduled for a maintenance shutdown from October 2024 to March 2025 and this will reduce the amount of water available within the system and specifically the Vaal Dam as there will be no water transferred during this period.

The Lesotho Highlands Water Project will transfer a total of approximately 511 million m^3 in the 2024-2025 water operating year as per updated delivery schedule provided by the Lesotho Highlands Development Authority.

The Annual Operating Analysis (AOA) for the Financial Year (FY) 2024-2025 reported that there is a 5% risk of Vaal Dam reaching Minimum Operating Rule (MOL) set at 18% by February 2025, which could result in releases from Sterkfontein Dam. In the event of releases from Sterkfontein Dam to Vaal Dam, pumping from Woodstock Dam will be necessary to replenish storage at Sterkfontein Dam and keep it full as per the operating rule. This will be achieved via the Thukela - Vaal Transfer which currently has an available pumping capacity of 15.3 m^3/s.

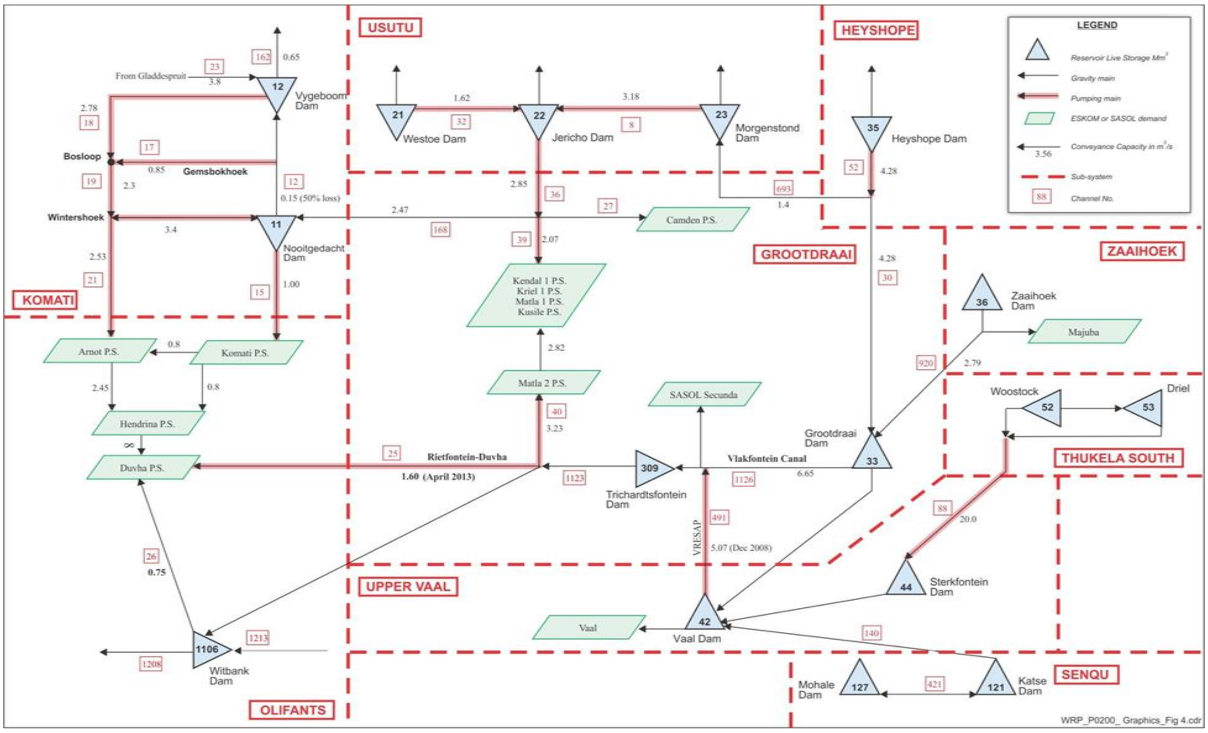


Figure 17: Vaal River Eastern Subsystem Augmentation Project simple schematic

Table 5 shows summarized scenarios analysed as part of the IVRS 2024/2025 AOA.

	Scenario reference & label		A Base	B: Grootdraai	C: RW Low projection	D: Extended LHWP Tunnel Outage	E: Geelhoutboom out for entire operating year
	Rand Water Projection			A	Proj 1600	A	A
1	Thukela- Vaal transfer	2024	13.2 m3/s available from Driel if required	Determine if Sterkfontein release required due to Vaal level (LHWP tunnel Outage)			
		2025 onwards	Driel: 18m3/s, canal 2.1 m3/s, Total: 20.1m3/s Pump: Bloemhof Full	As per A	As per A	As per A	As per A
2	VRESAP transfer	2024	From July 2024: 2 m3/s (2 pumps) to keep Trichardsfontein & Bossiespruit Dams full	As per A	As per A	As per A	As per A
3	LHWP Tunnel Outage		1 October 2024 – 31 March 2025	As per A	As per A	D1: 30 June 2025 D2: 30 Sept 2025	As per A
4	Vlakfontein Canal	2024	From July 2024: 6 weeks dry, 2 weeks wet cycles	As per A	As Per A	As per A	As per A

Table 5: Scenarios

Operating Rule Recommendations

- No restrictions for IVRS (2024/2025)
- Thukela Transfer and Sterkfontein Releases- possibility of release from Sterkfontein to Vaal due to low Vaal storage (LHWP Tunnel Outage). To be monitored.
- If release is required, pumping from Thukela should take place to replenish Sterkfontein Dam and keep it full.
- VRESAP transfer: Will need to transfer more than 2m^3/s for the entire 2024/2025 water operating year to compensate for Vlakfontein 6 weeks dry, 2 weeks wet cycles.

WATER QUALITY EXPLAINED - a continuation from the June 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 the chemical, physical, and biological properties of water 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 the health of aquatic ecosystems, identifying sources of pollution, and developing effective management strategies.

PART D: CHEMICAL WATER QUALITY PARAMETERS – ORGANIC POLLUTANTS

Important organic pollutants for water quality assessment include Pesticides, Volatile Organic Compounds, Pharmaceuticals and Personal Care Products, Polycyclic Aromatic Hydrocarbons, Endocrine-Disrupting Compounds, Microplastics and Industrial contaminants like dioxins, furans, and polychlorinated biphenyls. These organic pollutants can have harmful effects on aquatic ecosystems, wildlife, and human health, making monitoring and mitigation crucial for maintaining water quality.

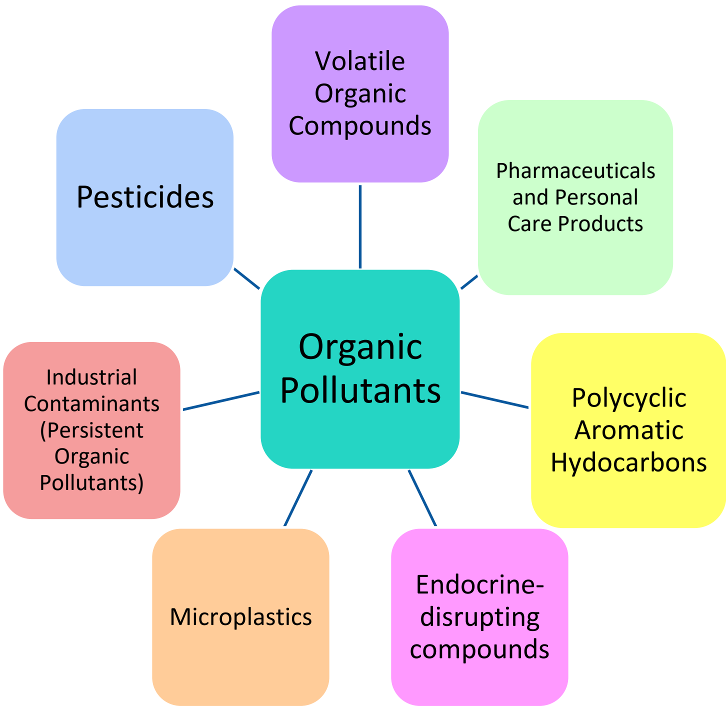


Figure 18: Organic pollutants that affect water quality

PESTICIDES

Pesticides are categorized into several distinct groups based on their target species, with insecticides, herbicides and fungicides being the most used in agricultural farmland and urban settings. They contaminate water sources through various pathways:

- Agricultural runoff – chemicals from fields and farms enter nearby waterways
- Atmospheric deposition – airborne pesticides settle on water surfaces
- Industrial discharge
- Soil leaching: chemicals seep into groundwater
- Direct application – pesticides used for direct aquatic weed control or mosquito larval control

The effects of pesticides on aquatic ecosystems, wildlife and human health are as follows:

- Aquatic toxicity – harm to fish, invertebrates and algae
- Bioaccumulation – the buildup in aquatic organisms and wildlife lead to potential harm in humans consuming them
- Disruption of aquatic ecosystems
- Human health risks – cancer, reproductive issues, neurological problems and endocrine disruption.

Insecticides

Insecticides are used in farmlands, food storage facilities or home garden to control insects. Two common groups of insecticides are the Organochlorine and Organophosphate pesticides. Organochlorine pesticides consist of non-polar and lipophilic atoms including carbon, chlorine, and hydrogen atoms. Common organochlorine pesticides include dichlorodiphenyl trichloroethane (DDT), aldrin (a complex arrangement of chlorine atoms and a naphthalene ring), and lindane (hexachlorocyclohexane). Organochlorine pesticides have long-term persistence in the environment and tend to accumulate in the fatty tissue of animals (Syafrudin *et al.*, 2021).

Organophosphorus pesticides can occur in their aliphatic, cyclic, and heterocyclic forms and possess a central phosphorus atom in the molecule. Common organophosphate pesticides include malathion (which consists of a phosphorus-sulphur molecule with ethyl and methoxy groups attached), diazinon (which consists of a phosphorus-sulphur molecule with ethyl, isopropyl, and pyrimidinyl groups attached) and parathion (which consists of a phosphorus-sulphur molecule with ethyl and nitrophenyl groups attached). Organophosphorus pesticides tend to infiltrate into aquifers and reach groundwater (Syafrudin *et al.*, 2021).

Herbicides

Herbicides are weed-killing compounds and are normally included in plant growth regulators. A common group of herbicides are the Triazines. Triazines contain a six-membered ring structure composed of three nitrogen atoms and three carbon atoms and have the general formula $C_3H_3N_3$. Atrazine and simazine are common triazine derivatives. The world's most widely used herbicide is glyphosate (Xu, J. *et al.*, 2019) and it is used extensively in wheat cultivation. Glyphosate is an organic acid composed of a phosphonomethyl and glycine functional groups.

Fungicides

Fungicides are biological agents used to prevent or eliminate fungus infection in plants or seeds before the fungus is present or after the fungus infects the plant species. As fungal diseases pose a significant threat to crop production, using fungicides to combat fungal infestations is often deemed necessary to ensure the global food supply (Zubrod et al., 2019). Dithiocarbamates, phenylamides and chloronitriles constitute major fungicide groups.

Several water treatments (Saleh *et al*., 2020) can be used to remove pesticides from water:

- Activated Carbon Filtration: effective for removing organic pesticides like atrazine and simazine
- Reverse Osmosis: can remove most pesticides, including inorganic compounds like copper-based fungicides
- Advanced Oxidation Processes: techniques like ozone treatment, UV(UltraViolet) light, and hydrogen peroxide can break down pesticide molecules
- Nanofiltration/Ultrafiltration: membrane filtration can remove pesticides based on size and charge
- Ion Exchange: can remove charged pesticide compounds like glyphosate
- Biological Treatment: certain microorganisms can degrade pesticide molecules
- Chemical Coagulation/Flocculation: removes pesticides by forming insoluble precipitates
- Granular Activated Carbon with UV: a combination of adsorption and oxidation
- Ceramic Filtration: some ceramic filters can remove pesticides through size exclusion and adsorption
- Distillation: can remove most pesticides, but is energy-intensive and costly.

The choice of treatment depends on the type and concentration of pesticides present, water quality and characteristics, treatment goals and regulations and the cost and operational considerations.

VOLATILE ORGANIC COMPOUNDS

Volatile organic compounds (VOCs) correspond to a class of organics characterised by their highly volatile nature under existing environmental conditions and are a major concern due to their toxicity and persistence in the environment. The main subgroups of VOCs include halogenated volatiles such as dichloroethane, trichloroethane, bromodichloromethane and dibromochloromethane; monocyclic aromatic hydrocarbons, organic sulphides and sulphoxides, BTEXs (benzene, toluene, ethyl benzene and xylene), trihalomethanes, acetone, and esters. Trihalomethanes occur in water as a result of water-disinfection byproducts. Major anthropogenic sources of VOCs in the aquatic environment are paints and coatings, gasoline/fuel spills, solvents, industrial and urban wastewaters, urban and rural run-offs, and atmospheric depositions. Apart from accumulating and persisting in the environment, VOCs contribute to increased greenhouse effects and associated ozone depletion (Chary *et al.,* 2012). VOCs in water can present various health risks, including cancer, neurological effects, reproductive issues, and liver and kidney damage (Mangotra and Singh, 2024). Treatment options for VOCs in water include activated carbon filtration, advanced oxidation processes, biological treatment, membrane filtration (reverse osmosis and nanofiltration), distillation and UV treatment.

PHARMACEUTICALS AND PERSONAL CARE PRODUCTS

Common pharmaceuticals and personal care products (PPCPs) found in water include antibiotics (e.g. sulphamethoxazole and trimethoprim), anti-inflammatory medications (e.g. ibuprofen and naproxen), hormones (e.g. estrogen and progesterone), antidepressants (e.g. fluoxetine and sertraline), as well as personal care products such as soaps, detergents, shampoos, conditioners, cosmetics, skincare products, fragrances, and perfumes that contain triclosan and parabens (Esplugas *et al*., 2007). Triclosan is an antibacterial and antifungal agent while parabens are chemicals that are commonly

used as preservatives. Sources of PPCPs in water are from wastewater treatment plant effluent, industrial discharge, domestic sewage, landfills and waste disposal sites.
PPCPs affect water quality by contaminating drinking water sources, impacting aquatic ecosystems and developing antibiotic-resistant bacteria. Treatment options for PPCPs in water include advanced oxidation processes, activated carbon filtration, membrane bioreactors, nanofiltration and biodegradation by biological treatments.

POLYCYCLIC AROMATIC HYDROCARBONS

Polycyclic aromatic hydrocarbons (PAHS) are a class of organic compounds containing two or more fused aromatic rings of carbon and hydrogen atoms. The simplest PAH is naphthalene. In drinking water, the highest concentrations of PAHs are fluoranthene, phenanthrene, pyrene, and anthracene (WHO, 1998). PAHs in water originate from fossil fuel combustion, industrial processes, vehicle emissions, agricultural runoff and waste disposal. They are important in water quality due to the following reasons:

- PAHs are known to be carcinogenic, mutagenic and teratogenic – posing risks to human health and aquatic life
- PAHs are persistent – they are resistant to degradation and remain in the environment for long periods
- PAHs are bioaccumulative and can accumulate in organisms causing potential harm
- PAHs are widespread and are found in various water sources, including surface water, groundwater and wastewater.

Treatment options for PAHs in water include activated carbon filtration, advanced oxidation processes, biodegradation where microorganisms degrade PAHs through aerobic and anaerobic processes, membrane filtration (reverse osmosis and nanofiltration) and by ion exchange where resins remove PAHs by exchanging ions.

ENDOCRINE-DISRUPTING COMPOUNDS

The endocrine system is a complex network of glands and organs in which hormones control and coordinate the body's metabolism, energy level, reproduction, growth and development and response to injury, stress and mood (Kumar and Clark, 2017). Endocrine Disrupting Compounds (EDCs) are chemicals that interfere with the endocrine system by binding to the endocrine receptors to activate, block or alter natural hormone synthesis (Pironti *et al.,* 2021). EDCs reach the aquatic environment through various routes such as pharmaceutical and hospital waste disposal, wastewater treatment plant effluent, leaching of chemicals used in industrial and household items (detergents and personal care products), and release of pesticide residues from agricultural activities**.** Common EDCs affecting water quality are:

- Estrogenic compounds such as estradiol, estrone and estriol
- Androgenic (sex hormone) compounds such as testosterone
- Thyroid-disrupting compounds such as polychlorinated biphenyls (PCBs)
- Pesticides such as atrazine, DDT and lindane
- Industrial chemicals such as bisphenol A (from plastics), phthalates and perfluorinated compounds
- Pharmaceuticals such as birth control pills and hormone replacement therapy

The effects of endocrine disruption on aquatic life and human health are linked to reproductive issues, development problems, cancer, neurological effects and disturbances in the immune and nervous system function (US EPA, 2024). Treatment strategies (Liu *et al*., 2008) for the removal of EDCs in water and wastewater treatment involve physical treatments such as activated charcoal filtration, membrane filtration and nanofiltration, chemical treatments such as advanced oxidation processes where oxidising agents like ozone break down the EDCs, chemical coagulation and flocculation where the EDCs are removed by forming insoluble precipitates; biological treatment where microorganisms and/or enzymes are used to break down EDCs. In addition, natural treatment systems such as wetlands utilize processes like sedimentation, filtration, and biodegradation to remove EDCs. Aquatic plants are also used for phytoremediation to eliminate EDCs (Rajhi and Bardi, 2022).

MICROPLASTICS

Plastics are synthetic organic polymers formed by the process of polymerisation. Microplastics are generally characterised as water-insoluble, solid polymer particles that are ≤5 mm in size (Koelmans *et al.,* 2019). The most common microplastics in water sources are polyethylene, polypropylene, polyvinyl chloride (PVC), polyethylene terephthalate and polystyrene. Fragments, fibres, film, foam and pellets are the most frequently reported shapes of microplastics in water (Koelmans *et al.,* 2019). These microplastics can come from:

- Breakdown of larger plastic debris
- Microbeads in personal care products
- Synthetic fibres from clothing
- Plastic pellets used in industrial processes

Microplastics in water can cause physical harm to aquatic life, ingestion and bioaccumulation of toxic chemicals, alteration of aquatic habitats and ecosystems, and contamination of the food chain (WHO, 2019).

Treatment options for microplastics in water include physical removal through filtration e.g. membrane bioreactors (a combination of biological treatment with physical separation using membranes), chemical treatment through coagulation and flocculation, biological treatment (biodegradation) and advanced oxidation processes.

PERSISTENT ORGANIC POLLUTANTS

Industrial contaminants such as dioxins, furans, and polychlorinated biphenyls (PCBs) are persistent organic pollutants (POPs) that can have significant impacts on water quality, human health, and aquatic ecosystems. POPs are a group of harmful chemicals that have long-term negative effects on human health and the environment. These pollutants are resistant to breaking down and can remain in the environment for extended periods, leading to bioaccumulation and biomagnification in the food chain (US EPA, 2009). Dioxins, furans and PCBs are formed during industrial processes such as waste incineration and chemical manufacturing. PCBs are used in industrial applications, as coolants and lubricants in transformers, capacitors, and other electrical equipment because they don't burn easily and are good insulators (US EPA, 2009). They can enter water bodies through various pathways such as industrial effluent, waste incineration, atmospheric deposition and contaminated soil and sediment.

Note: Organic pollutants that have been mentioned earlier such as DDT – an organochlorine pesticide is also listed as a POP. Treatment options for POPs in water have been covered under Pesticides.

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Glossary

Term	Definition
DDT	dichlorodiphenyl trichloroethane
EDCs	Endocrine Disrupting Compounds
ENSO	El Niño-Southern Oscillation
EF	Enhanced Fujita (scale)
FSC	Full Storage Capacity
HY	Hydrological Year
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated biphenyls
POPs	Persistent Organic Pollutants
PPCPs	Pharmaceuticals and Personal Care Products
SAWS	South African Weather Service
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
VOCs	Volatile Organic Compounds
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 a needed water treatment system

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