Groundwater

Overview

- Present the methodology followed to prioritise Resource Units
  - Recap: Delineation of groundwater resource units
  - Recap: Status quo assessment, classification scenarios
  - Prioritisation
- Present the methodology followed to evaluate Resource Units
  - Selection of sub-components (criteria), indicators
- Present the draft Resource Quality Objectives
  - Numerical limits, narrative limits

Groundwater
1. Prioritisation of GRUs

Groundwater resource units

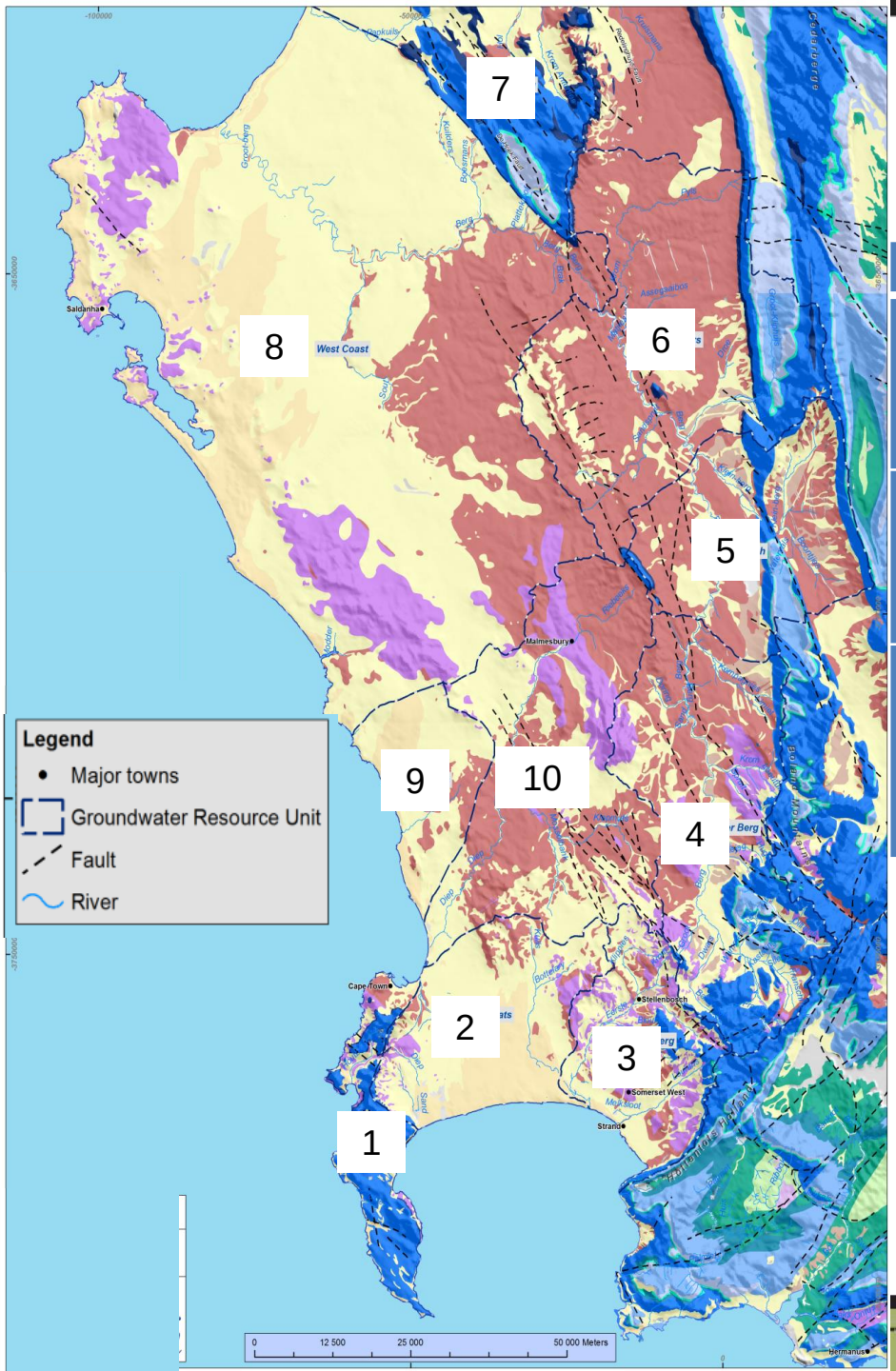
- Unit of analysis for:
  - Status quo assessment: recharge, discharge, groundwater use, trend analysis
  - Groundwater balance model, present status
  - Impact of classification scenarios on groundwater
  - Prioritisation of areas
  - Determination of RQOs

➢ Hydraulic boundaries for groundwater

Groundwater resource units

Delineation took the following into consideration:

- Surface water topographical divides
- Geological structures
- Recharge zones
- Discharge zones
- River systems
- Groundwater use
- Groundwater management (size and extent of units)



Groundwater Resource Units

Sub-Region	GRU	Quaternary
Greater Cape Town	1-Peninsula	G22A and G22B
	2-Cape Flats	G22C, G22D and G22E
	3-Helderberg	G22G; G22H; G22K and G22J
Upper Berg	4-Paarl-Upper Berg	G10A; G10B; G10C and G10D
	5-Tulbagh Valley	G10E and G10F
	6-24 Rivers	G10G; G10H and G10J
Lower Berg	7-Piketberg	G30A and G30D
	8-West Coast	G10K; G10M; G10L and G21A
	9-Atlantis	G21B
	10-Malmesbury	G21C; G21D and G21E

Geology
- Quaternary Deposits
- Tertiary Deposits

Coastal Deposits
- Bredasdorp Group

Cape Supergroup
- Witteberg Group

Bokkeveld Group
- Traka/Bidouw Sub-Grp
- Ceres Sub-Grp

Table Mountain Group
- Nardouw Sub-Grp
- Skurweberg FM
- TMG (undifferentiated)
- Cedarberg (shale) FM
- Peninsula FM
- Piekenierskloof & Graafwater FM

Namibian to Early Cambrian Successions
- Cape Granite Suite
- Malmesbury Group

Delineation summary

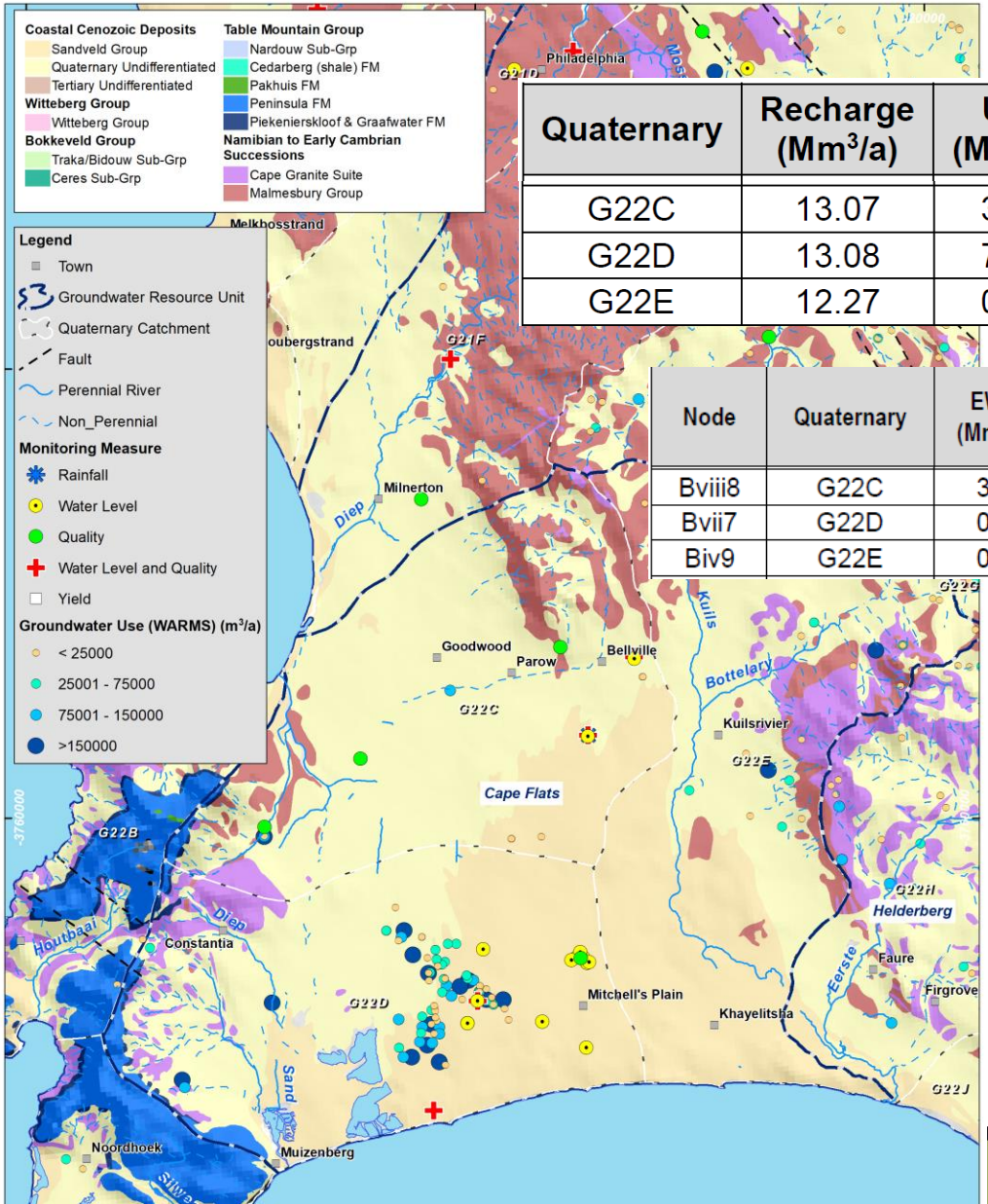
- We consider the data and make the necessary assessments at GRU scale, also considering neighbouring GRUs where there may be flow between them
- We also provide numerical results at quaternary catchment scale, and use quaternary catchments to zoom in on areas within the GRU
- From quaternary catchment scale, the information can be amalgamated to IUA scale

➢ **RQOs developed for quaternary catchment(s) per GRU, ensuring at least 1 catchment per GRU is prioritised (where possible)**

Recap: Status quo assessment & classification scenarios

- Status quo report & EWR Report
  - Description of major groundwater flow regime per GRU
  - Description & quantification of recharge, use, discharge per GRU
  - Groundwater balance model (per GRU and quaternary)
  - GW-SW interactions (per quaternary)
  - Groundwater Present Status (based on quantity and quality)
  - Trend analysis (water level, water quality)
- Scenarios report
  - Potential impact of development / conservation scenarios on future groundwater status (quantity) - in order to inform prioritisation and protection

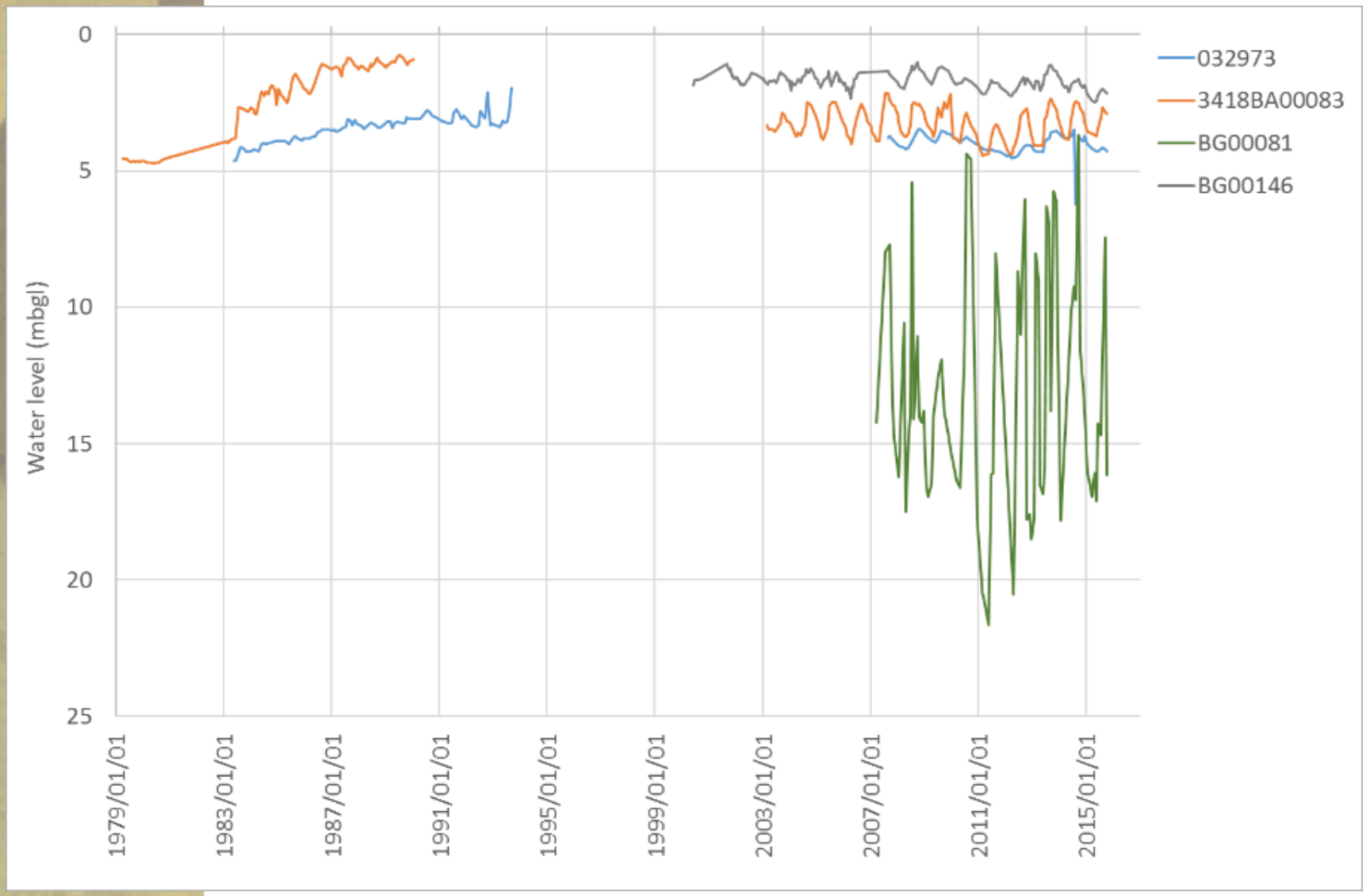
Status Quo: GRU2 Cape Flats



Quaternary	Recharge (Mm^3/a)	Use (Mm^3/a)	GWBF (Mm^3/a)	Balance (Mm^3/a)	Use/Recharge (%)	Present Status
G22C	13.07	3.54	2.56	6.97	27%	II
G22D	13.08	7.31	2.40	3.37	56%	II
G22E	12.27	0.92	2.63	8.71	8%	I

Node	Quaternary	EWR (Mm^3/a)	EWR-MLF (Mm^3/a)	nMAR (Mm^3/a)	GWBF (Mm^3/a)	GWBF/EWR	GWBF/EWR-MLF	GWBF/nMAR
Bviii8	G22C	3.6		23.2	1.0	28%		4%
Bvii7	G22D	0.7	0.3	4.5	0.2	28%	57%	4%
Biv9	G22E	0.6		20.3	2.4	389%		12%

Status Quo: GRU2 Cape Flats



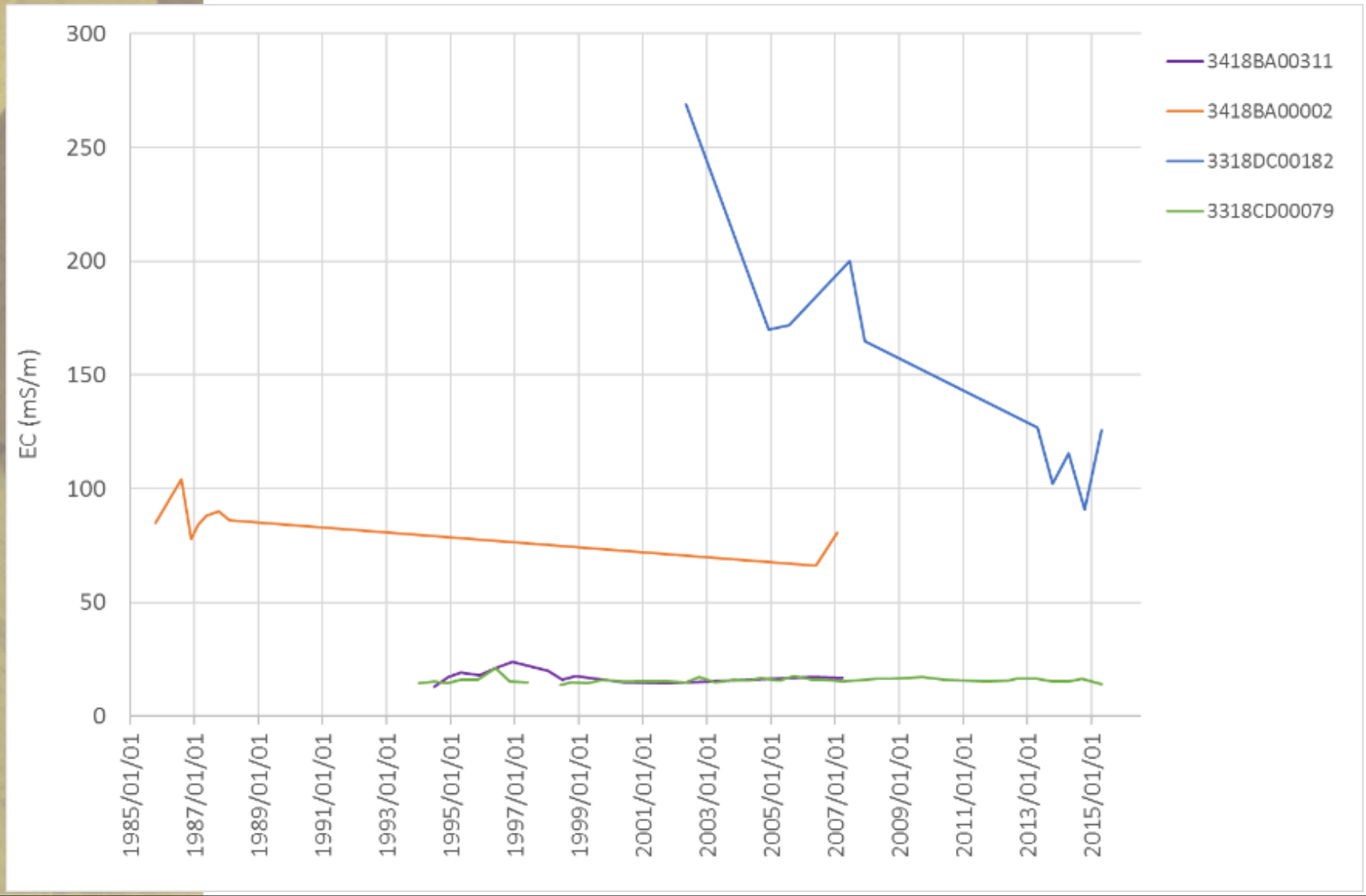
Status Quo: GRU2 Cape Flats

TABLE 9: PRESENT STATUS CATEGORY BASED ON DWA WATER QUALITY GUIDELINES FOR DOMESTIC USE

PRESENT Status	DESCRIPTION	COMPLIANCE (SPATIAL/TEMPORAL)
I	DWA class 0 or 1 or natural background	95 %
II	DWA class 2 (95 % compliance) or natural background (75 % compliance)	75 %
III	DWA class 3 or 4 or natural background (<75 % compliance)	<75 %

			EC (mS/m)				NO_3 (as N) (mg/l)			
Area	Major Aquifer	Count (number of data points)	Median	75 Percentile	90 Percentile	95 Percentile	Median	75 Percentile	90 Percentile	95 Percentile
Whole Berg	CCD		90	231	555	942	0.1	1.2	5.5	9.7
	TMG		9	25	74	119	0.1	0.4	0.7	2.4
	Basement		181	399	670	953	1.0	4.0	8.5	12.4
G22C	CCD	58	117	169	186	256	0.1	2.4	5.1	5.8
G22D	CCD	470	90	100	109	120	1.1	3.6	7.1	9.9
G22E	CCD	24	187	454	477	563	0.1	0.9	2.3	3.7

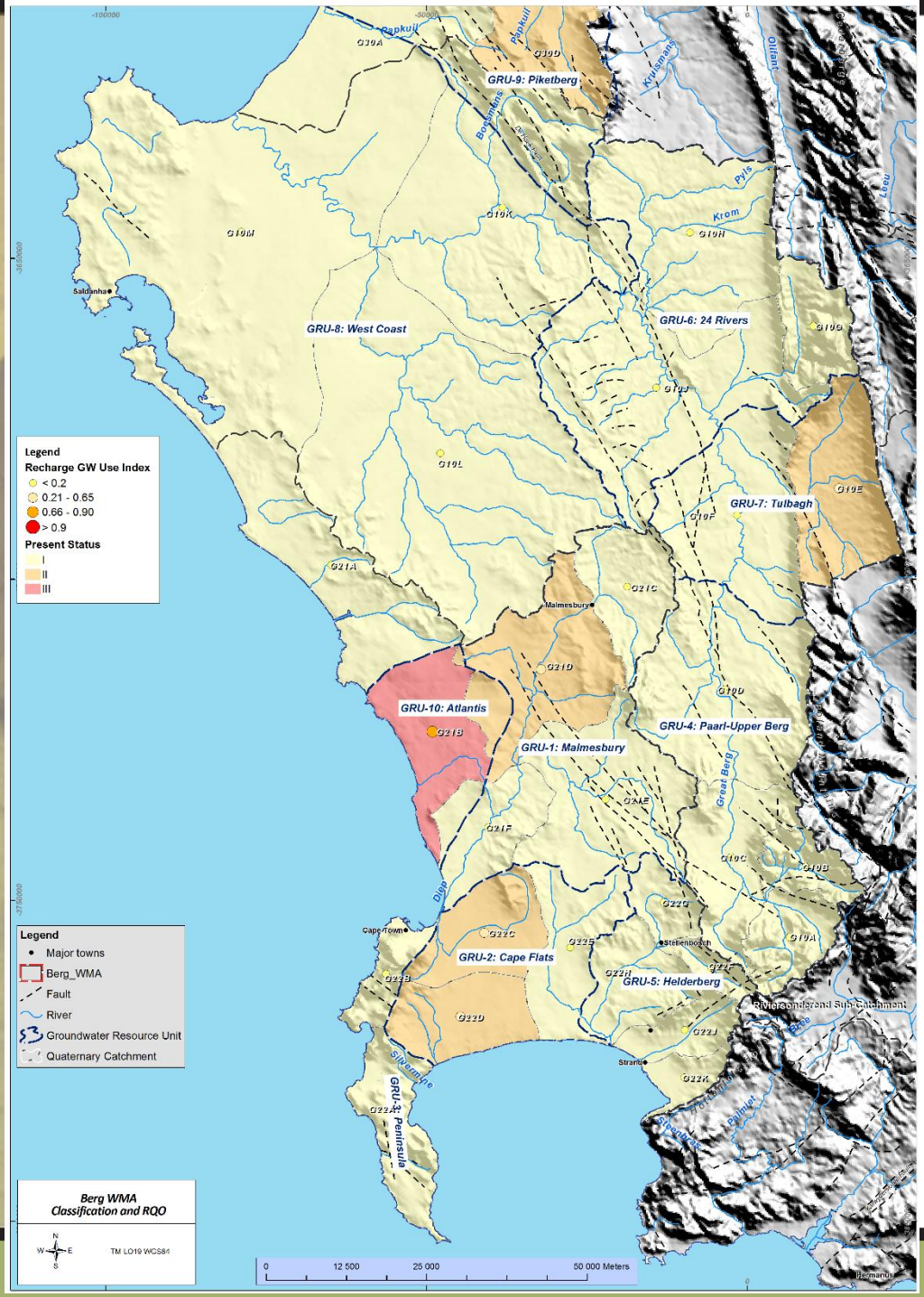
Status Quo: GRU2 Cape Flats



Extract of groundwater balance model

Table 7.5 Groundwater Balance, Use/recharge (Stress), and Present Status per Quaternary catchment

Quaternary	Recharge (Mm^3/a)	Use (Mm^3/a)	GWBF (Mm^3/a)	Balance (Mm^3/a)	Use/Recharge (%)	Present Status
G10A	21.09	3.90	7.25	9.93	19%	I
G10B	12.27	0.36	5.34	6.57	3%	I
G10C	22.88	2.64	2.26	17.98	12%	I
G10D	31.03	3.87	5.00	22.15	12%	I
G10E	16.05	4.65	2.25	9.14	29%	II
G10F	15.05	0.98	4.33	9.74	7%	I
G10G	8.84	0.00	2.73	6.11	0%	I
G10H	17.18	1.62	3.28	12.28	9%	I
G10J	23.74	0.38	2.36	21.00	2%	I
G10K	39.34	7.50	1.18	30.66	19%	I
G10L	44.35	4.17	1.99	38.19	9%	I
G10M	55.50	1.97	5.70	47.83	4%	I
G21A	14.77	0.77	0.29	13.71	5%	I
G21B	7.50	6.33	0.53	0.64	84%	III
G21C	8.84	0.57	1.95	6.32	6%	I
G21D	14.25	6.97	3.27	4.02	49%	II
G21E	21.85	3.97	4.21	13.67	18%	I

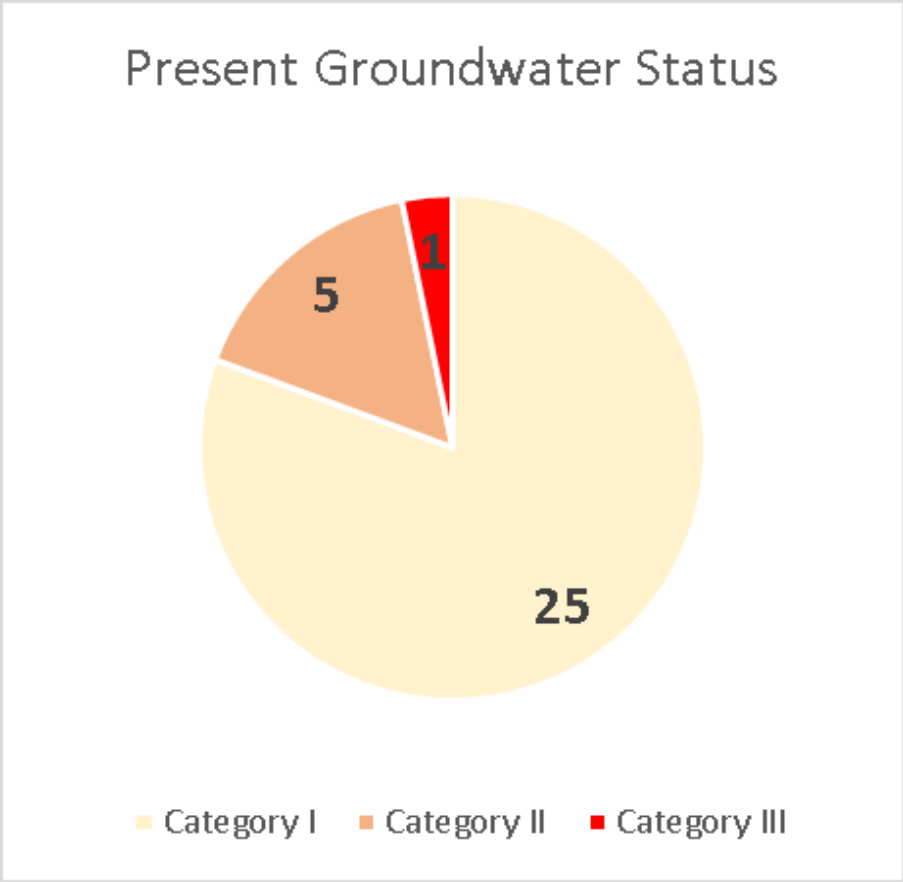


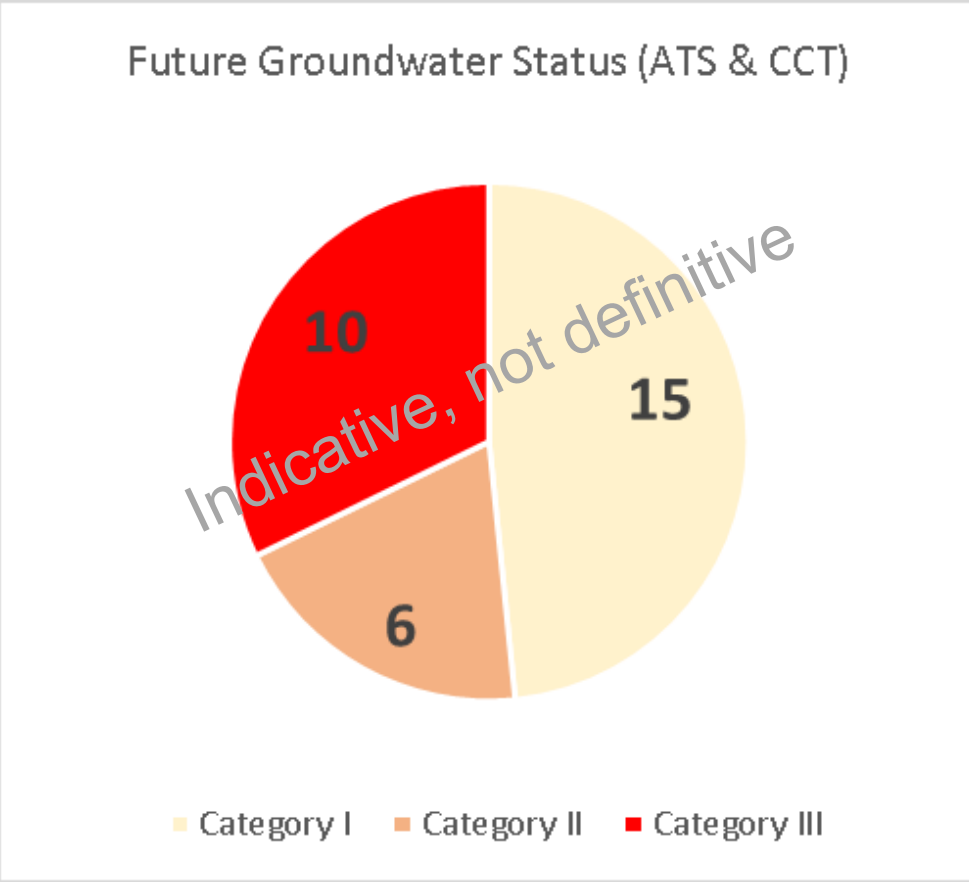
Present Status

- I : Use / recharge < 20 %
- II : Use / recharge 20-65%
- III : Use / recharge >65%

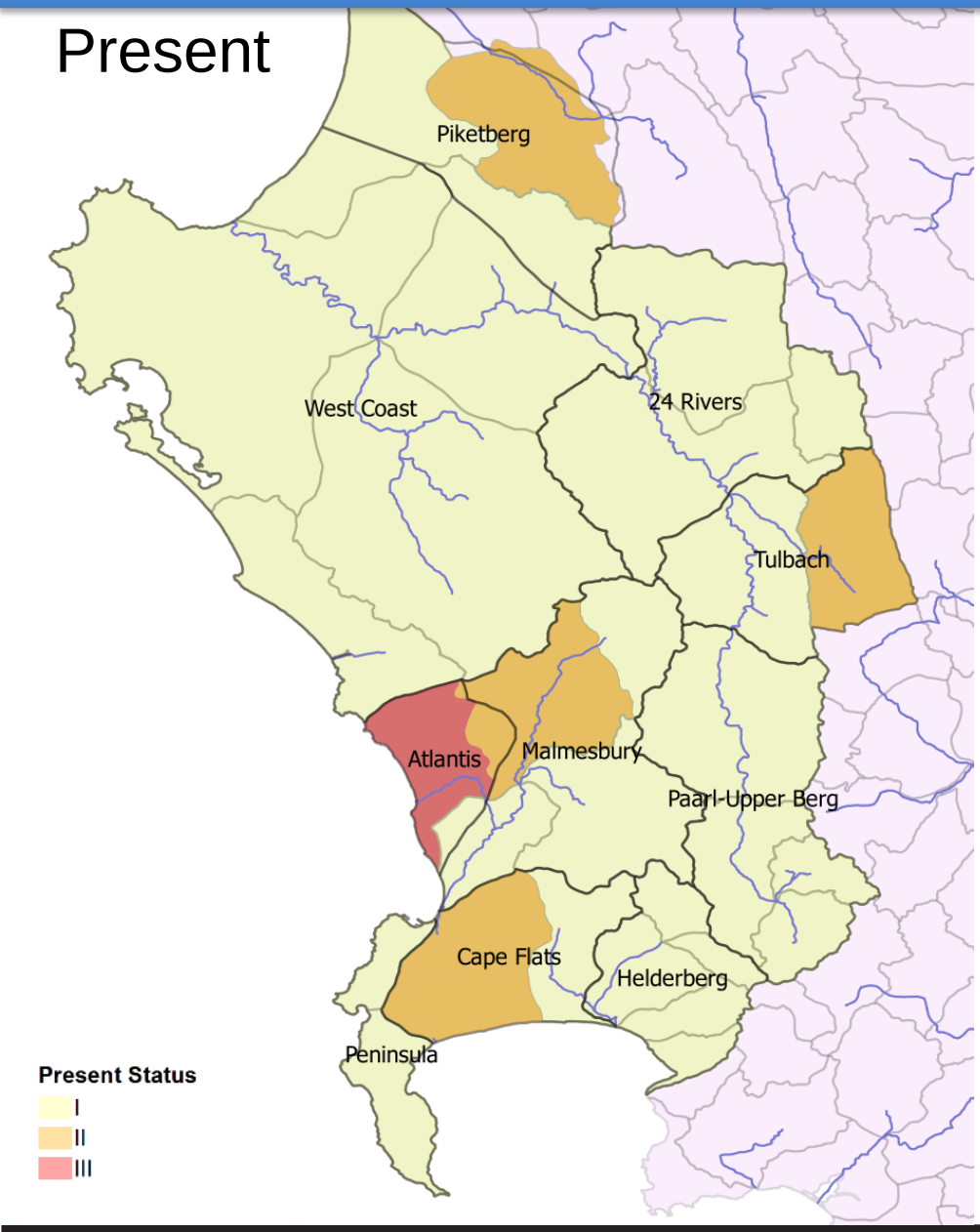
Scenario consequences on groundwater condition

- Results: maximum impact of planned development according to All Towns water demand projections and CCT developments
- Groundwater use from 370 to 542 million m^3/a





Scenario consequences on groundwater condition



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Prioritisation Criterion

- A set of criteria and sub-criteria were selected based on:
  - The framework for RU prioritisation (DWA, 2011)
  - Previous studies
  - **Applied to quaternary catchment scale, grouped together and handled per GRU in RQOs**

Criterion	Points (out of 100)
Importance for users	25
Level of surface water – groundwater interaction	30
Threat posed to users	30
Practical Considerations	15

Prioritisation sub-criteria

Criterion	Points	Sub-criteria	Weights (**% of the points**)	Rating guidelines (**factors**)
Importance for users	**25 points**	RUs in which groundwater is important in supporting domestic supply (current or future)	60 **15 points**	0 – RUs which do not support sole-supply settlements
				0.5 – RUs supporting some sole-supply settlements (1-2)
				1 – RUs supporting several sole-supply settlements (>2)
		RUs within strategic water source areas for groundwater	20 **5 points**	0 - RUs outside of SWSA-gw
				1 – RUs within SWSA-gw
		RUs where groundwater is most important in supporting activities contributing to economy (GDP, job creation) (e.g. commercial agriculture, industrial abstraction, bulk abstraction by water authorities)	20 **5 points**	0 – RUs which do not directly support any activities which contribute to economy [as indicated by <0.05l/s/km2]
				0.5 – RUs which moderately support activities which provide a contribution to economy [as indicated by 0.05-0.1l/s/km2]
				1 – RUs which significantly support activities which contribute to the economy [as indicated by >0.1l/s/km2]

Prioritisation sub-criteria

Criterion	Weights (%)	Sub-criteria	Weights (%)	Rating guidelines
Level of surface water – groundwater interaction	**30 points**	Relevance of groundwater contribution to maintain required low flow conditions	50 **15 points**	0 – RUs without relevant groundwater contribution (low GWBF/EWR) (GWBF/EWR < 11%)
				0.5 – RUs where groundwater contribution supports low flow condition (GWBF/EWR moderate, 12-75%)
				1 – RUs where groundwater contribution is crucial to maintain low flow condition (GWBF/EWR high >75%)
		Relevance of groundwater contribution to maintain priority groundwater-dependent ecology	50 **15 points**	0 – RUs without priority groundwater-dependent systems (estuaries / wetlands)
				1 – RUs with priority groundwater-dependent systems (estuaries / wetlands)

GWBF / EWR

Node	Quaternary	EWR (Mm^3/a)	nMAR	Final (current) GWBF (Mm^3/a)	(current) GWBF/EWR
Nii6	G50G	0.5	4.2	1.43	287%
Ni4	G50B	1.6	12.5	3.47	217%
Nx8	G40M	0.5	2.4	0.79	158%
Nv24	G50D	2.1	15.4	2.55	121%
Nii4	G40J	2.3	18.4	2.53	110%
Niv26	H70J	1.4	10.0	1.43	102%
Niv24	H70A	0.7	5.8	0.69	99%
giii10	K40A	3.9	12.4	3.79	97%
Nx6	G40H	0.7	5.1	0.60	86%
Niv44	G50C	2.5	18.8	2.05	82%
gvii7	K20A	6.9	27.0	5.54	80%
gx5	K70A	1.3	3.8	1.03	79%
gvii12	K30D	5.1	16.7	3.72	73%
giv4	K60F	12.9	23.6	9.35	72%

Range (%)	Count of quats
0-11	63
12-75	36
>75	12

Prioritisation sub-criteria

Criterion	Weights (%)	Sub-criteria	Weights (%)	Rating guidelines
Threat posed to users	**30 points**	Water quality (current impacts): Medium to Long-term declining trend	16 **5 points**	0 – RUs where no trend is visible
				0.5 – RUs where short-term trend is potentially visible, or minor
				1 – RUs where long-term trend is visible, or where no data is available to assess trend
		Water quality (current impacts): Presence of poor quality category (currently)	17 **5 points**	0 – RUs with category I water quality
				0.5 – RUs with category II water quality
				1 – RUs with category III water quality
		Water quality (future impacts): Potential risk to groundwater quality	17 **5 points**	0 – RUs where risk is low (low hazards, low vulnerability)
				0.5 – RUs where risk is moderate (moderate hazards, moderate vulnerability)
				1 – RUs where risk is high (high hazards, high vulnerability)

Prioritisation sub-criteria

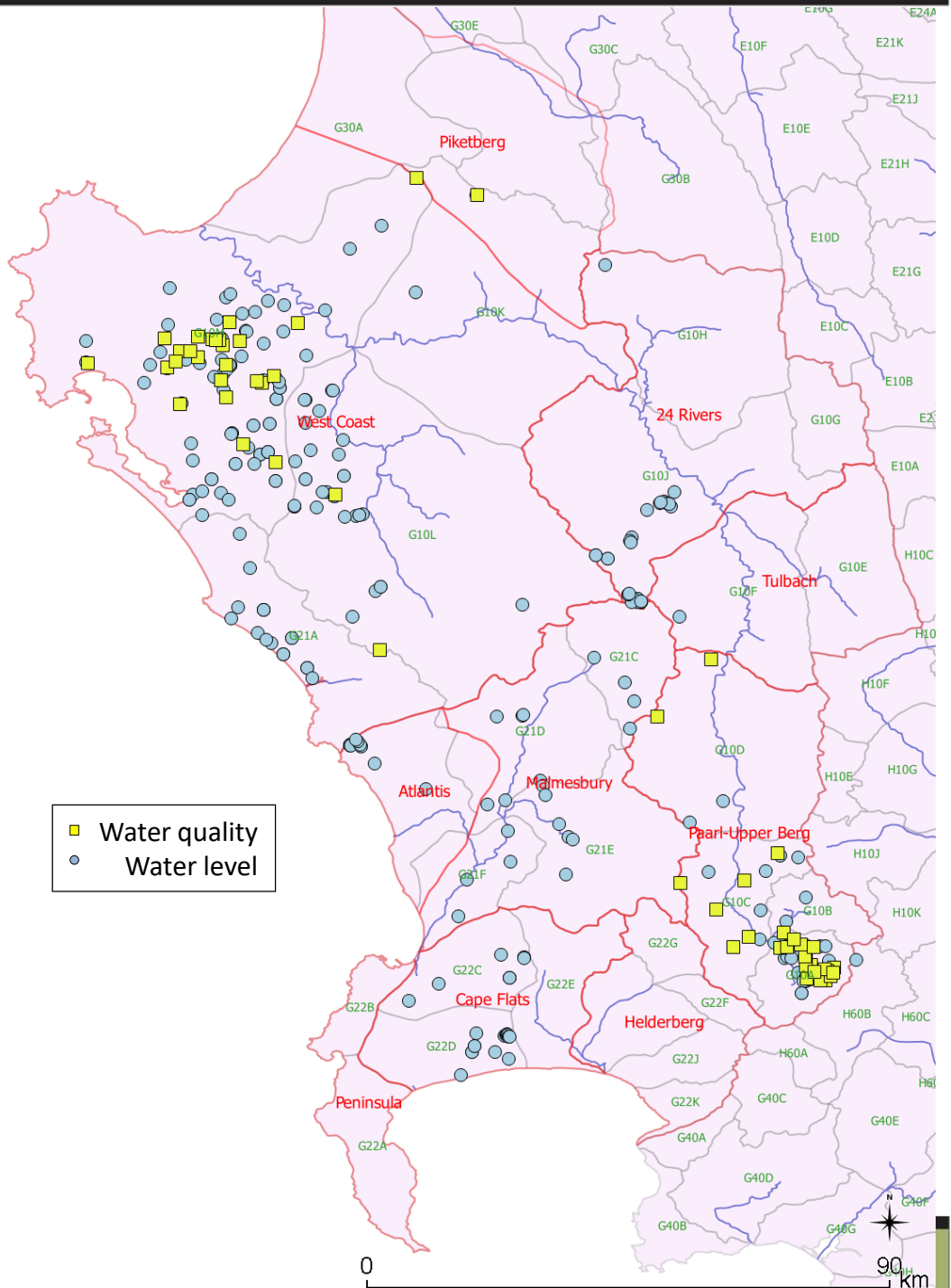
Criterion	Weights (%)	Sub-criteria	Weights (%)	Rating guidelines
Threat posed to users	**30 points**	Water quantity (current impacts): Medium to Long-term declining trend in water or piezometric levels	16 **5 points**	0 – RUs where no trend is visible
				0.5 – RUs where short-term trend is potentially visible, or minor
				1 – RUs where long-term trend is visible, or where no data is available to assess trend
		Water quantity (current impacts): Presence of high stress category (currently)	17 **5 points**	0 – RUs where stress is low (category I)
				0.5 – RUs where stress is moderate (category II)
		Water quantity (future impacts): Presence of high stress category (future)	17 **5 points**	0 – RUs where stress is low (category I)
				0.5 – RUs where stress is moderate (category II)
				1 – RUs where stress is high (category III)

Prioritisation sub-criteria

Criterion	Weights (%)	Sub-criteria	Weights (%)	Rating guidelines
Practical Considerations	**15 points**	Availability of water quality monitoring data (WMS monitoring boreholes) located within RU?	50 **7.5 points**	0 – RUs where no resource quality information exists
				0.5 – RUs for which a moderate level of resource quality information exists (1-4 points)
				1 – RUs for which there is a good availability of resource quality information (>4 points)
		Availability of water level monitoring data (DWA monitoring boreholes) located within RU?	50 **7.5 points**	0 – RUs where no water level information exists
				0.5 – RUs for which a moderate level of water level information exists (1-4 points)
				1 – RUs for which there is a good availability of water level information (>4 points)

- Criteria did not lead to areas being left out due only to lack of data

Current DWS monitoring



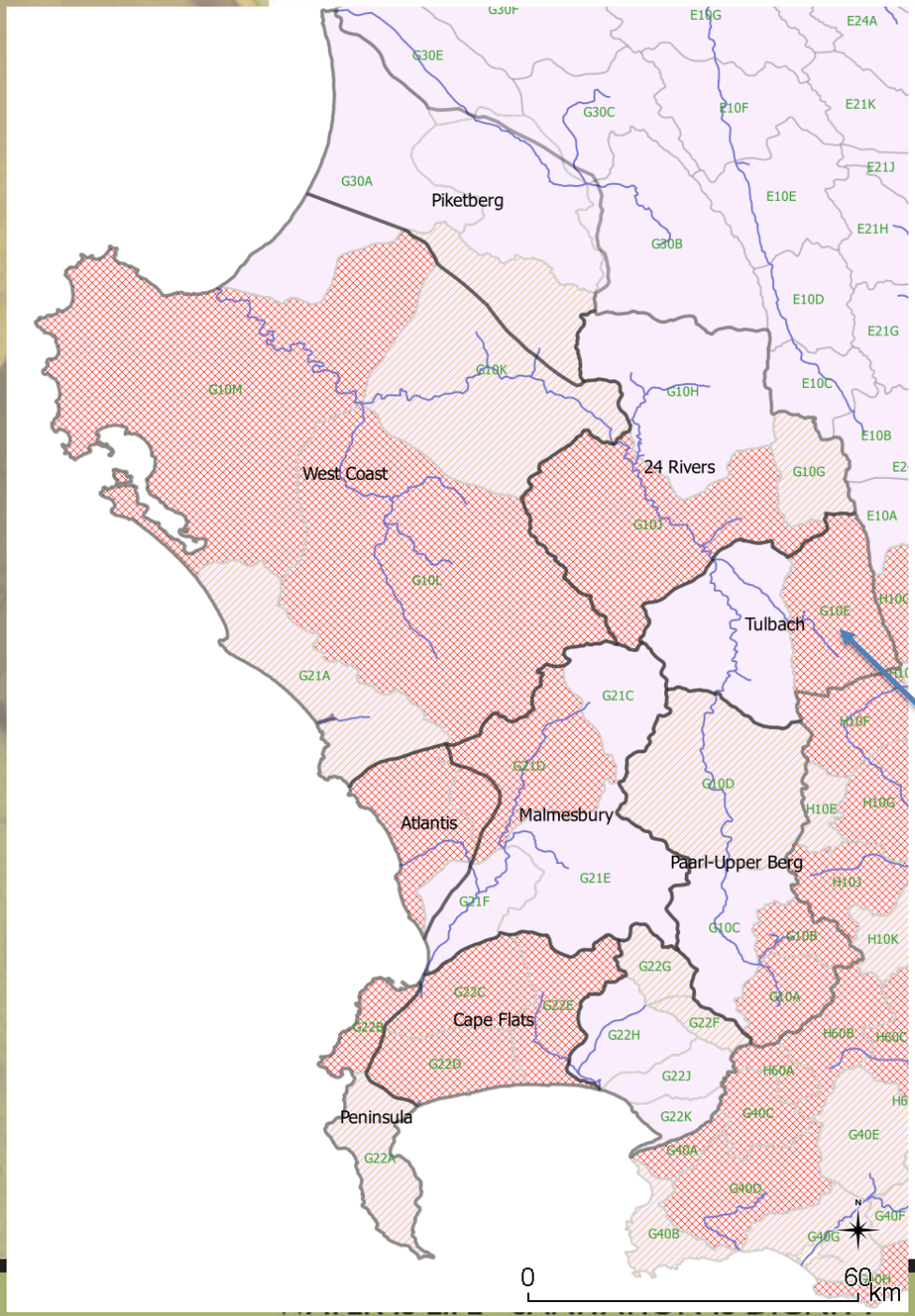
Prioritisation scoring

- Only one rating factor can be applied per resource unit, whereas the sub-criteria can have a spatial variability. The sub-criteria category which covers the largest part of the resource unit, or a worst case, was applied.
- Final score: 0 – 100
- Score divided into three categories based on the distribution of the final scores
  - 1 (not priority) - <28 [10 quats]
  - 2 (low priority) - 28 – 40 [7 quats]
  - 3 (high priority) - >40 [12 quats, or 41%]

Prioritisation scoring

- Diverted from this scoring where:
  - in GRUs with no quaternary catchments scoring a “3”, the quaternary catchment with the highest score within that GRU was manually assigned a “3” (**Red**), where meaningful

Prioritisation result



High priority resource unit (rated 3) for which RQOs are developed

Prioritisation results

GRU	Quat	RU PRIORITY (1 to 3)	SCORE
8-West Coast	G10M	3	80.0
8-West Coast	G10L	3	65.9
9-Atlantis	G21B	3	62.9
2-Cape Flats	G22D	3	60.3
4-Paarl-Upper Berg	G10A	3	47.7
6-24 Rivers	G10J	3	47.4
4-Paarl-Upper Berg	G10B	3	46.3
2-Cape Flats	G22C	3	42.8
2-Cape Flats	G22E	3	42.7
5-Tulbagh Valley	G10E	3	42.7
10-Malmesbury	G21D	3	39.0
1-Peninsula	G22B	3	37.2

Prioritisation scoring example

- **See EXCEL sheet**

Discussion

- Indicators, data used to support them
- Scoring system
- Prioritisation results - any adjustments necessary

Groundwater
2. Evaluation of GRUs

Evaluation of RUs

- Identify sub-components that may be important to users and the environment and select indicators for which RQOs and Numerical Limits should be developed.
- Resource Unit Evaluation Tool used as a guideline - the components routinely considered for rivers (quality, quantity) are equally applicable to groundwater.
- Recent examples from other catchments

Evaluation of RUs

Component	Sub-Component	Indicator
Quantity	Abstraction	Water level recovers from abstraction impact during wet season, under consideration of climate change and drought cycles
	Groundwater level	Water level
	Discharge	Relative water levels between groundwater and surface water
	Low flow in river	Compliance with the lowflow requirements in the river
Quality	Nutrients	NO_3
	Salts	EC
	Pathogens	E-coli
	Pathogens	Total Coliform

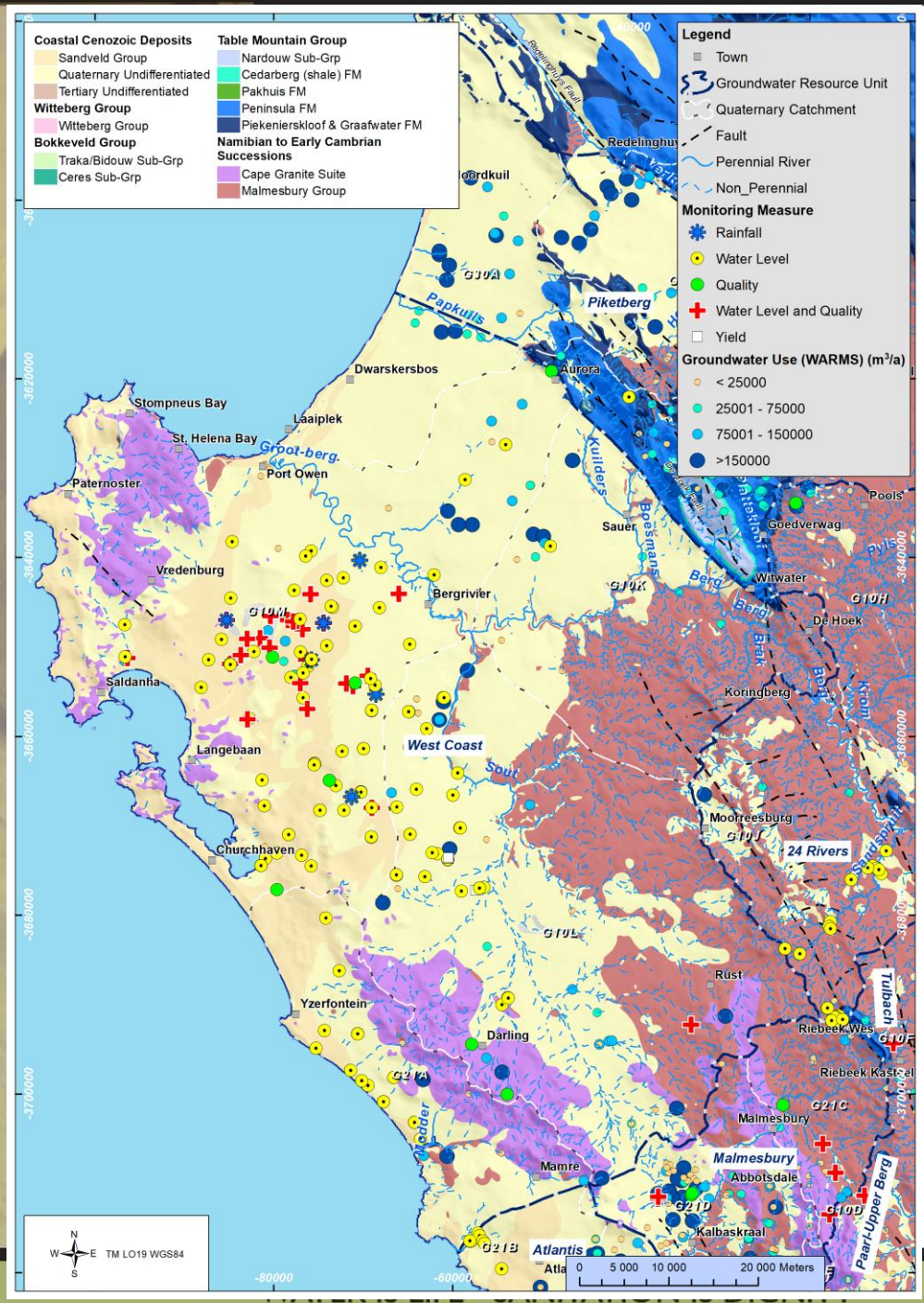
2. Develop an RQO (objective-descriptive), and numerical limit per indicator (if possible)

1. Consider the relevant components / sub-components / Indicators in each prioritised RU

3. Per major aquifer, per prioritised quaternary (grouped per GRU)

Groundwater
3. RQOs

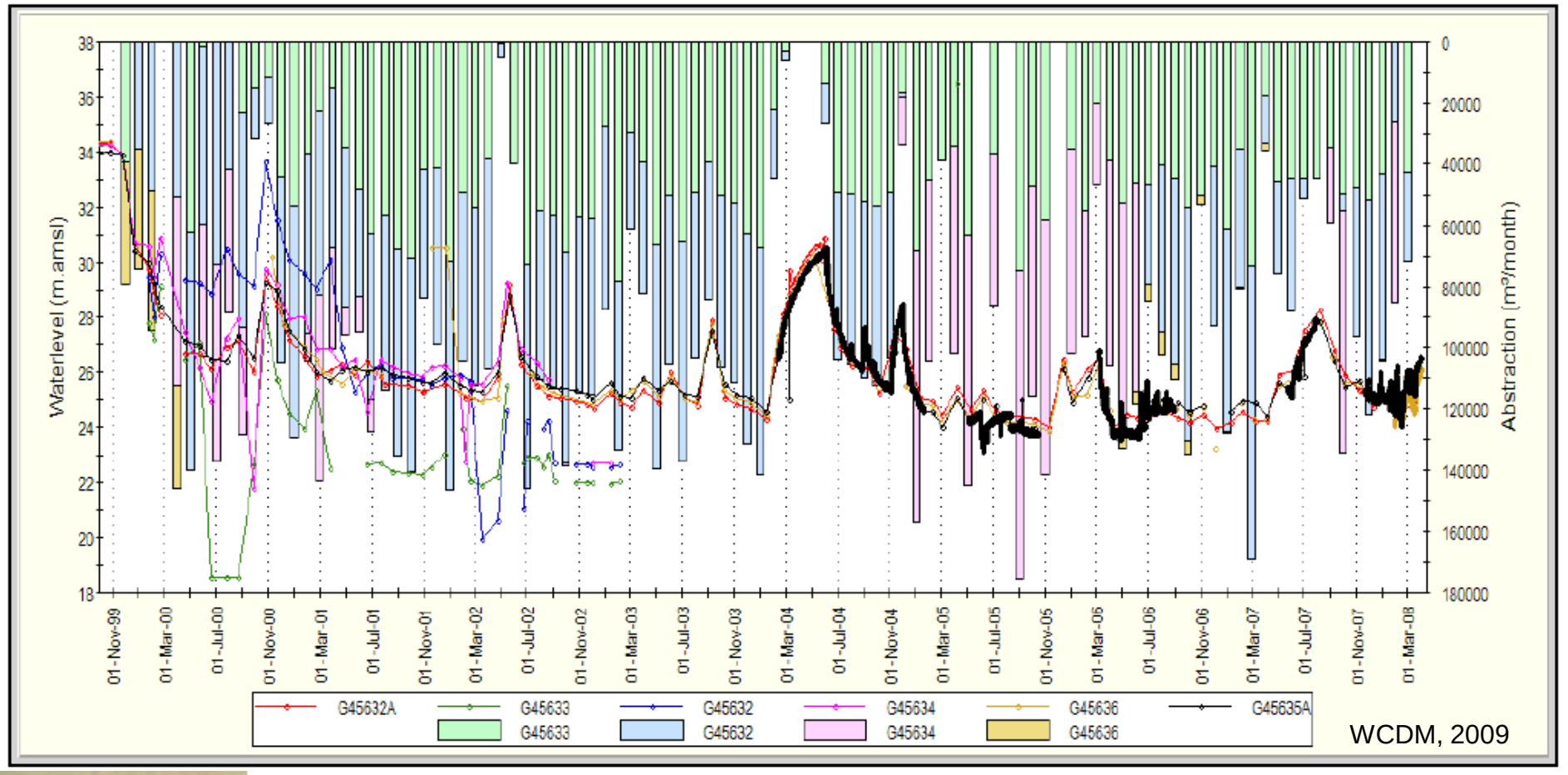
GRU8 West Coast: G10M



GRU8 West Coast: G10M (1)

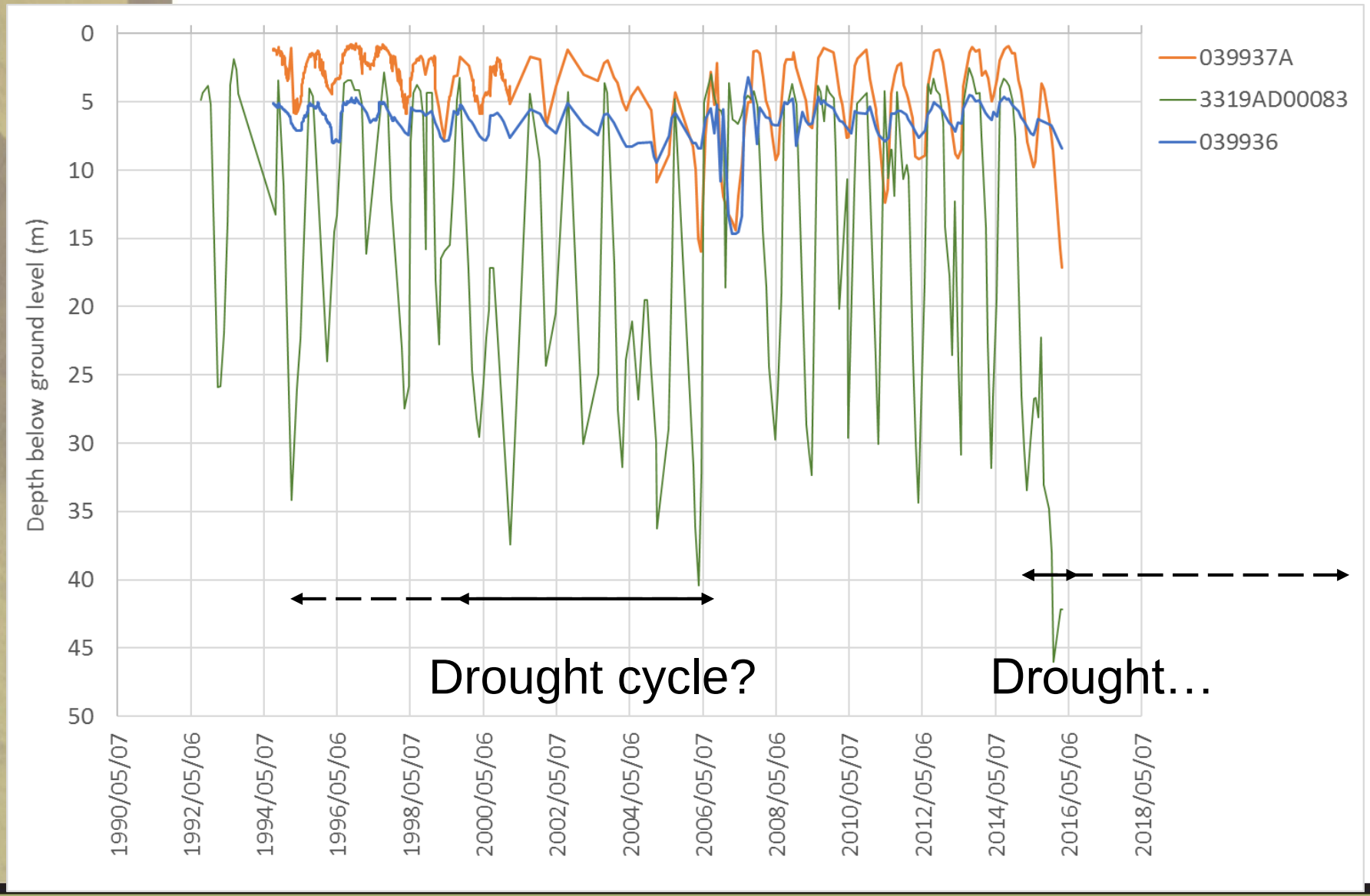
GRU	Quat(s)	Aquifer	Component	Sub-Component	RQO Description (narrative)	Indicator	Numerical Value
8-West Coast	G10M	All	Quantity	Abstraction	Groundwater use should be sustainable for all users and the environment	Seasonal abstraction: water level recovers from abstraction impact during wet season, under consideration of climate change and drought cycles. Permanent abstraction: water level decline stabilises under consideration of aquifer response time.	n/a
		All		Groundwater level	Water level in abstraction boreholes within 2.5km from the ocean does not fall below minimum, to avoid saline intrusion	Water level	>1 mamsl
		All		Discharge	The natural gradient between groundwater and surface water should be maintained	Relative water levels between groundwater and surface water (in mamsl)	n/a
		All		Discharge	No groundwater abstraction around wetland and river FEPAs in accordance with the implementation manual for FEPAs	Buffer zones	250m
				Discharge	Compliance to the groundwater flow requirements to the estuary, as per estuary RQO requirement	Compliance with the groundwater flow requirements to the estuary	See section 3.1
		All		Low flow in river	Compliance to the low flow requirements in the river, as per surface water RQO requirement	Compliance with the low flow requirements in the Sout & Berg River	See section 3.1

Sub-component: abstraction, Indicator: Water level



WCDM, 2009

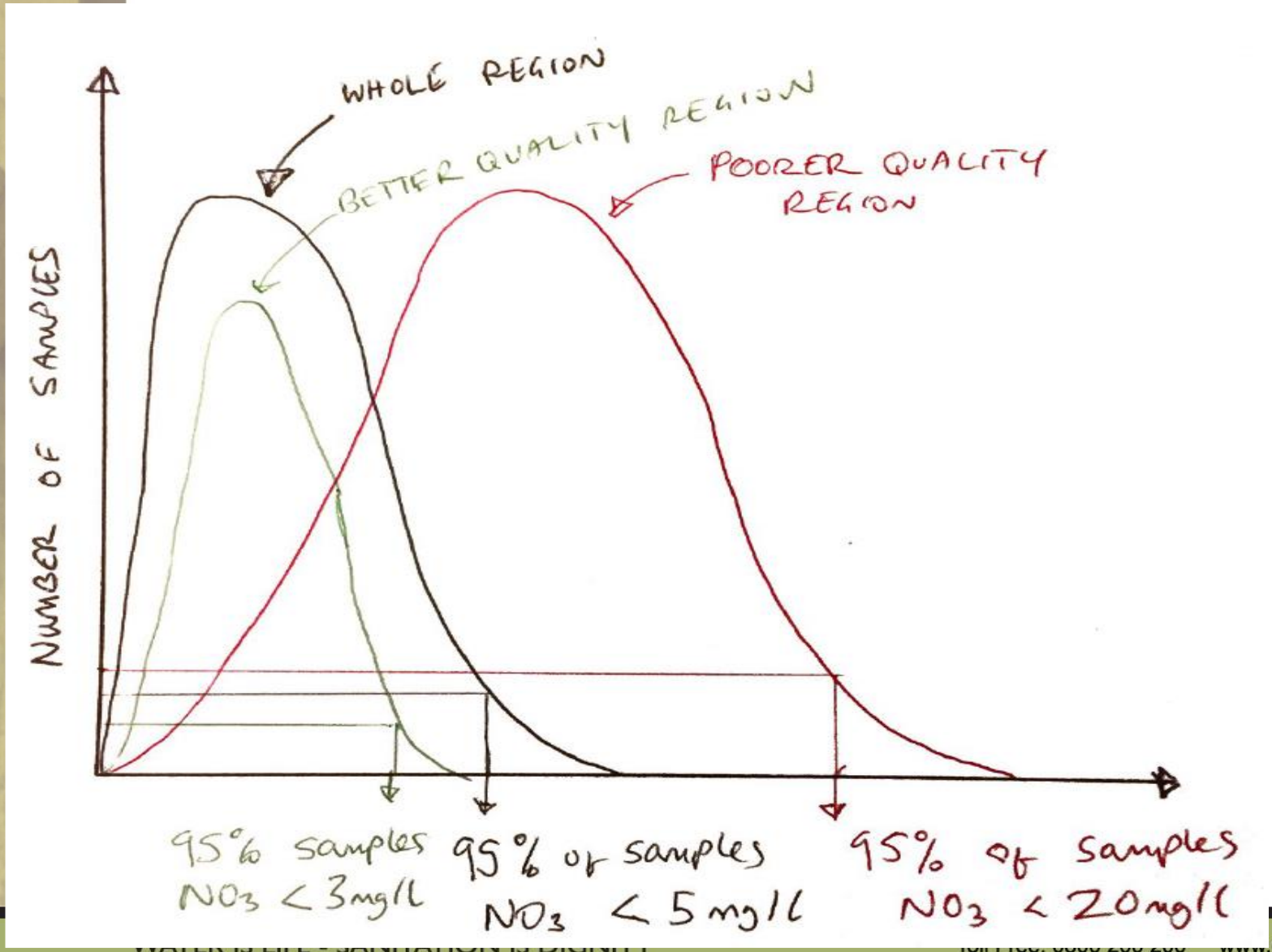
Sub-component: abstraction, Indicator: Water level



Component: Water quality

- Status quo analysed
  - Statistics for main chemical parameters per major geology per catchment & GRU
  - Establish “natural background” per major geology per catchment, and natural variability (majority are ‘normal’)
- Analysis for RQO development included
  - Establish appropriate limit to “natural background”
  - Most are 95%tile, or 90%tile where impacted

Component: Water quality



GRU8 West Coast: G10M (2)

GRU	Quat(s)	Aquifer	Component	Sub-Component	RQO Description (narrative)	Indicator	Numerical Value
8-West Coast	G10M	Coastal cenozoic sand	Quality	Nutrients	Groundwater should be fit for domestic use after treatment; and groundwater quality shall not show a deteriorating trend from natural background	NO_3 (as N)	< 11.0 mg/l
				Salts		EC	< 520 mS/m
		Basement		Nutrients		NO_3 (as N)	< 11.0 mg/l
				Salts		EC	< 1571 mS/m
		All		Pathogens		E-coli	0 counts / 100 ml
		All		Pathogens		Total Coliform	<10 counts / 100ml

Based on 95%tile of this area & geology (=11.3mg/l, but for simplicity applied 11.0)

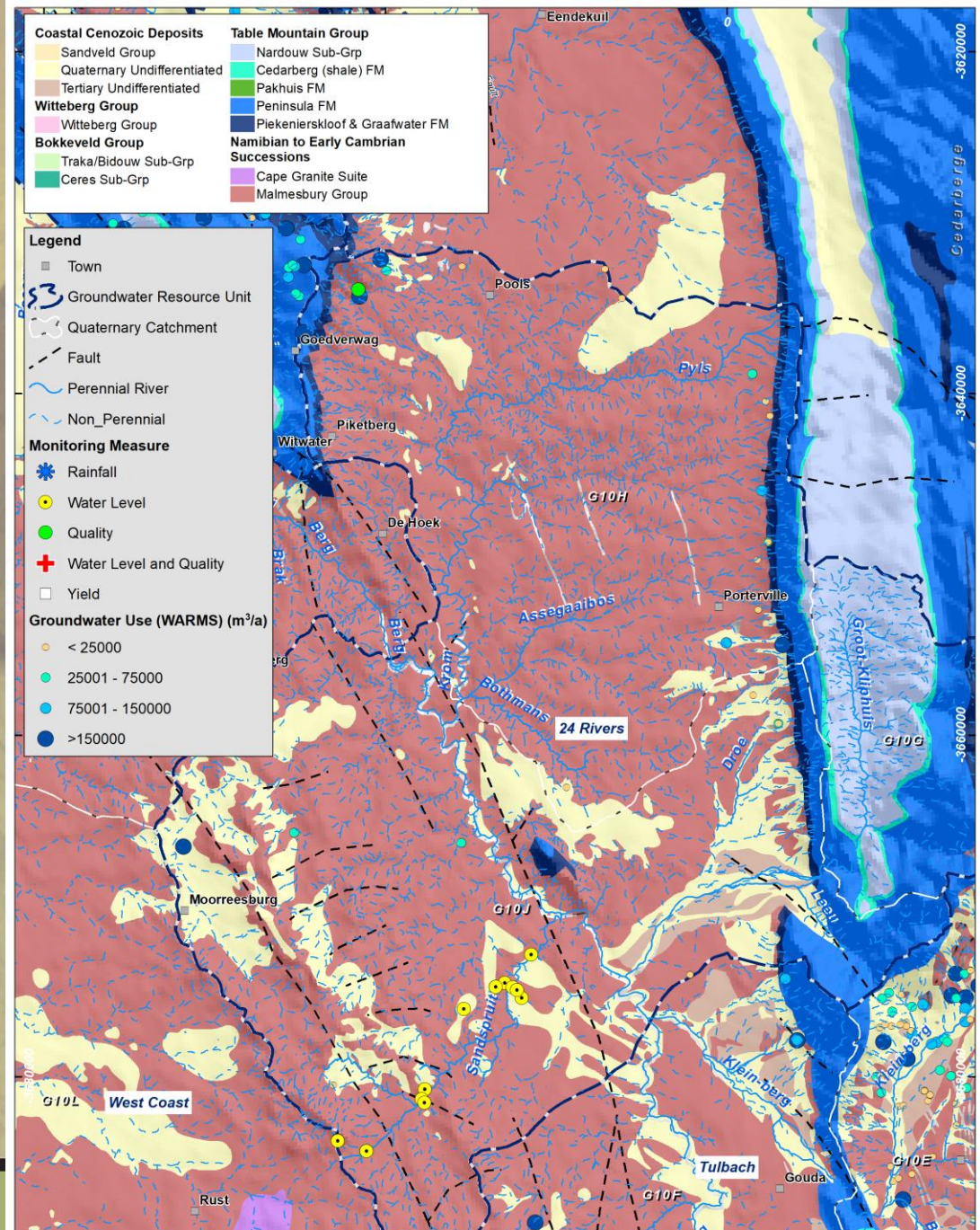
Based on 75%tile of this area & geology because low median (~500mg/l, but for simplicity applied 520 as old DWS class 3)

Insufficient local data: based on SANS214 which matches local data from neighbouring G10L

Based on 90%tile of this area & geology (median is ~800mg/l)

Other RQO examples

GRU6 24 Rivers: G10J

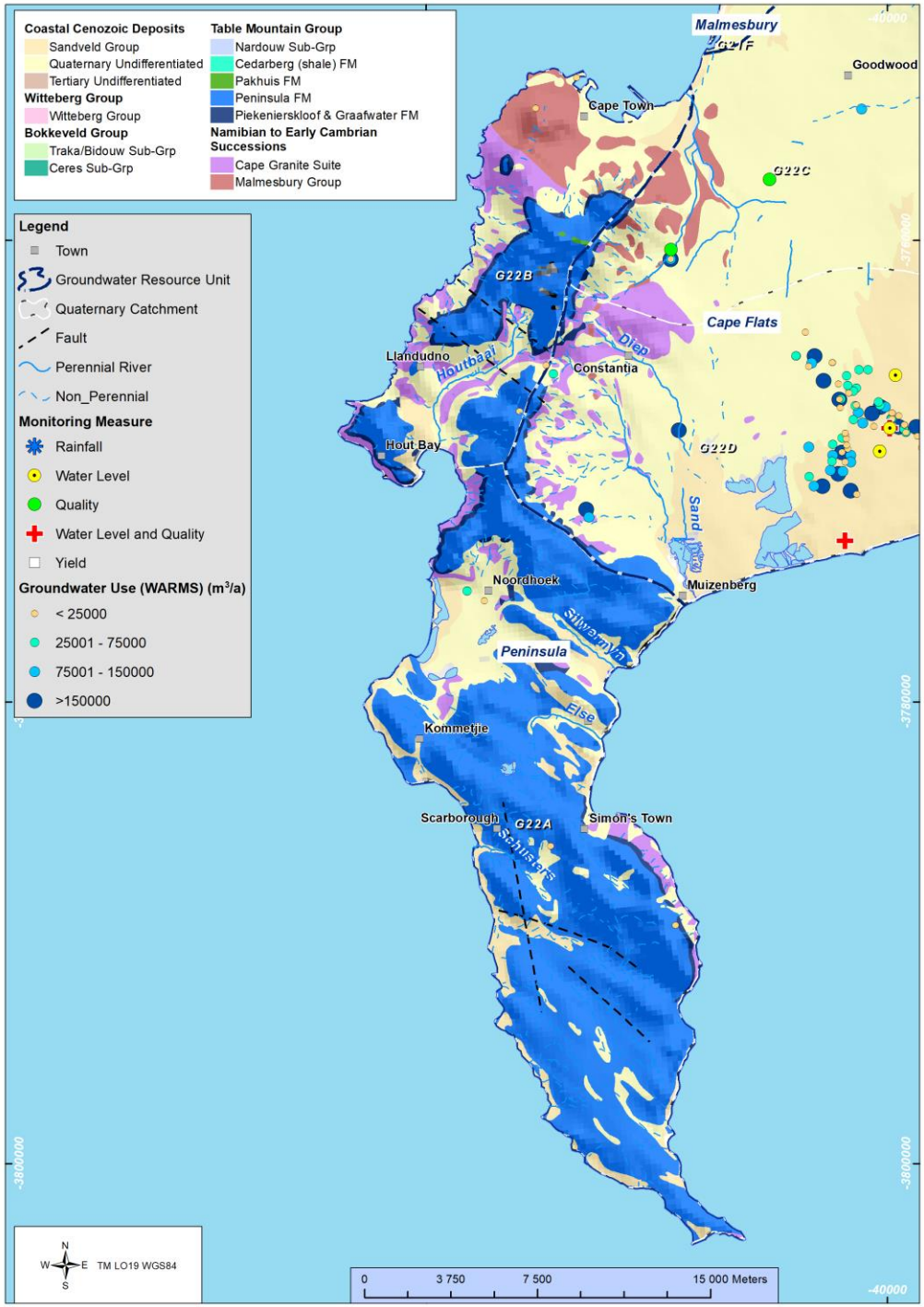


GRU6 24 Rivers: G10J

GRU	Quat	Aquifer	Component	Sub-Component	RQO Description (narrative)	Indicator	Numerical Value
6 – 24 Rivers	G10J	Superficial aquifers	Quantity	Discharge	The natural gradient between groundwater and surface water should be maintained	Relative water levels between groundwater and suface water (in mamsl)	n/a
		All		Discharge	No groundwater abstraction around wetland and river FEPAs in accordance with the implementation manual for FEPAs.	Buffer zones	250m
		All		Low flow in river	Compliance to the low flow requirements in the river, as per surface water RQO requirement	Compliance with the lowflow requirements in the river	See section 3.1

Excludes buried Peninsula Formation; not connected to SW, essentially no “natural gradient”

RQO focus: protection of GW discharge to SW (sustainable abstraction RQO not applied)



GRU1 Peninsula: G22B

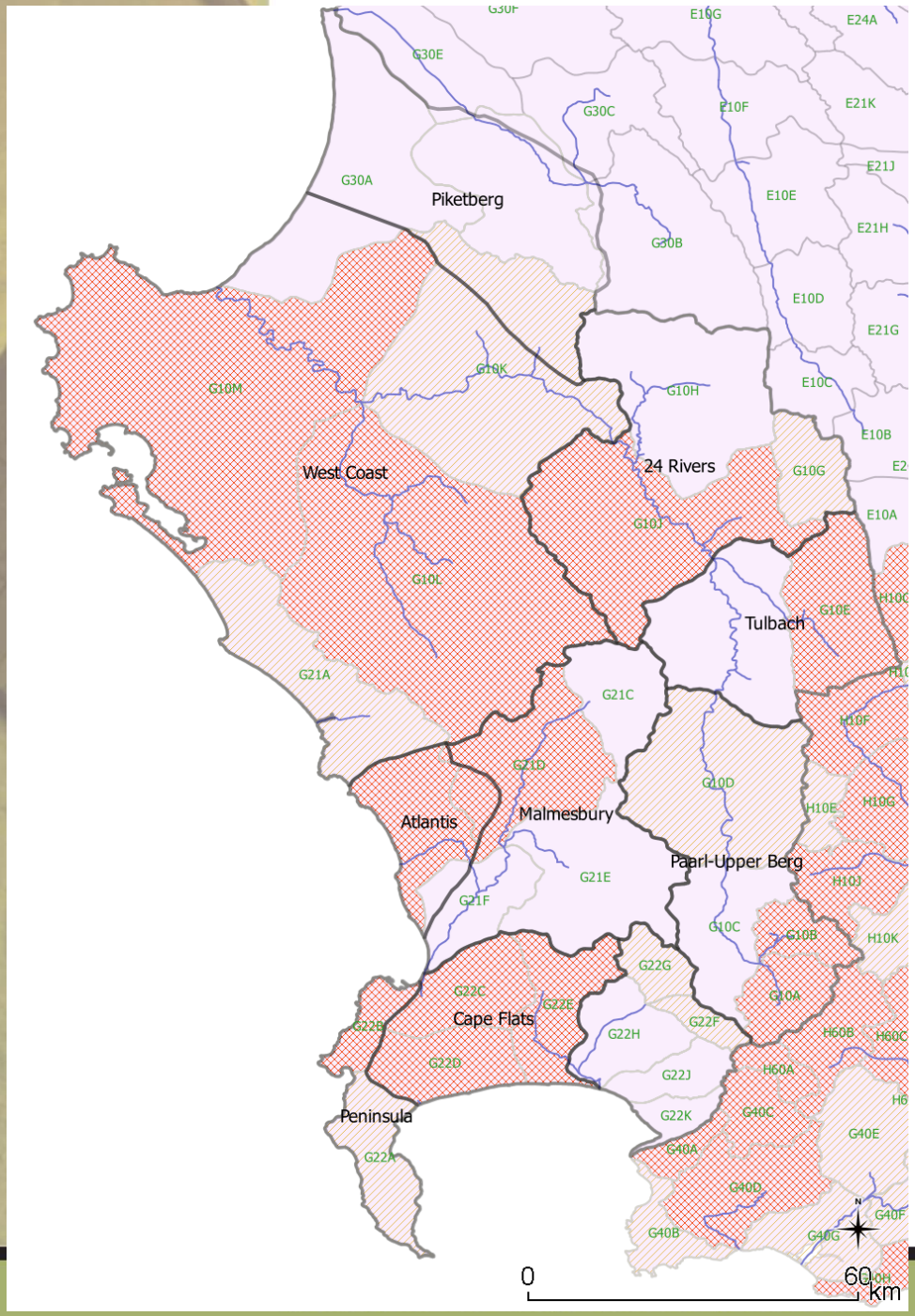
GRU1 Peninsula: G22B

GRU	Quat(s)	Aquifer	Component	Sub-Component	RQO Description (narrative)	Indicator	Numerical Value
1-Peninsula	G22B	Coastal cenozoic deposits	Quality	Nutrients	Groundwater should be fit for domestic use after treatment; and groundwater quality shall not show a deteriorating trend from natural background	NO_3 (as N)	**< 9.7 mg/l**
				Salts		EC	**< 942 mS/m**
		Table Mountain Group		Nutrients		NO_3 (as N)	**< 2.4 mg/l**
				Salts		EC	**< 119 mS/m**
		Basement		Nutrients		NO_3 (as N)	**< 11.0 mg/l**
				Salts		EC	**< 953 mS/m**
		All		Pathogens		E-coli	0 counts / 100 ml
		All		Pathogens		Total Coliform	<10 counts / 100ml

All based on 95%tile from across the region as no local data and uncertain which data to use as proxy.
Recommend that DWS set “preliminary RQOs” whilst a baseline is established.

Discussion

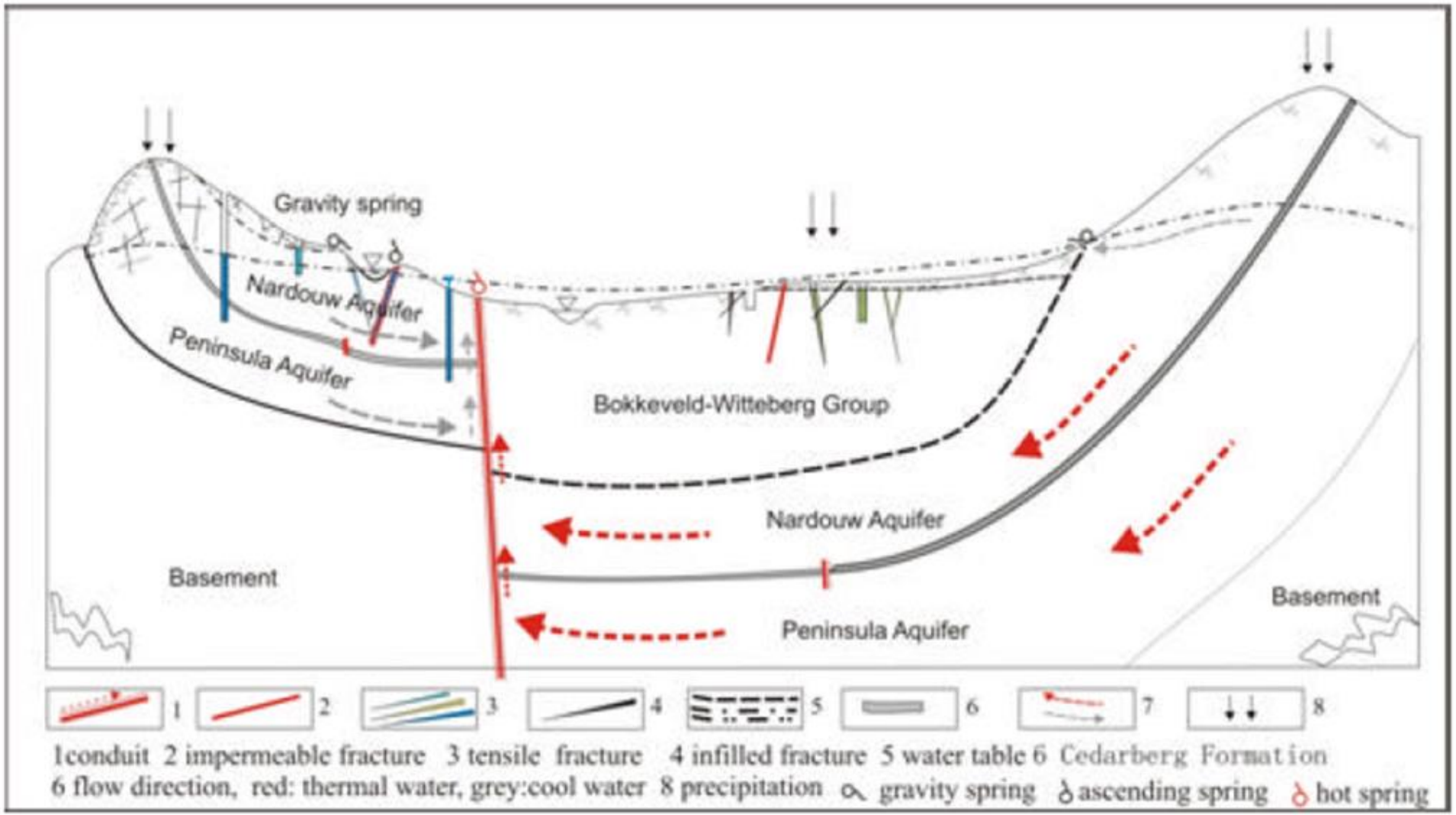
- Overall approach
- Criteria & sub-criteria established
- Descriptive RQOs
- Numerical values applied



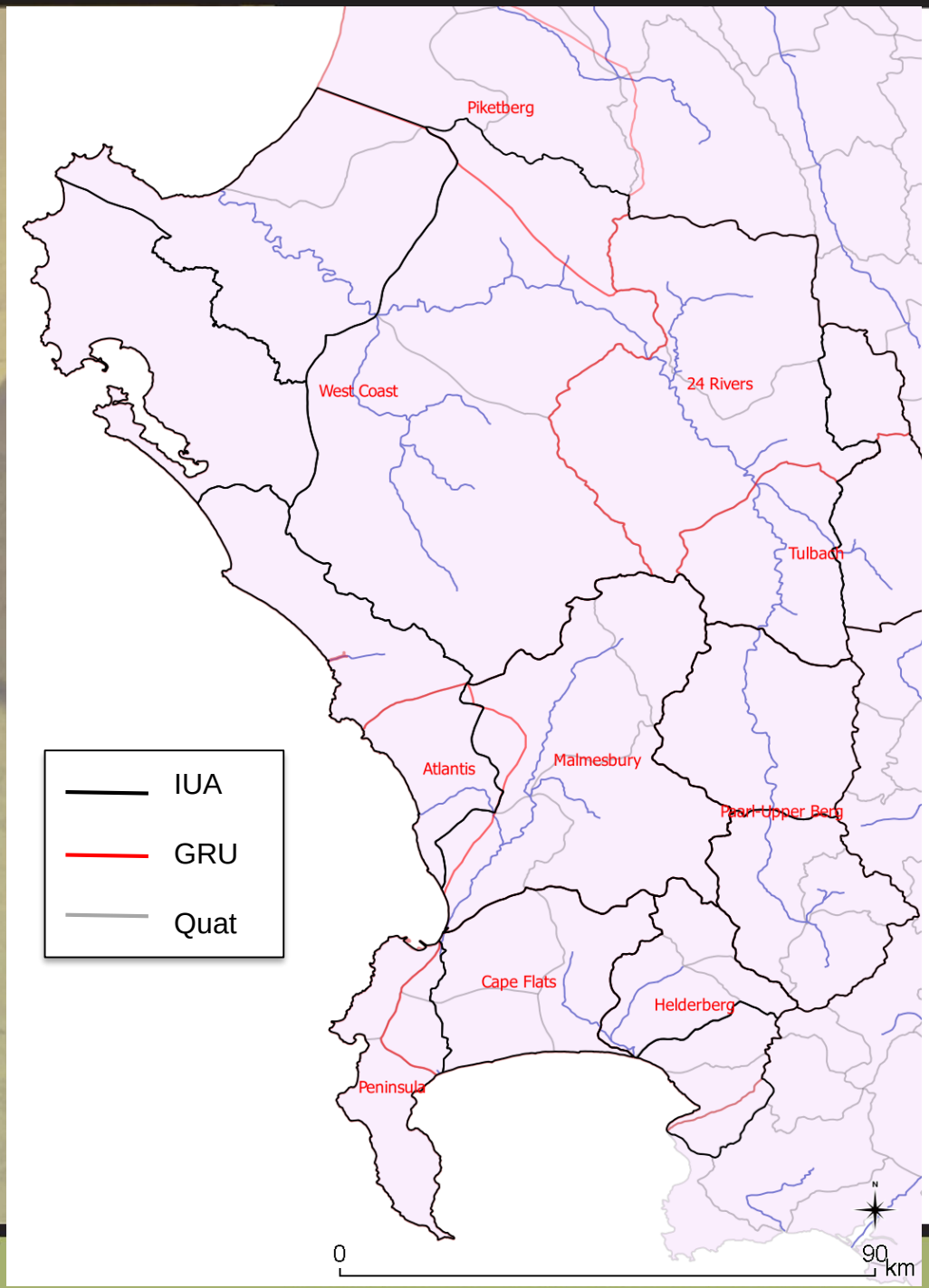
Specific interest in other areas?

Groundwater additional slides

Groundwater resource units



(adapted from Wu, 2005)


Piketberg
West Coast
24 Rivers
Tulbach
Atlantis
Malmesbury
Paarl Upper Berg
Cape Flats
Helderberg
Peninsula
IUA
GRU
Quat
0
90
km

Groundwater
Intro: Scenarios

Overall Groundwater Balance and Stress

Groundwater Balance, Use/recharge (stress) and Present Status for Groundwater Resources Units in the Berg.

GRU Name	Recharge (Mm^3/a)	Use (Mm^3/a)	GWBF (Mm^3/a)	Balance (Mm^3/a)	Use/Recharge (%)	Present Status
GRU-1: Malmesbury	47.19	10.48	10.37	26.34	22%	II
GRU-10: Atlantis	10.43	7.51	1.31	1.61	72%	III
GRU-2: Cape Flats	38.34	11.78	7.57	19.00	31%	II
GRU-3: Peninsula	11.25	0.10	3.93	7.22	1%	I
GRU-4: Paarl-Upper Berg	86.92	10.77	19.79	56.36	12%	I
GRU-5: Helderberg	45.21	3.31	8.25	33.65	7%	I
GRU-6: 24 Rivers	49.85	2.00	8.41	39.45	4%	I
GRU-7: Tulbagh	30.86	5.63	6.51	18.71	18%	I
GRU-8: West Coast	153.50	8.92	5.47	139.11	6%	I
GRU-9: Piketberg	44.19	17.52	1.71	24.95	40%	II

Scenario consequences on groundwater condition

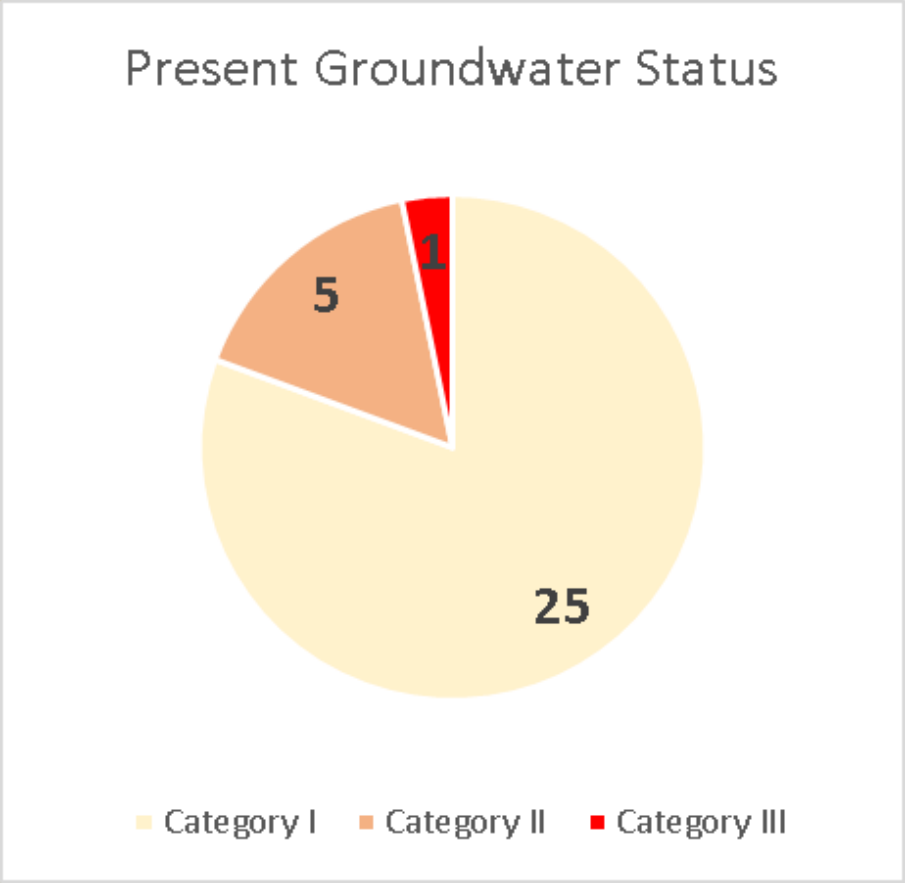
- Definition for groundwater status relates to alteration from pre-development state: informed by use/recharge ('stress') ratio
- Level of 'stress' used to determine the resulting groundwater status per water resources classification scenario, resulting from increases in groundwater use for future development, or meeting surface water deficits

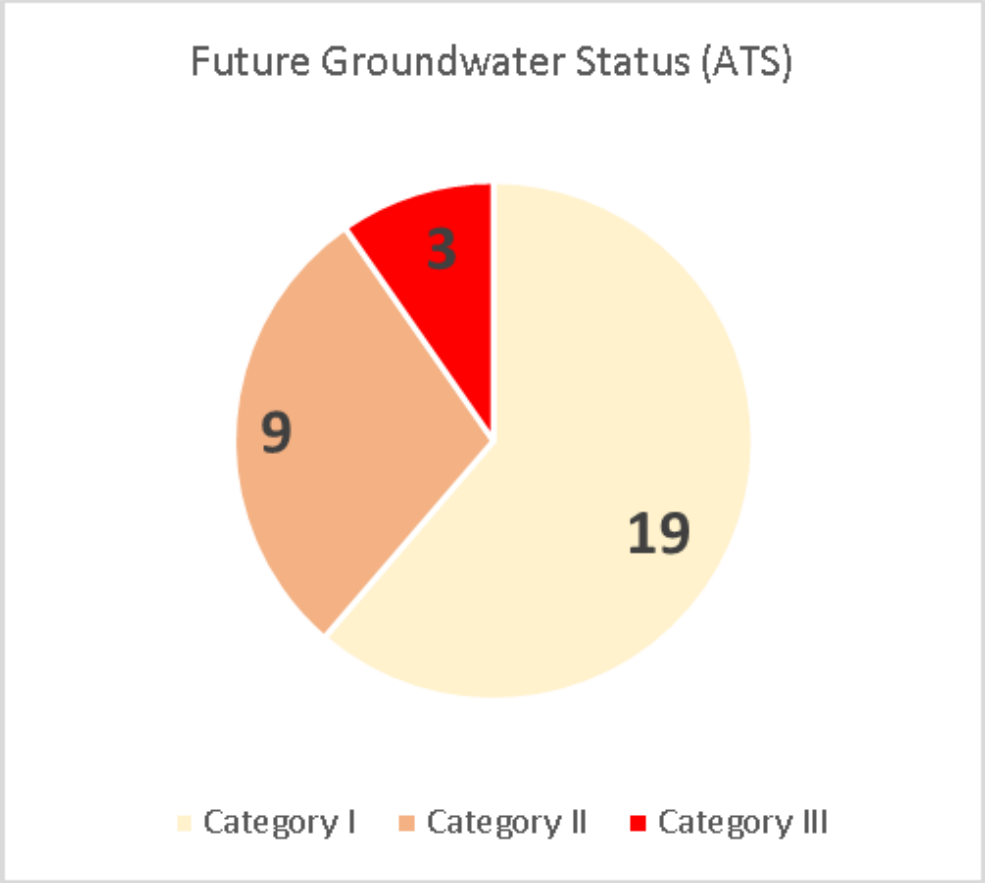
Groundwater Status Category		Generic Description	Use/ Recharge (Stress)
I	Minimally used	The water resource is minimally altered from its pre-development condition	≤20%
II	Moderately used	Localised low level impacts, but no negative effects apparent	20-65%
III	Heavily used	The water resource is significantly altered from its pre-development condition	>65%

(modified from Dennis *et al*, 2013)

Scenario consequences on groundwater condition

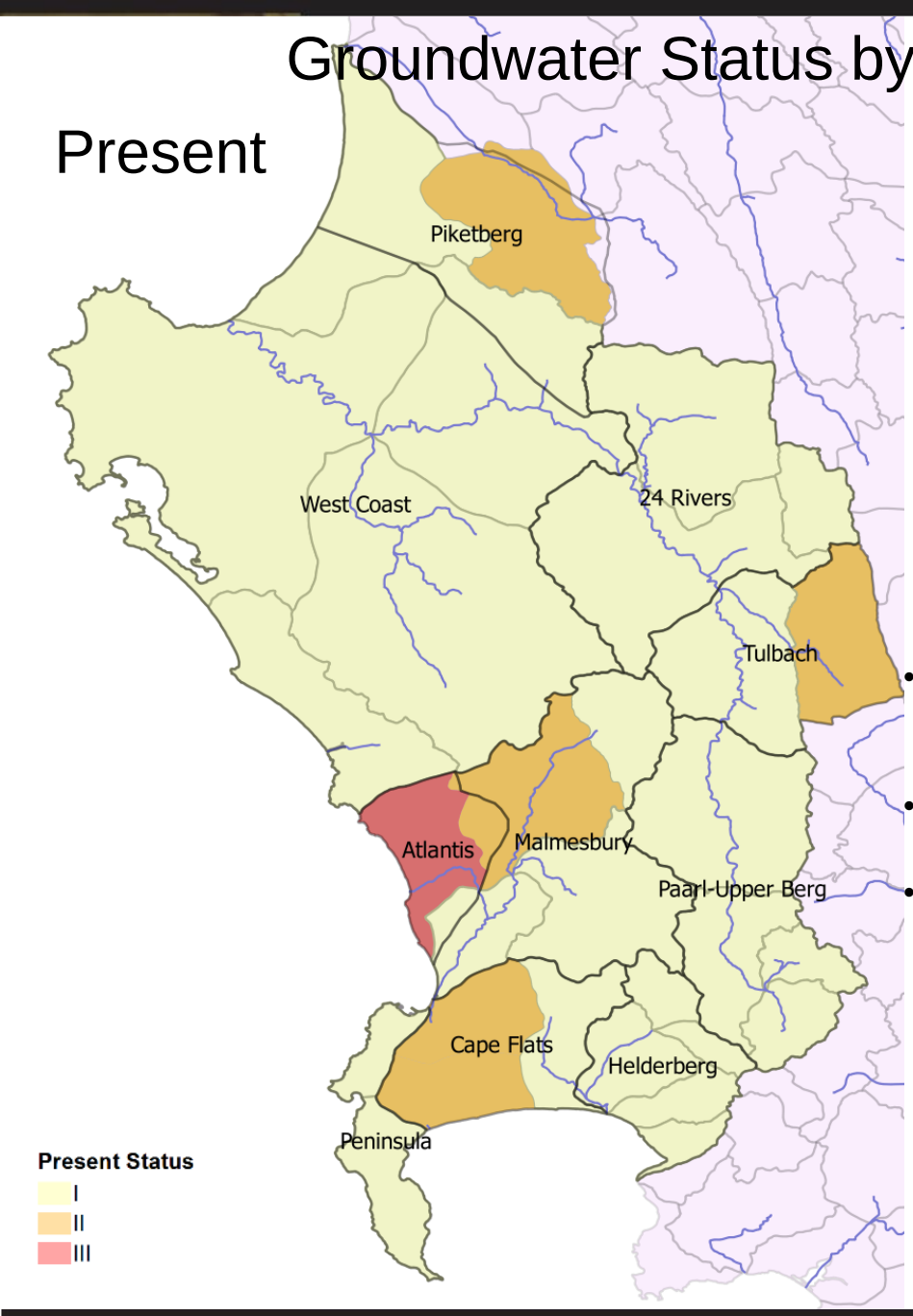
- Results: maximum impact of planned development according to All Towns water demand projections
- Groundwater use from 370 to 445 million m^3/a



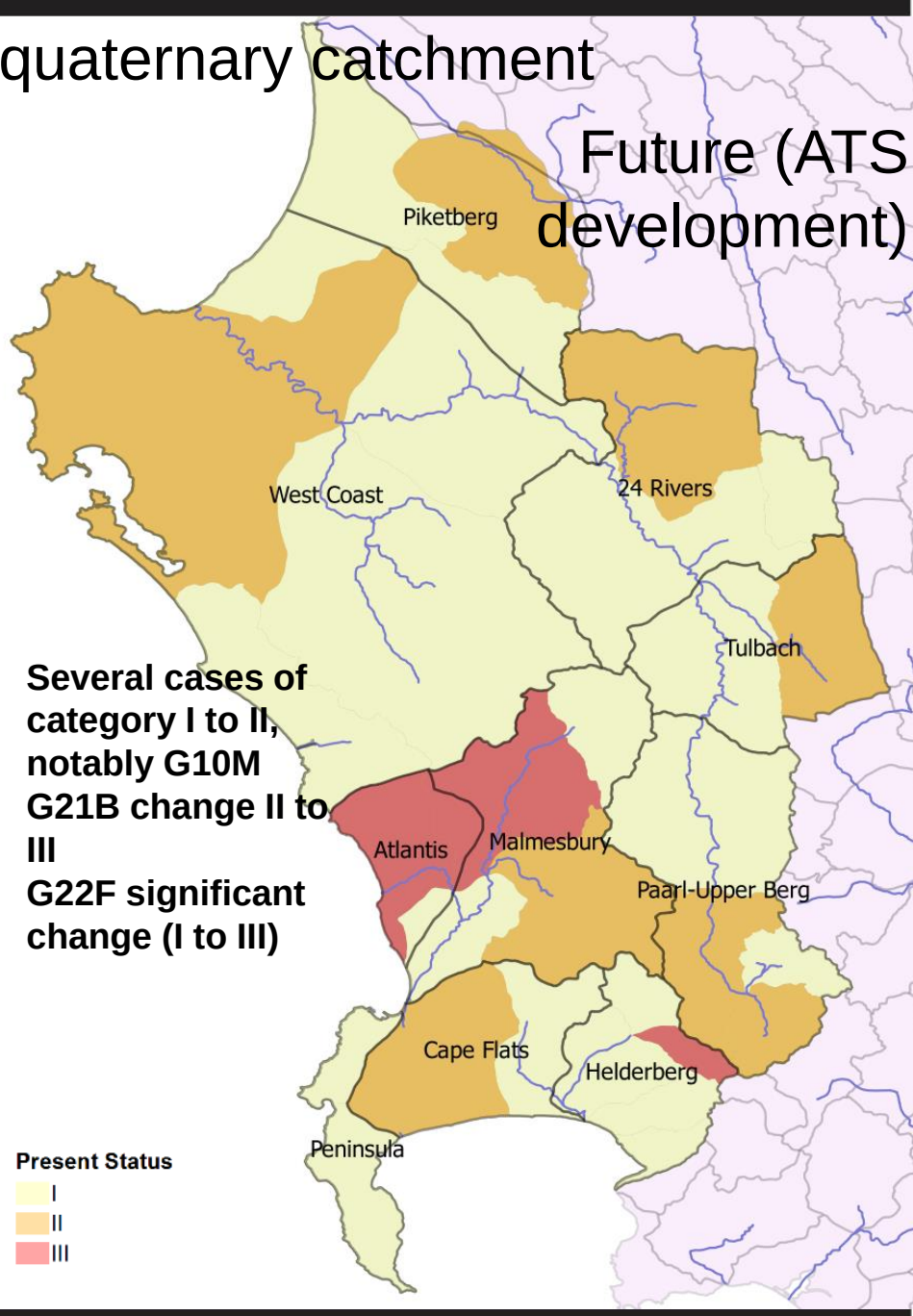


Groundwater Status by quaternary catchment

Present



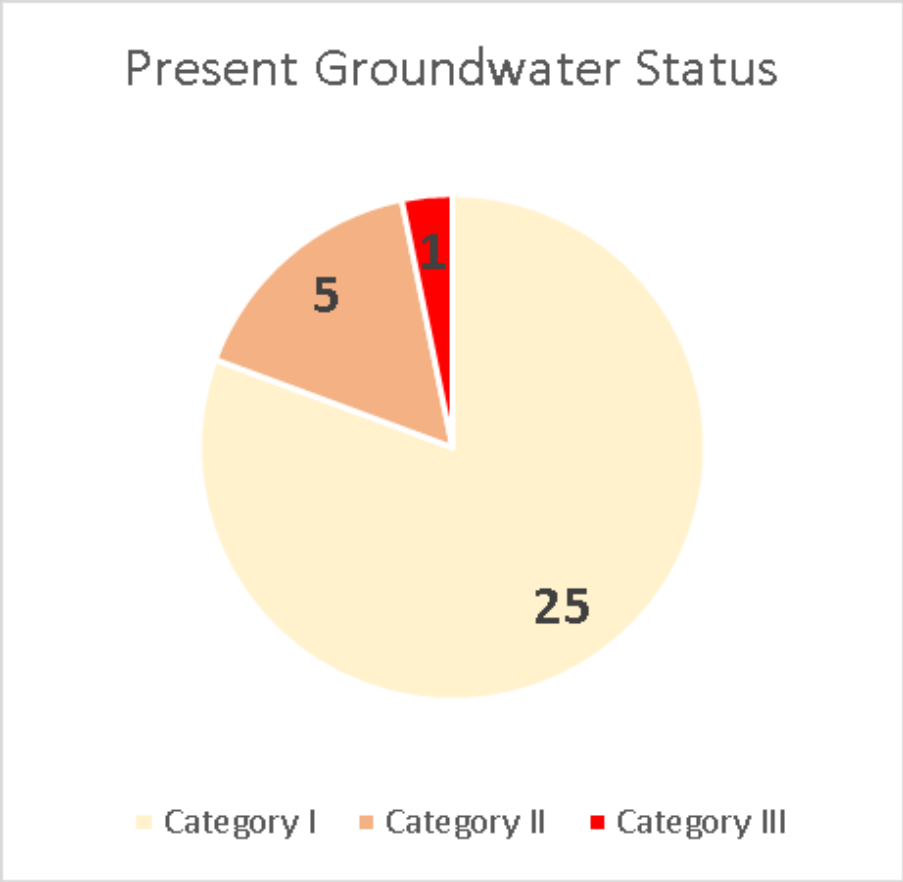
Future (ATS development)

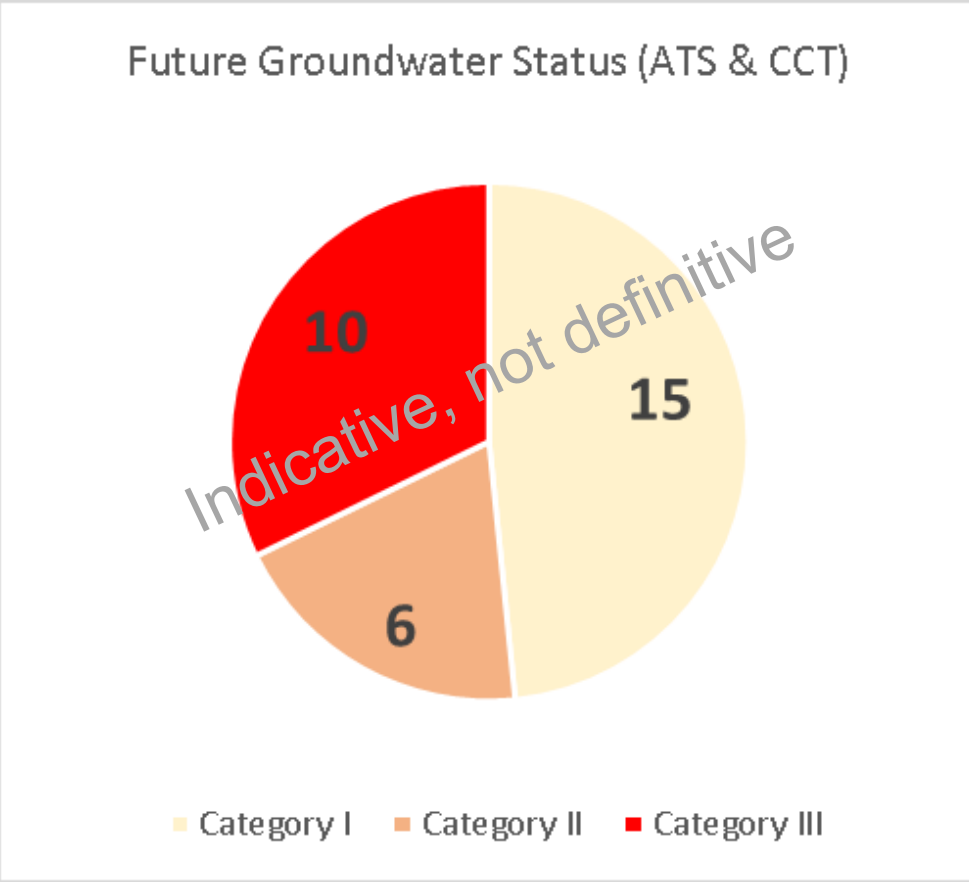


- **Several cases of category I to II, notably G10M**
- **G21B change II to III**
- **G22F significant change (I to III)**

Scenario consequences on groundwater condition

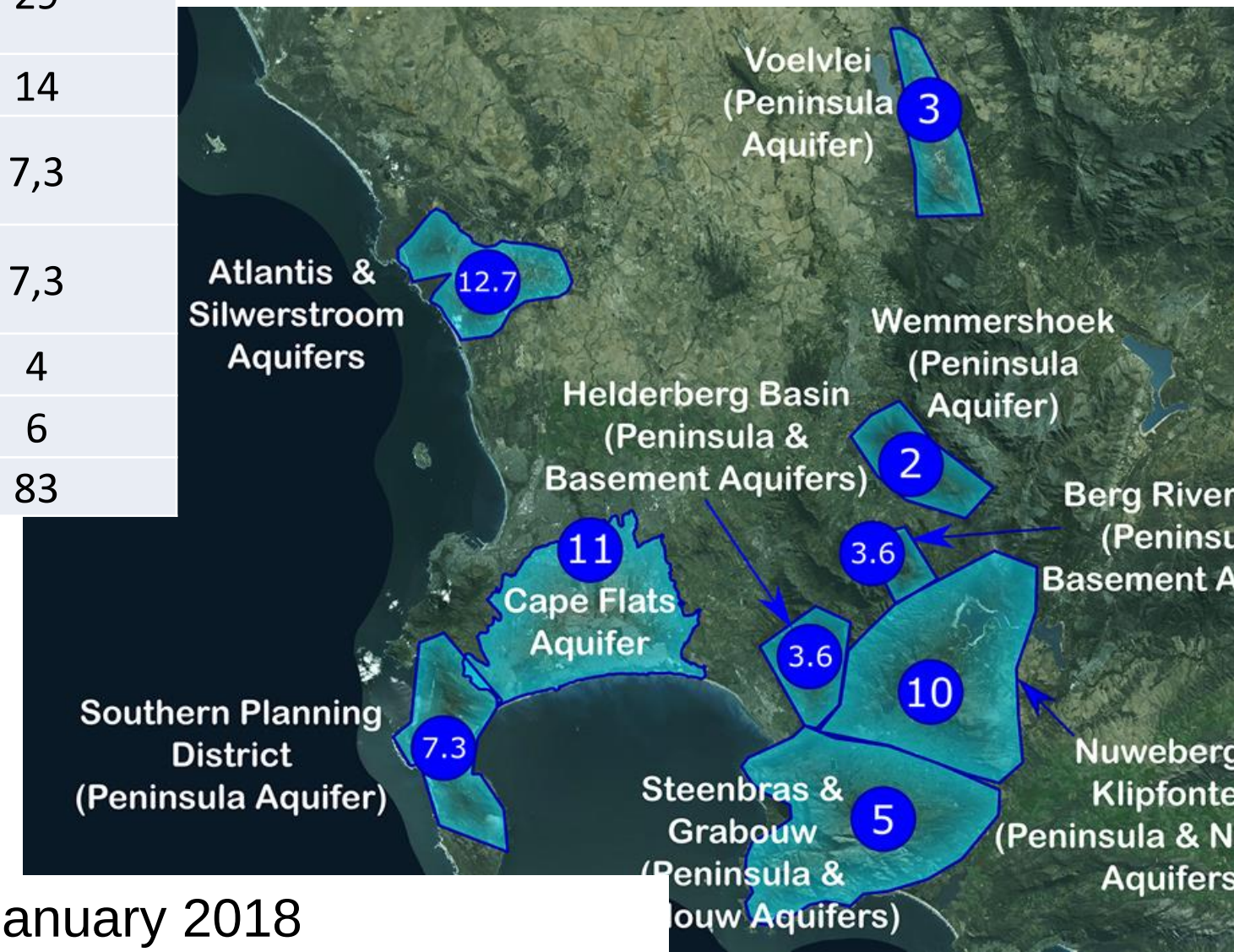
- Results: maximum impact of planned development according to All Towns water demand projections and CCT developments
- Groundwater use from 370 to 542 million m^3/a





CCT GW use (Umvoto, 2018)

Project/Aquifer	Phase 3 (hm^3/a)
CFA	30
Atlantis & Silwerstroom	29
SPD	14
Helderberg Basin	7,3
Berg River Valley	7,3
Wemmershoek	4
Voelvlei	6
Total	83



From Umvoto, January 2018

Groundwater Status by quaternary catchment