DETERMINATION OF WATER RESOURCE CLASSES AND RESOURCE QUALITY OBJECTIVES FOR THE LOWER ORANGE RIVER CATCHMENT, WP11438

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Designation: PSP

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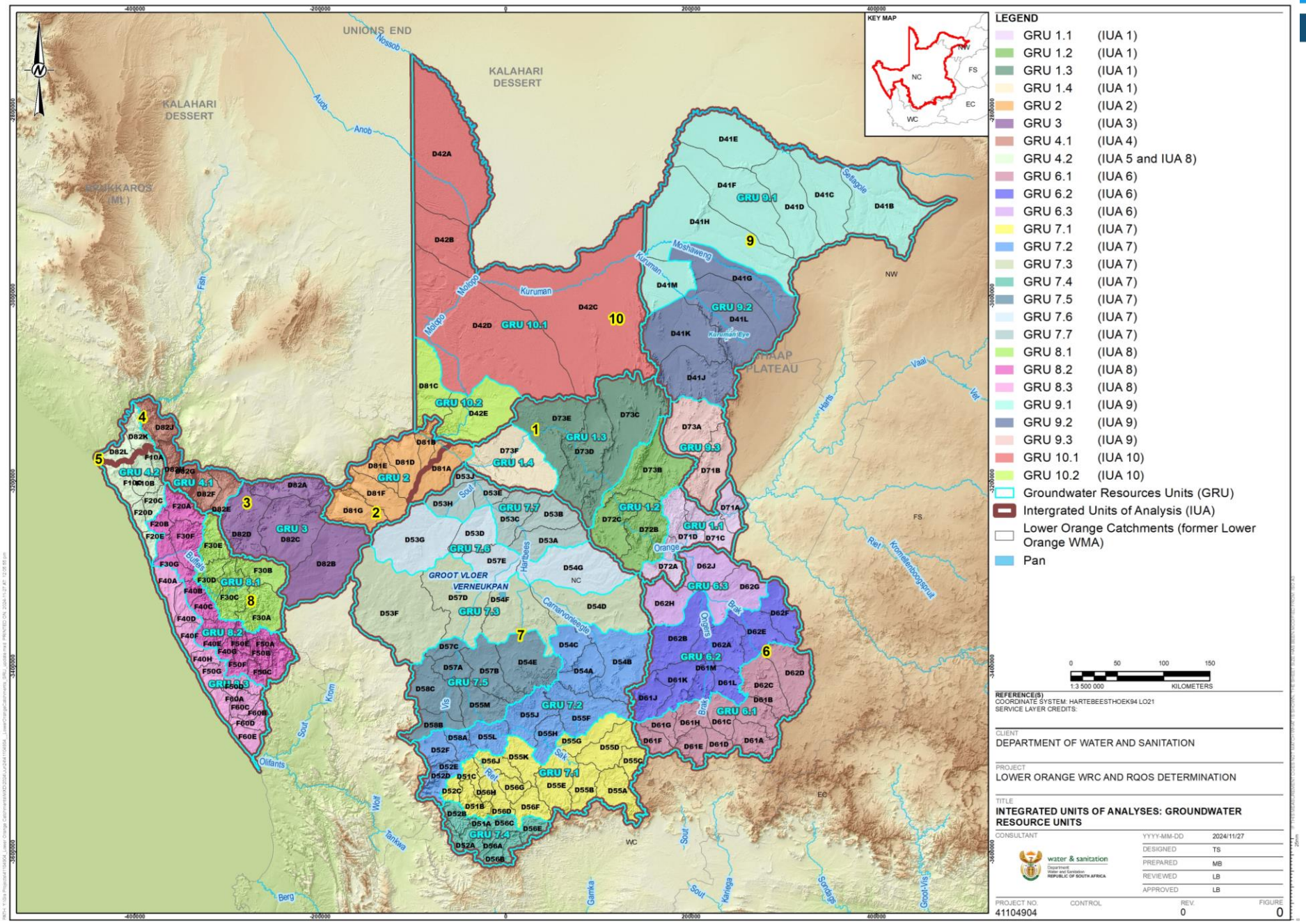
WATER IS LIFE - SANITATION IS DIGNITY

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

2030 NDP


KEY MAP
NW
NC
FS
EC
WC
LEGEND
GRU 1.1 (IUA 1)
GRU 1.2 (IUA 1)
GRU 1.3 (IUA 1)
GRU 1.4 (IUA 1)
GRU 2 (IUA 2)
GRU 3 (IUA 3)
GRU 4.1 (IUA 4)
GRU 4.2 (IUA 5 and IUA 8)
GRU 6.1 (IUA 6)
GRU 6.2 (IUA 6)
GRU 6.3 (IUA 6)
GRU 7.1 (IUA 7)
GRU 7.2 (IUA 7)
GRU 7.3 (IUA 7)
GRU 7.4 (IUA 7)
GRU 7.5 (IUA 7)
GRU 7.6 (IUA 7)
GRU 7.7 (IUA 7)
GRU 8.1 (IUA 8)
GRU 8.2 (IUA 8)
GRU 8.3 (IUA 8)
GRU 9.1 (IUA 9)
GRU 9.2 (IUA 9)
GRU 9.3 (IUA 9)
GRU 10.1 (IUA 10)
GRU 10.2 (IUA 10)
Groundwater Resources Units (GRU)
Intergrated Units of Analysis (IUA)
Lower Orange Catchments (former Lower Orange WMA)
Pan
0 50 100 150
1:3 500 000 KILOMETERS
REFERENCE(S)
COORDINATE SYSTEM: HARTEBEESTHOEK94 LO21
SERVICE LAYER CREDITS:
CLIENT
DEPARTMENT OF WATER AND SANITATION
PROJECT
LOWER ORANGE WRC AND RQOS DETERMINATION
TITLE
INTEGRATED UNITS OF ANALYSES: GROUNDWATER RESOURCE UNITS
CONSULTANT
water & sanitation
Department: Water and Sanitation
REPUBLIC OF SOUTH AFRICA
YYYY-MM-DD 2024/11/27
DESIGNED TS
PREPARED MB
REVIEWED LB
APPROVED LB
PROJECT NO. 41104904
CONTROL
REV. 0
FIGURE 0
UNIONS END
KALAHARI DESSERT
KOMKKAROS (ML)
NAMAQUALAND HIGHLANDS
KAROO PLATEAU
GROOT VLOER
VERNEUKPAN
Nossob
Auob
Anob
Molopo
Kuruman
Moshaweng
Kuruman Eye
Setlagole
Vaal
Harts
Riet
Kromellenboogspruit
Orange
Hartbees
Carnarvonriegte
Brak
Ongers
Buffels
Fish
Sout
Vis
Kom
Olifants
Wolf
Tankwa
Berg
Gamka
Karoega
Sondags
Groot-Vis
Sak
Ref
NW
FS
NC
EC
WC

Groundwater Resource Quality Objectives (RQOs)

Establishment of **RQO Indicators-Measures-Narratives** for groundwater resource units is based on the following measurable hydrogeological parameters:

- **Quantity** (Mm^3/a as measures and limits):
  - Recharge – Mm^3/a (merely from chloride mass balance methodology + GRA II Assessments);
  - Groundwater Use – Mm^3/a (estimated from GRA II Assessments and updated WARMS dataset and hydrocensus surveys) and
  - Groundwater Stress Index (calculation indicating the aquifer stress factor – Apply a limit of 65% indicating a Poor Condition)
  - Aquifer water level depth (metres below ground level obtained from groundwater monitoring programs).
    - Water depth and water level depth trend (indicator and measure) is (i) an indicator for aquifer depletion due to abstraction and should be followed by (ii) an aquifer recharge replenishment during periods of aquifer recharge events; and
    - Limits can be set for aquifer water level depths, e.g., to "metres above master water strike".

Groundwater Resource Quality Objectives (RQOs)

- **Quality** (mgTDS/L and specific hydrochemical constituent concentrations as measures and limits):
  - Total Dissolved Solids – Provides an direct indicator of the groundwater quality status
    - TDS as a baseline aquifer water quality-type indicator; and/or
    - TDS trend (indicator) and gradient (measure of rising/recessing trend) for aquifer water quality status indicating (i) recharge/refreshing conditions, or (ii) deteriorating conditions due to pollution and up-coning of deeper saline water, or marine water intrusion at the coastline(s).
  - Water quality dissolved constituents present and concentrations:
    - Aquifer water quality type: A measure of specific baseline-aquifer water quality type(s), i.e., Ca/Mg-HCO3, Na-HCO3, Na-Cl, Ca/Mg-SO4 – the measure is to remain aquifer water type to the baseline water type by preventing hydrochemical pollution or other deteriorating sources;
    - Water quality trend (indicator) and gradient (measure of rising/recessing trend over time) using specific hydrochemical constituents like Na-Cl or Ca/Mg-SO4; and
    - Specific CoCs like Nitrate, fluoride, ammonium (NH4) or ortho-phosphate (PO4)

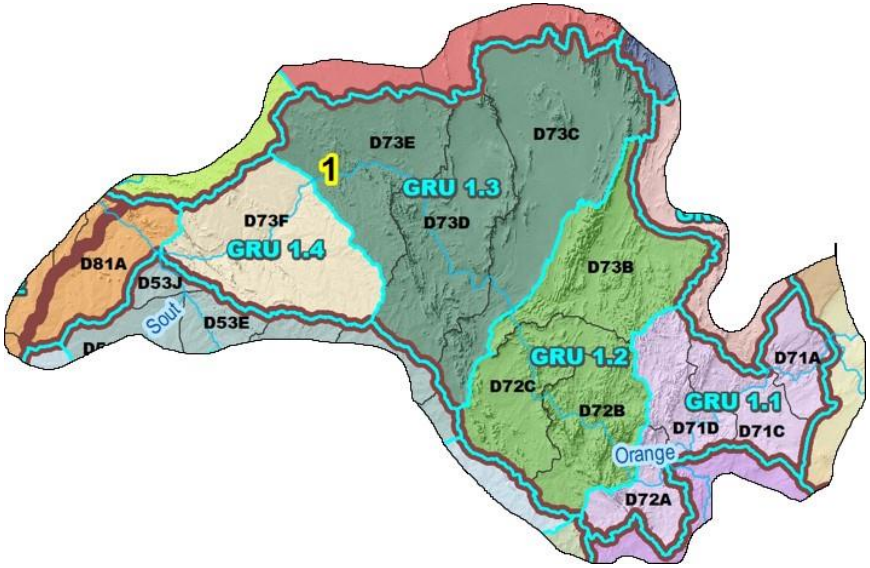
Groundwater Resource Quality Objectives (RQOs)

- **Aquifer Vulnerability** – (specific indicators that arise from primary or secondary conditions that may impacts on the vulnerability of the aquifer system posing a concern/threat for the health/aesthetic status of the aquifer system). Several Aquifer Vulnerability attributes have been included as indicators with proposed measures to impose specific protection protocols for the groundwater resource(s).
  - Depth to water level – Shallow aquifer systems (<60 mbgl)
    - Measure: radius of influence to protect groundwater driven wetlands, dolomite eyes from depleting water levels;
    - Preferential recharge of dolomite (karst) aquifer systems having potential pollution risk (due to poor waste and wastewater treatment); and
    - It could also indicate a limit for groundwater level depletion to protect indigenous flora (such as the Kathu Camelthorn Forest in the Northern Cape Province.

Groundwater Resource Quality Objectives (RQOs)

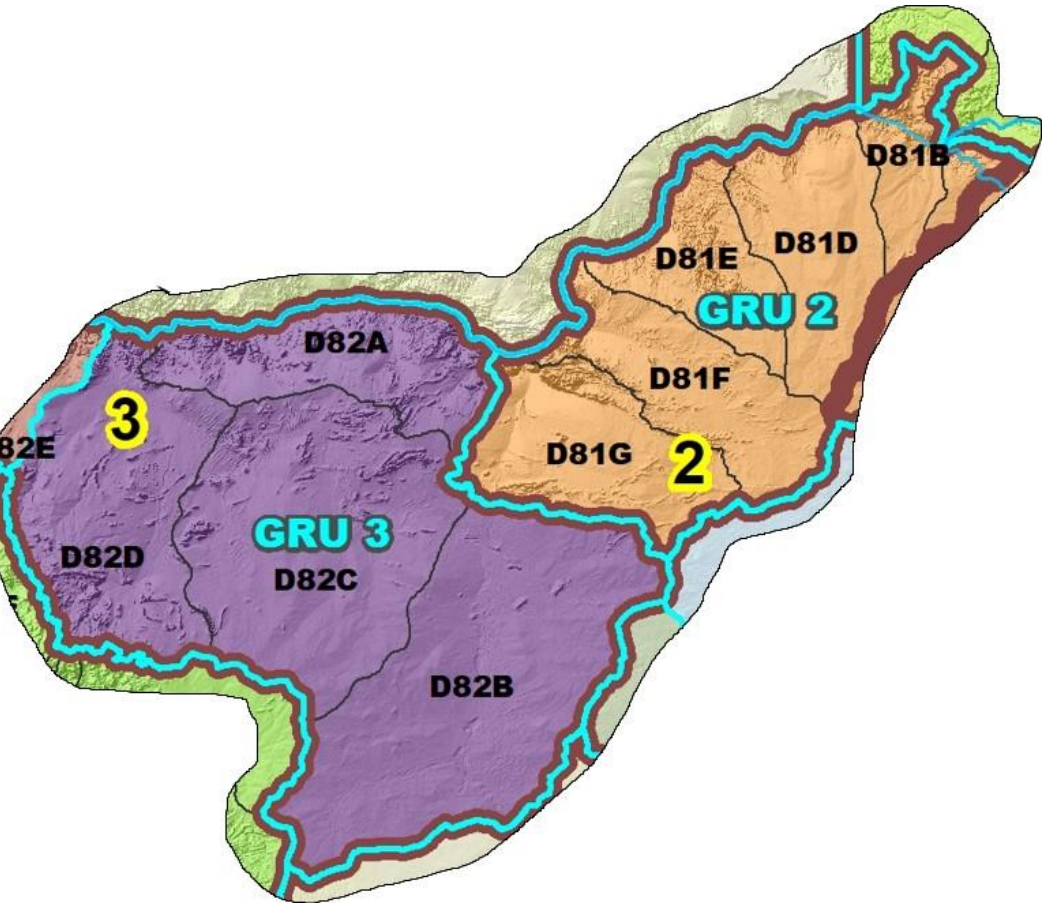
- Water level depletion (alien vegetation and irrigated land)
  - Measure: arial coverage (ha's) and groundwater level impact of uncontrolled alien tree population expansion along drainage channels (rivers) and large veld areas (starts with satellite imagery in critical areas); and
  - Measure: expansion of hectares used for groundwater irrigation schemes in river flood plains and large aquifer systems (DLMTs).
- Aquifer Recharge (mm/a) and Aquifer Abstraction (groundwater use)
  - Measure: annual estimations of recharge volumes to specify annual "allocable yield" volumes; and
- Hydraulic Conductivity (HC)
  - Measure: As an indicator some aquifer formations (fractured and weathered thick sandstone formation have high hydraulic conductance's that may allow high-yielding boreholes that could allow over-abstraction of the aquifer water balances – bulk water supply schemes.
  - Measure: aquifers with high HC susceptible to significant lateral impacts (i.e., sandstone/dolomite aquifer types) due to high groundwater flux in aquifer and storativity (/storage) that may enhance the migration of unwanted polluted substances to enter the deeper parts of the aquifer system.

IUA/GRU 1.1 to 1.4



WATER RESOURCE CLASSIFIACTION: I (Class 1 (A))
Complex Fractured Aquifer Type with limited bulk aquifer storage (occasional fracture flow systems not sustainable in the medium to long-term exploitation).
RESOURCE QUALITY OBJECTIVES:
Quantity: SI status is Natural/Good (± 18% allocated) **RQOs:** 1 - Allocable Yield: <C2 Category; 2 – Limits on long-term water level trends (negative)
Quality: Current WQC = C2 **RQOs:** 1 - Limit to a Class 2 (Marginal) water quality criteria; 2 – CoCs: Note Natural NO3 and F cases; and 3 – To include Arsenic, T-Coliforms and metals (Fe & Mn).
Vulnerability: 1 – Low groundwater recharge; and 2 – Water level recession rate (limit <2.5m/a over 2 HCs)

IUA/GRU 2 & 3



WATER RESOURCE CLASSIFIACTION: III (Class 3 (C))

Primary groundwater quality plays an important role in the groundwater class specification due to (i) geological formation (elevated fluoride) and (ii) insignificant rainwater recharge.

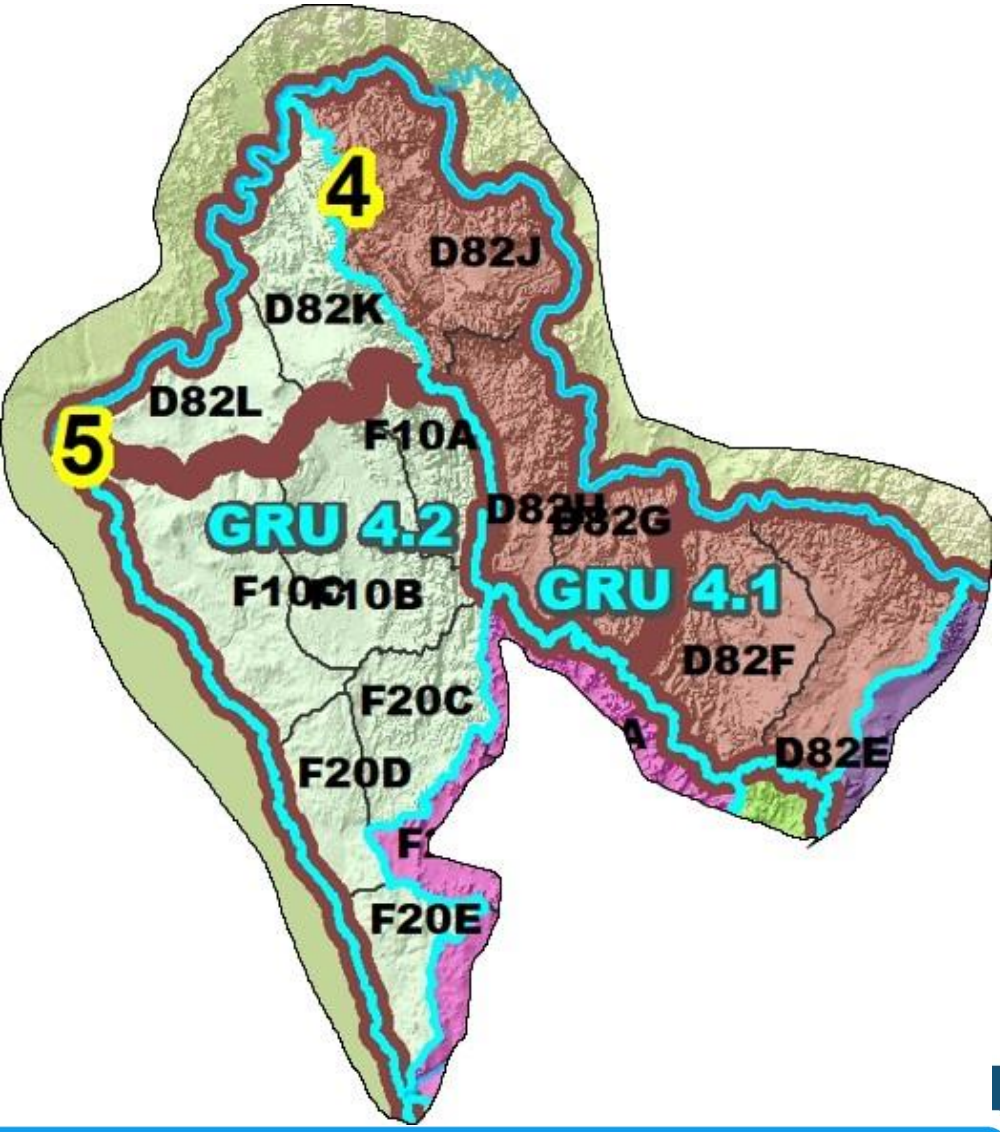
RESOURCE QUALITY OBJECTIVES:

Quantity:
SI status is Critically Modified (both GRUs>100% allocated)
RQOs:
1 - Allocable Yield: C3 Category;
2 – Limits on long-term water level trends (negative)

Quality:
Current WQC = Poor C3 for both GRUs
RQOs:
1 - Limit to a Class 3 (Upper Marginal) water quality criteria;
2 – CoCs: Note Natural NO3 and F cases; and
3 – To include Arsenic, T-Coliforms and metals (Fe & Mn).

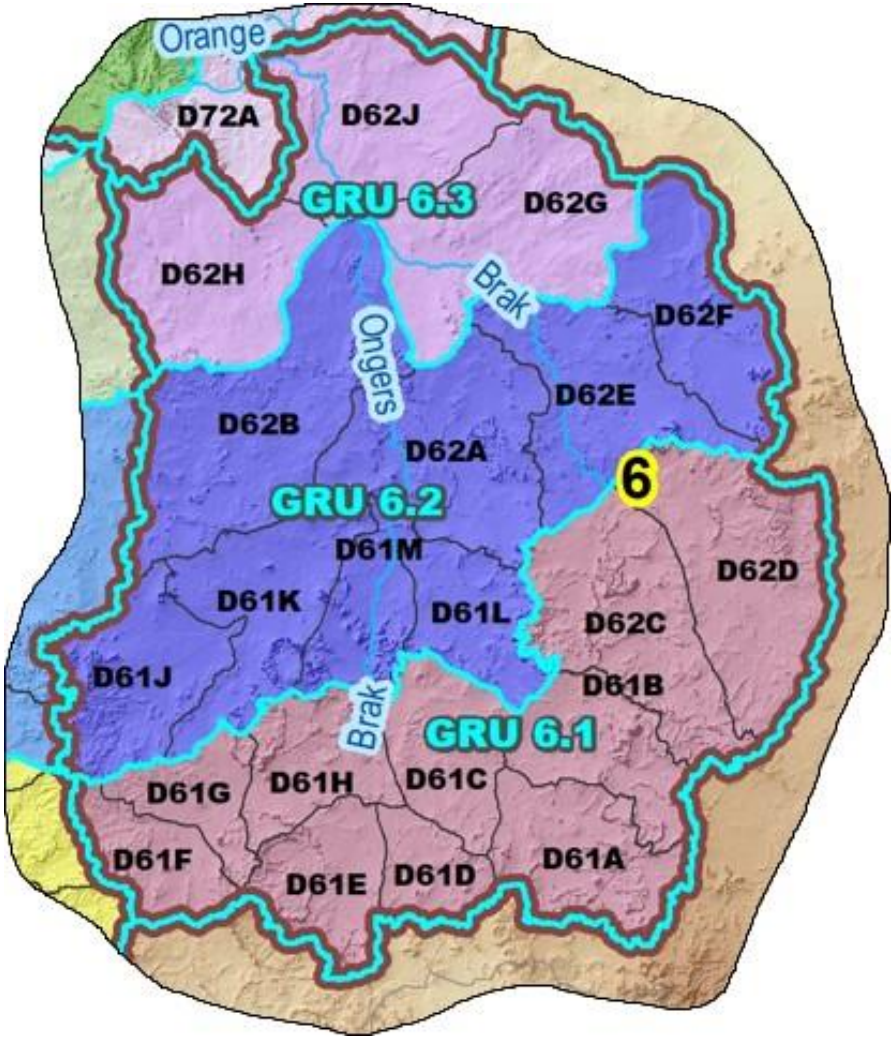
Vulnerability:
1 – CoCs (NO3 & F) naturally elevated to > 10 and >1.1 mg/L limits.
2 – Water level recession rate limit <5.0m/a over 2 HCs.

IUA/GRU 4.1 & 4.2



WATER RESOURCE CLASSIFIACTION: III (Class 3 (C))
Primary groundwater quality plays an important role in the groundwater class specification due to (i) geological formation (elevated nitrate & fluoride) and (ii) insignificant (low) rainwater recharge.
RESOURCE QUALITY OBJECTIVES:
Quantity: SI status is Moderately (48%) to Heavy (125%) used. **RQOs:** 1 - Allocable Yield: C3 Category upper limit; 2 – Limits on long-term (>2-yrs) (-)water level trends.
Quality: Current WQC = Poor C3 for both GRUs **RQOs:** 1 - Limit to a Class 3 (Lower limit) water quality criteria; 2 – CoCs: Note Natural NO3 and F cases; and 3 – To include Arsenic, T-Coliforms and metals (Fe & Mn).
Vulnerability: 1 – CoCs (NO3 & F) Health Limits to > 10 and 1.5 mg/L limits respectively. 2 – Water level recession rate limit <5.0m/a over 2 HCs. 3 – Hydrochemical Trends (TDS!).

IUA/GRU 6.1, 6.2 & 6.3



WATER RESOURCE CLASSIFIACTION: I (Class 1 (A))

Shallow hard rock (sandstones) formation drives preferential recharge mechanism(s).
Higher rainfall drives higher recharge and refresh aquifer water quality status.

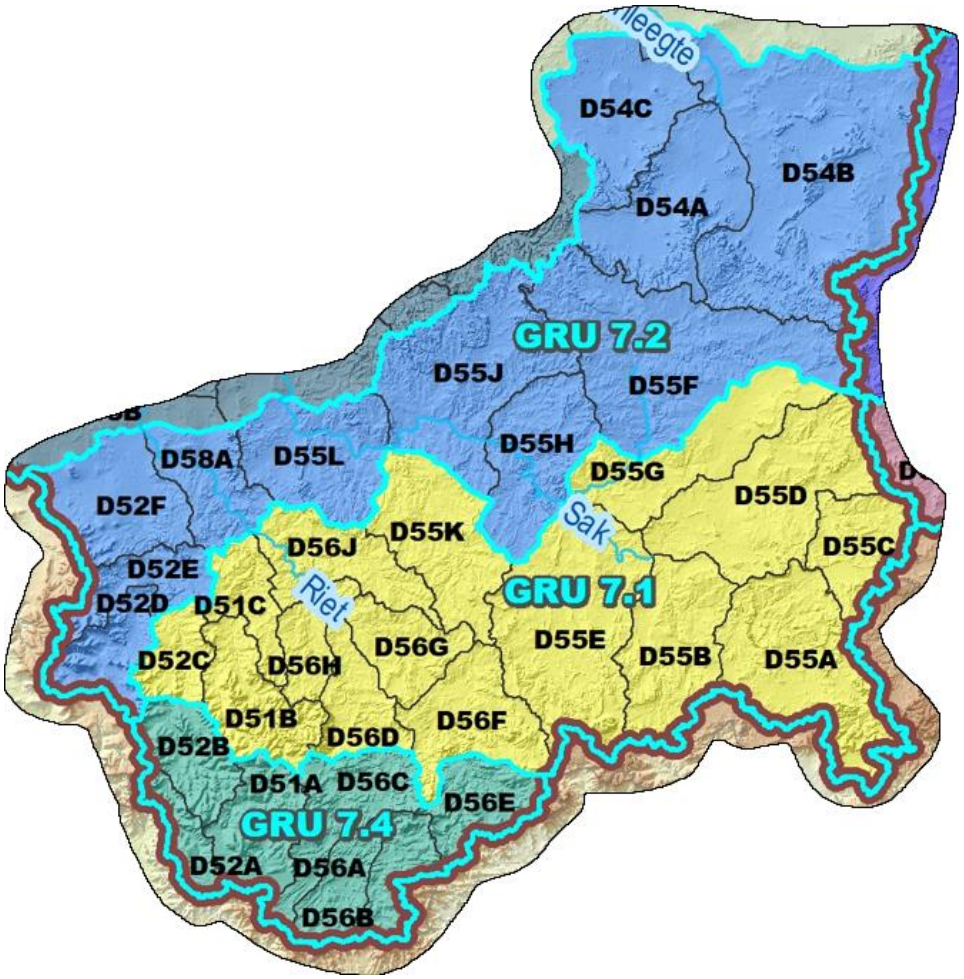
RESOURCE QUALITY OBJECTIVES:

Quantity:
SI status is Minimally Used (<20%).
RQOs:
1 - Allocable Yield: C1 Category recommended;
2 – Limits DD to +5m above "main-water-strike".

Quality:
Current WQC = Good WQT C1 for all GRUs
RQOs:
1 – TDS-Concentration MAX Limit of 1000 mgTDS/L;
2 – Critical WQl Indicator Limits: T-Coli, NO3 and F!;
3 – Critical to frequently monitor PO4 and NH3.

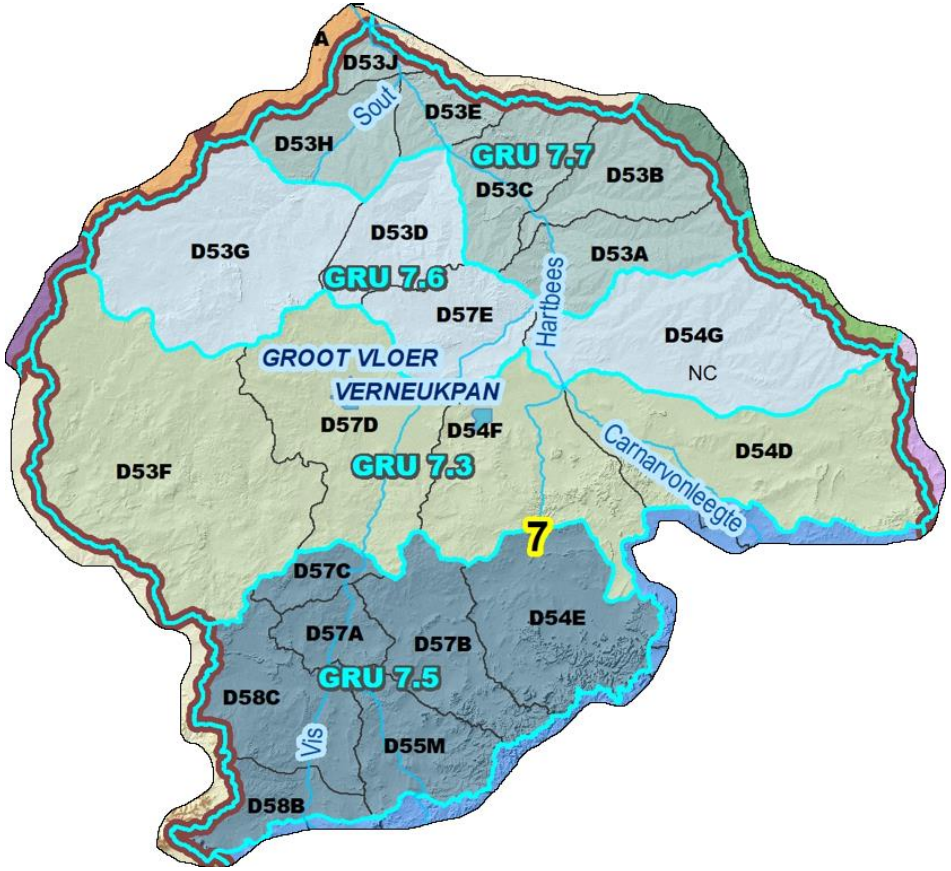
Vulnerability:
1 – Aquifer Hydraulic Conductivity Status control on individual high abstraction well fields.
2 – Expanding alien tree population in/near river valleys.

IUA/GRU 7.1, 7.2 & 7.4



WATER RESOURCE CLASSIFIACTION: I (Class 1 (A))
Lower rainfall impacts on (i) aquifer recharge and (ii) medium-term water quality (TDS). Protection required (RQO) against over-utilization for bulk users.
RESOURCE QUALITY OBJECTIVES:
Quantity: SI status is Moderately Used (25%) used. **RQOs:** 1 - Allocable Yield: C1 Category recommended; 2 – Limits DD to +5m above "main-water-strike".
Quality: Current WQC = Marginal WQT C2 for all GRUs **RQOs:** 1 – TDS-Concentration MAX Limit of 2400 mgTDS/L; 2 – Critical WQl Indicator Limits: T-Coli, NO3 and F!; 3 – Critical to frequently monitor PO4 and NH3.
Vulnerability: 1 – Expansion of alien tree population; 2 – Expansion of irrigation land area (limitation on ha's); 3 – Aquifer Hydraulic Conductivity Status control on individual high abstraction well fields (bulk water supply schemes)

IUA/GRU 7.3, 7.5, 7.6 & 7.7



WATER RESOURCE CLASSIFIACTION: II (Class 2 (B))

Lower rainfall input reduces annual recharge as much as 33%. Primary salinity of aquifer formation becomes more dominant and over-utilization could increase the salinity.

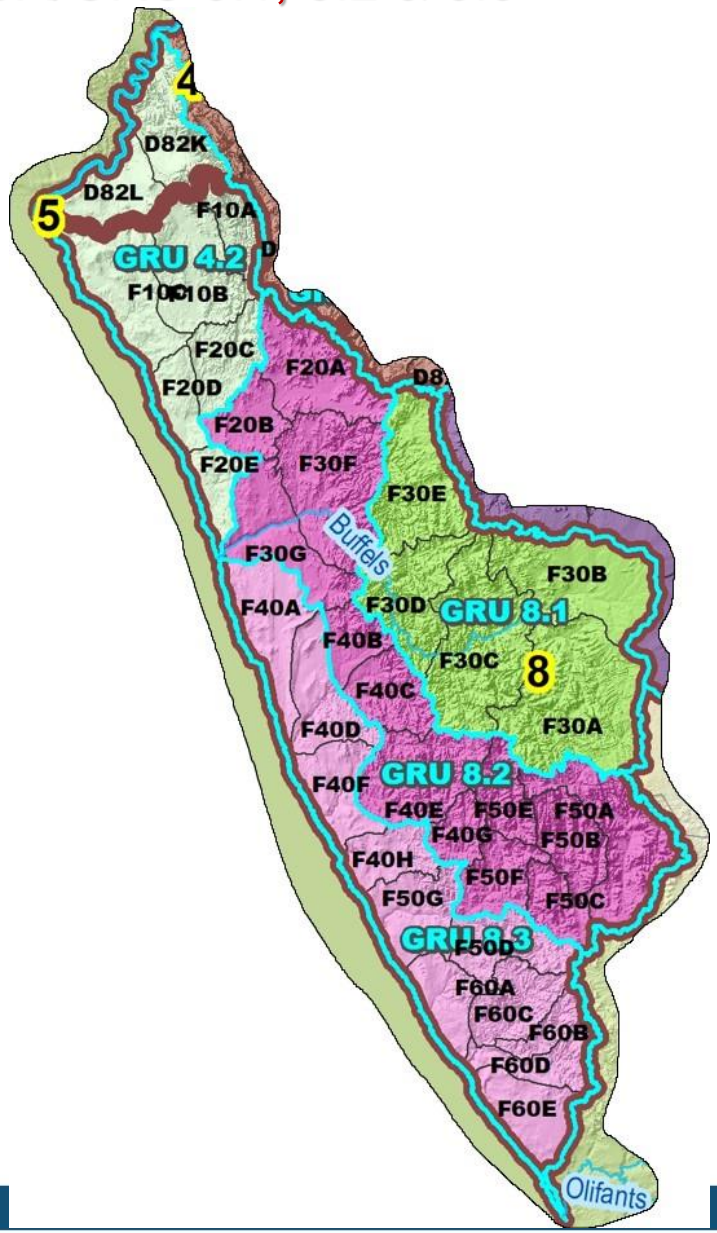
RESOURCE QUALITY OBJECTIVES:

Quantity:
SI status is between Minimally (7.3), Moderately (7.5 & 7.6) and Heavily (7.7 @ 82%) Used.
RQOs:
1 - Allocable Yield Categories: C1 (and C3 for GRU 7.7);
2 – Borehole yields should be balanced with actual rainfall.

Quality:
Current WQC = Marginal WQT C2 for all GRUs
RQOs:
1 – TDS-Concentration (an indicator of recharge) MAX Limit of 2400 mgTDS/L;
2 – WQI Indicator Limits: T-Coli, NO3, F, PO4 and NH3;
3 – Natural elevated NO3 and F should be noted.

Vulnerability:
1 – Expansion of alien tree population encroachment;
2 – Deteriorating water quality due to reduced recharge;

IUA/GRU 8.1, 8.2 & 8.3



WATER RESOURCE CLASSIFIACTION: III (Class 3 (C))

Primary groundwater quality impacted by marine aerosols and water-rock formation interaction (elevated salinity, e.g. NaCl and fluoride). Water quality criteria is the most critical measure/objective due to natural conditions/ climate impact(s).

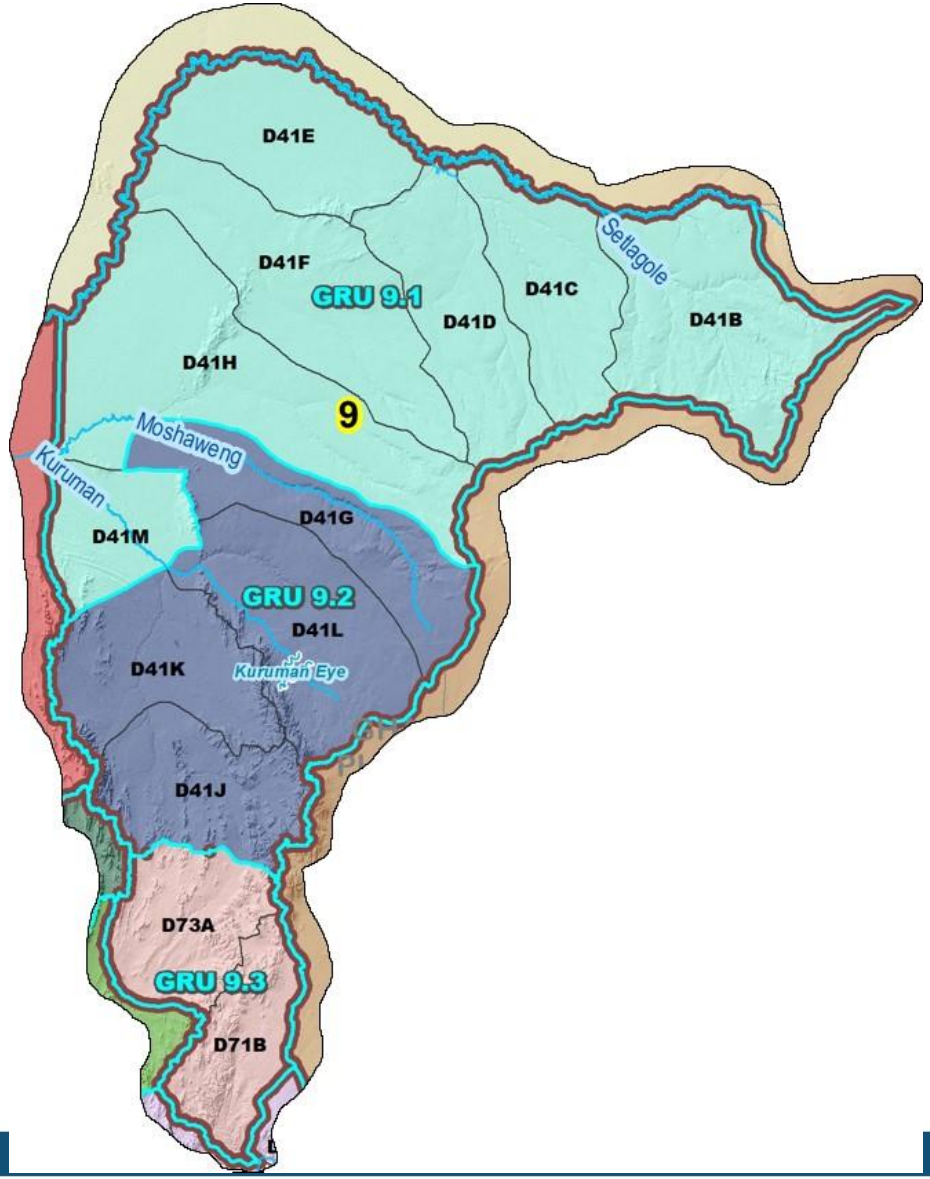
RESOURCE QUALITY OBJECTIVES:

Quantity:
SI status is Moderately Used (~48%).
RQOs:
1 - Allocable Yield Categories: a C1;
2 – Annual water level trend should be stable/oscillating according to the annual recharge phases.

Quality:
Current WQC = Marginal WQT Class 2 for all GRUs
RQOs:
1 – Upper limit for TDS be limited to 2400 mgTDS/L;
2 - WQl Trend Indicator: NaCl dilution in aquifers.

Vulnerability:
1 –Background NO3 & F Municipal Well Fields and stock kraals.;
2 –Note: Insignificant to Low Borehole Yield Classification.

IUA/GRU 9.1, 9.2 & 9.3



WATER RESOURCE CLASSIFIACTION: III (Class 3 (C))

Shallow hard rock formations (high recharge) and dolomite aquifer (high potential for serious pollution form surface flows). High demand for groundwater exploitation (no surface water resources available). Significant mining developments (dewatering) taking place and high rural population growth (high domestic use).

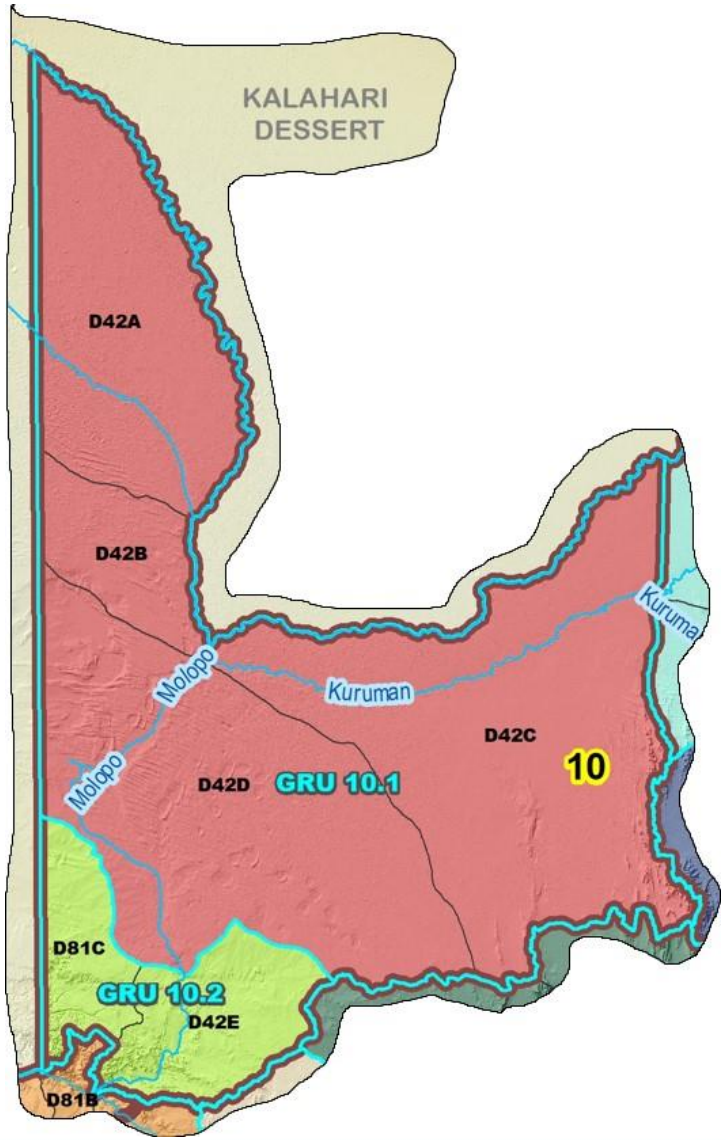
RESOURCE QUALITY OBJECTIVES:

Quantity:
SI status is Moderately (9.1 at 42%) and Heavily Used (9.2 & 9.3 at ~89%).
RQOs:
1 - Allocable Yield Categories: a upper limit Class C1 (9.1) and C3 (9.2 & 9.3);
2 – Water trend analyses should not remain negative for >2 HCs.

Quality:
Current WQC = Marginal WQT Class 2 for all GRUs
RQOs:
1 – Upper limit for TDS be <1000 mgTDS/L; and
2 – "Three Tire" water quality limits proposed.

Vulnerability:
1 – Water level recession trends <2.5m/a MAX 1½-yrs.

IUA/GRU 10.1 &10.2



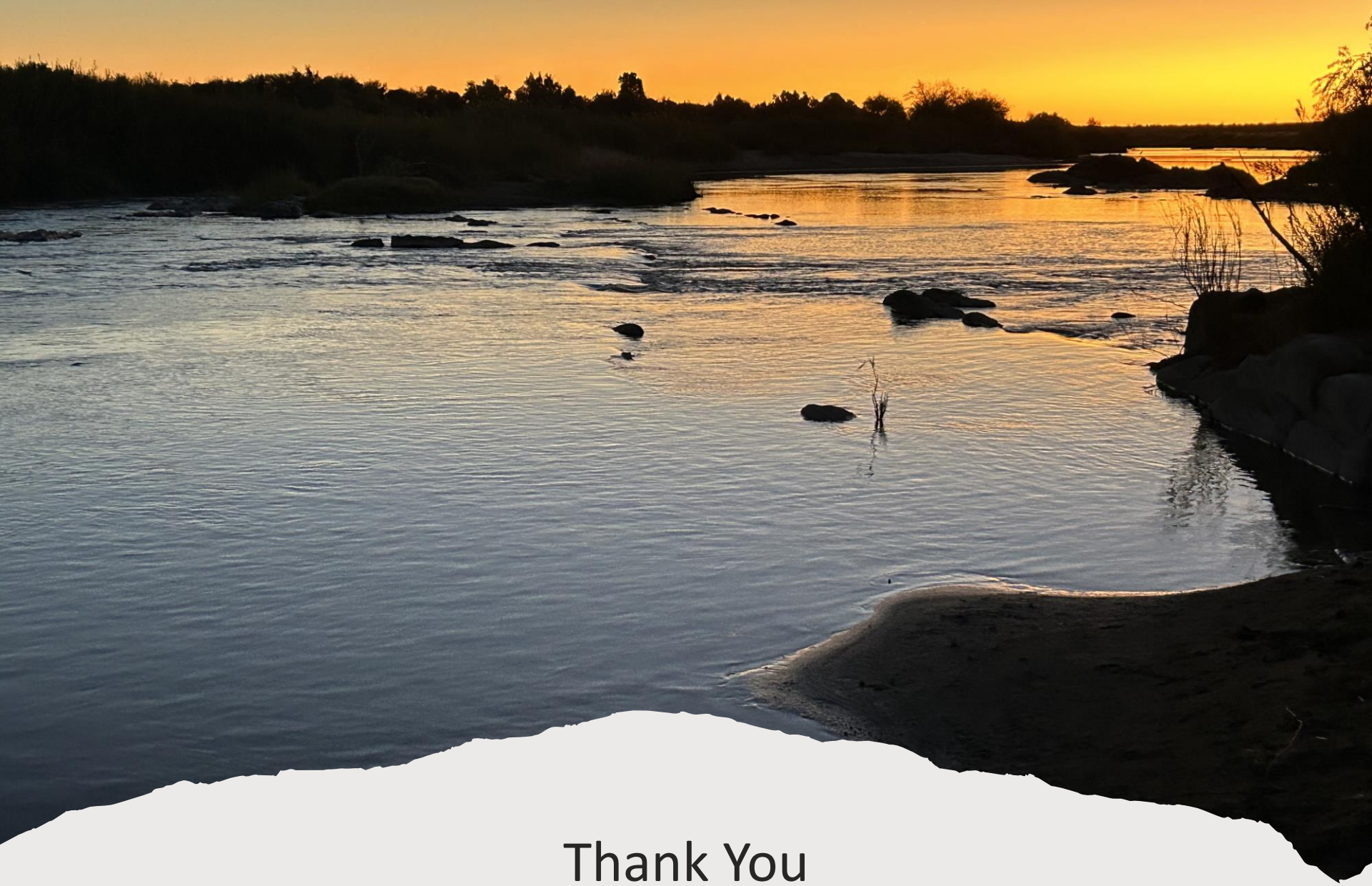
WATER RESOURCE CLASSIFIACTION: II (Class 2 (B))
Very limited groundwater recharge (MAP <250 mm/a to 75 mm/a (GRU10.2) Kalahari Group Aquifer Systems with only sporadic recharge events (flush flooding in Molopo and Kuruman River. Low yielding vulnerable freshwater aquifers in Lower Kuruman River (Van Zylsrus – Andriesvale Area).
RESOURCE QUALITY OBJECTIVES:
Quantity: SI status is Moderately (42%). **RQOs:** 1 - Allocable Yield Categories: a Class C2 recommended; 2 – Borehole yields should be limited to prevent saline water intrusion from deeper saline aquifer system.
Quality: Current WQC = Marginal WQT Class 2 for all GRUs **RQOs:** 1 – Upper limit for TDS be <1000 mgTDS/L; 2 – Specific limits for Na, TAL, Cl and SO4.
Vulnerability: 1 – Water level recession trends <0.5m/a MAX 1½ - yrs 2 – Over abstraction from unique T-Qk Aquifer Systems.

Groundwater RQO tables – what you will see

Sub-component		Indicators	Measures	Context o/t RQO / Narrative
IUA 9 (GRUs 9.2, 9.3) **Complex aquifer combinations including shallow hard rock formation (high recharge) and dolomite aquifer (high potential for serious pollution form surface flows).** **High demand for groundwater exploitation (no surface water resources available).** **Significant mining developments taking place and high rural population growth (high domestic use)**				
Quantity (Qn)	Aquifer water level (table) depths (mbgl) or elevation of aquifer saturation elevation (mamsl)	Rainfall Depths	Groundwater Annual Recharge (mm/a)	Seasons with lower rainfall depths have lower recharge rates. Consider actual annual rainfall figures instead of Long-Term average values. Test scenarios using depleted rainfall input.
		Borehole water level (depth metres below ground level).	Water Level (time series) trend analysis.	An indicator of recharge and abstraction balance) .
	Sustainable Use:	Stress Index (factor) (Water Use volumes). Upper limit of SI value = 65% (or 0.65). Allocable Yield (AlY): Difference between water used (BHN+EWR+GwBF)+Total Use) and an annual-based recharge value.	Groundwater recharge values and Total Groundwater Use figures. Establish water use figures for main water users. SI MAX 0.65 Allocable Yield (MIN 2.0 Mm3/a)	Indicator of "Allocable Yield" and status of aquifer storage volume (89% Alloc'd).
				Important aspect of calculation of Total Water Use in SI Classification. Available Volume (2025) = 96 Mm3/a Water Use Sectors (Stock watering & irrigation): 0.8 and 35Mm3/a.

Sub-component		Indicators	Measures	Context o/t RQO / Narrative
Quality (QI)	TDS, Macro element concentrations and Constituents of Concern (CoCs) and Microbial Status.	Monthly salinity measurements (TDS mg/L). Measure TDS-values for time series analysis.	TDS (salinity): Concentration should be limit to ≤700 mgTDS/L. TDS trend analyses should not indicate a rising trend over 2 consecutive years. Calculated TDS-Trend Analyses.	Baseline water quality indicator (natural water quality status to remain within a 10% oscillation). Indicator of poor recharge/over-abstraction/pollution over time.
		Macro element concentrations: Sodium; TAL; Chloride; and Sulphate. CoC: Fluoride, Nitrate, Ammonia and Orthophosphate.	Quarterly analyses required and individual concentrations should be limit to a Class 1 (Good) water quality criteria: Sodium: <60 mgNa/L. Long-term (7.5-yr) trend should not approach +10% TAL: dominant anion hydrochemical constituent – should remain <400 mgHCO3/L. Chloride: <53 mgCl/L. Long-term (7.5-yr) trend should not approach+10%. Sulphate: <27 mgSO4/L. Long-term trend should not approach+10%.	As per Reserve Determination specifications. In addition, any of these indicators may have relevance to pollution sources from agricultural and domestic water treatment related activities. Long-term TDS trend should not approach +10% (not to overrun 770 mgTDS/L). Water quality objective: QI = C1 (Good water quality type).
		Microbiological status (Total coliform counts) Nutrients Nitrate: NO3, mgN/L; Toxin– Fluoride: F, mgF/L; Toxin– Arsenic: As, mgAs/L; and Diss. Metals: Iron and Manganese (mgFe-Mn/L).	Total coliform counts: <10 counts/100 ml) Nitrate: Less than 10 mgN/L; Fluoride: <1.0 mgF/L; Arsenic: <0.05 mgAs/L; Iron-Manganese: <0.2 mgFe/L and <0.4 mgMn/L.	Total coliform counts and nitrate/nitrite concentrations are indicators of domestic pollution and should be regarded as critical water quality indicators – annual trends are therefore required through specific monitoring programmes. Additional care: PO4 and HN4.

Sub-component		Indicators	Measures	Context o/t RQO / Narrative
Vulnerability Status	Aquifer water level trend	Annual positive or negative water level trend (time series dataset) – water level recession rate (M/a)	Annual water level recession rate must be less than 2.5 m/a. If an ongoing negative trend is observed, abstraction yield (L/s) should be decreased by subsequent intervals of 12.5% per annum until stable trend is observed (i.e., until sufficient recharge has occurred to reset the negative trend.	Water level trend should be stable over time and reporting natural seasonal oscillations driven by wet/dry climate cycles – any deviation from this trend-pattern should be regarded as an indicator of aquifer stress (too low recharge and/or over-abstraction). If trend remains negative (+2 Hydrological Cycles), a special investigation is required to identify and address the cause of the water level recession.
	Hydro-chemical trends:	Time series trends of TDS obtained from quarterly water quality analyses (monitoring program/network required).	Medium-term trend (5-yr cycle) increases should not approach +10% (as indicated by the Reserve Determination guideline). "Three Tire" Water Quality Approach: T1, T2 and T3:	Quality trend(s) should stay within natural annual oscillation (annual recharge freshening). Medium-term (18 to 24 months) negative trend must be investigated (source identification). The critical constituent for the area is nitrate due to industrial and domestic waste generation.
	Aquifer Hydraulic Charac-teristics.	Hydraulic Conductivity Aquifer System(s).	Mapping of high yielding aquifer systems (Aquifer Zoning).	Potential to over-abstract aquifer when BYC indicates High to Significant BYCs. Stress Index Limitation (65% or 065). High HC unsaturated zone(s) enhances preferential infiltration into to saturated zone.



Thank You