water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

2030 NDP

Determining Water Resources Classes and Associated Resource Quality Objectives in the Berg Catchment (WP10987)

Project Steering Committee Meeting

26th February 2018

Venue: Rondekuil Conference Venue, Durbanville, WC.

Overview of study objectives & tasks

Berg Water Resource Classification

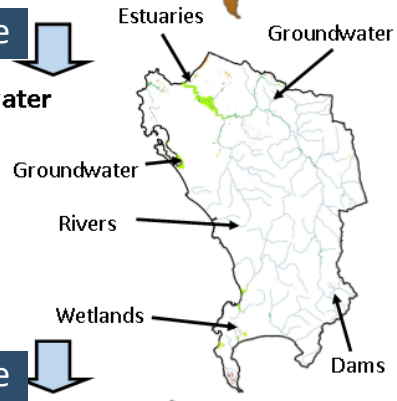
STEP 1: DELINEATE CATCHMENT & DESCRIBE STATUS QUO

Outcome: IUA & nodes

Socio-economic Zones

Complete

Significant water resources



Complete

Integrated Units of Analysis

Complete

STEP 2: LINK ECONOMIC & SOCIAL VALUE

Outcome: How economic value & social wellbeing influenced by ecosystem char. & use of water

SOCIAL WELL BEING

ECOSYSTEM INDEX

ECONOMIC PROSPERITY

Complete

STEP 3: QUANTIFY THE ECOLOGICAL WATER REQUIREMENTS AT EACH NODE

Outcome: EWR node table

in non-water quality EGSAs. Provide a table of EWRs for each node at various levels of ecological integrity.

Node: refer to different Ecological Base Conditions

Complete

STEP 4: SET A BASELINE FOR ECOLOGICAL SUSTAINABILITY

Outcome: ESBC scenario

Complete

Study Status

STEP 5: EVALUATE SCENARIOS WITHIN INTERATED WATER RESOURCE MANAGEMENT PROCESS

Outcome: Evaluate scenarios

In Progress

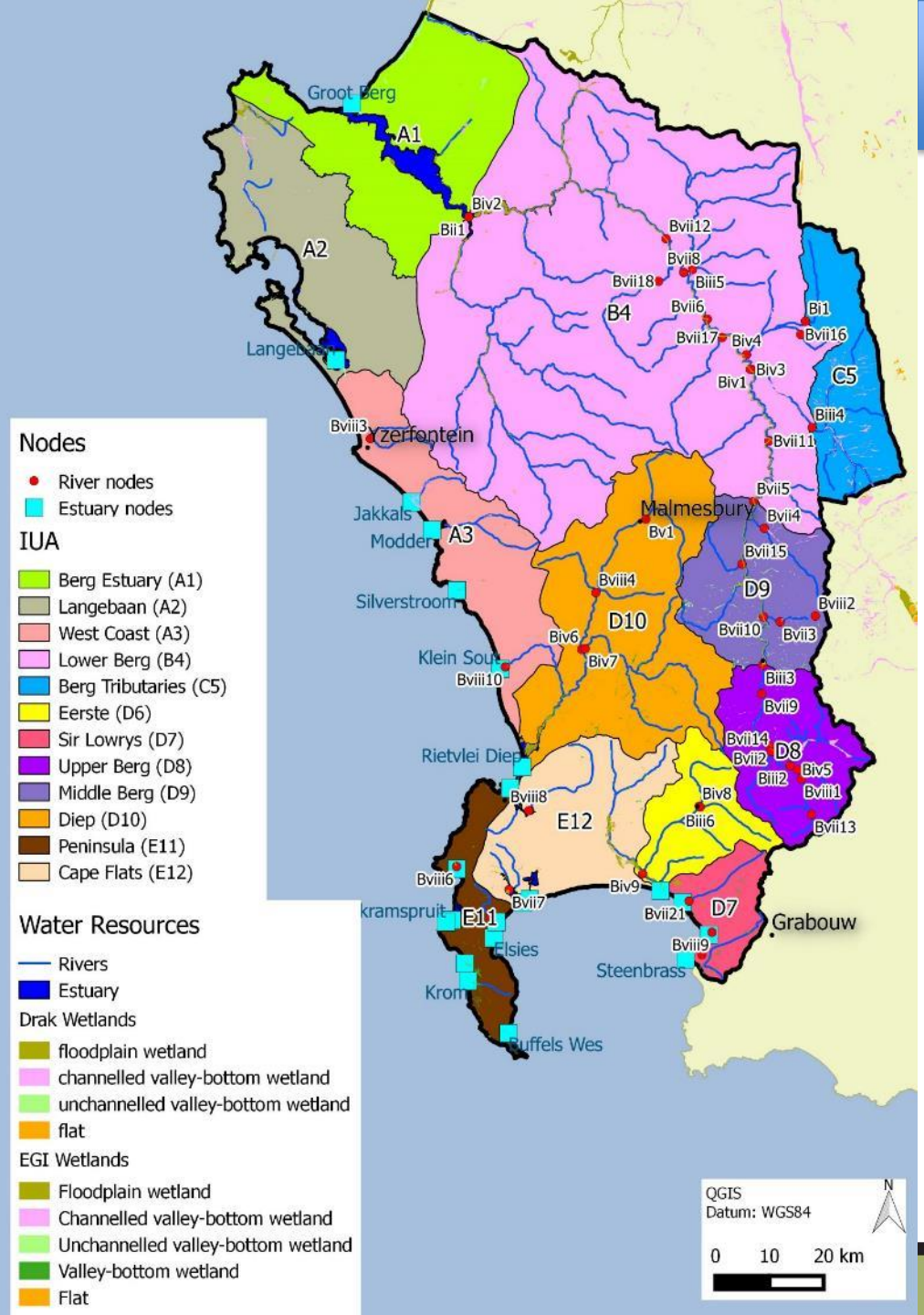
STEP 6: EVALUATE SCENARIOS WITH STAKEHOLDERS

Outcome: Scenario configuration

STEP 7: GAZETTE WATER RESOURCE CLASS CONFIGURATIONS

Outcome: Gazetted WRCs

Delineation of Resource Units and Integrated Units of Analysis



- 12 Integrated Units of Analysis (IUAs) identified In Study Area.
- Catchments G1, G2 and G40A.
- 45 river nodes identified.
- 8 existing Reserve Sites with EWRs already determined.
- 3 additional River EWR sited determined at Rapid Level III.
- 22 estuaries nodes identified.
- RDM studies undertaken to determined EWRs for 8 key estuaries in G2 catchments.
- 10 Groundwater Resource Units.

Scenarios Considered

Scenarios to be Considered

- Consider G1 and G2 catchments separately
  - G1 focused on the EWR impacts on the yield from WCWSS.
  - G2 focused on impacts on estuaries and wetlands.
  - Selected Groundwater scenarios considered separately.
- Scenarios to be considered:
  - Ecologically Sustainable Base Configuration (ESBC)
  - Present Ecological status (PES)
  - Recommended Ecological Category (REC)
  - Current and Future Developments
  - Possible Impacts of Climate Change
- Scenarios to be compared in terms of:
  - Overall ecological condition for river and estuary nodes
  - Wetland impacts
  - Water quality impacts
  - Impacts on water availability (Yield from WCWSS)
  - Groundwater impacts
  - Ecosystems Goods Services and Attributes (EGSA)
  - Additional infrastructure costs to provide shortfalls
  - Overall socio-economic costs/benefits.

Scenarios Considered: WCWSS and G1 Catchments

Scenario	Description
Scenario 1 (PES)	Current day infrastructure with 0.5 m^3s^{-1} minimum flow to the estuary.
Scenario 2 (ESBC)	Current Day infrastructure with ESBC at reserve sites and 0.5 m^3 minimum flow to the estuary
Scenario 3 (REC)	Current day infrastructure with REC at reserve sites and 0.6 m^3 minimum flow to the estuary
Scenario 4 (ESBC-FI)	Future infrastructure 2040 with ESBC at reserve sites and 0.5 m^3 minimum flow to the estuary.
Scenario 5 (REC-FI)	Future infrastructure 2040 with REC at reserve sites and 0.6 m^3 minimum flow to the estuary.
Scenario 6 (No EC-FI)	Future infrastructure 2040 with no environmental constraints
Scenario 7 (ESBC-CC)	Climate change hydrology, Future infrastructure 2040 with ESBC at reserve sites and 0.5 m^3 minimum flow to the estuary
Scenario 8 (REC-CC)	Climate change hydrology, Future infrastructure 2040 with REC at reserve sites and 0.6 m^3 minimum flow to the estuary.
Scenario 9 (No EC-CC)	Climate change hydrology, Future infrastructure 2040 including no return flows from treatment plants and no environmental constraints.

Scenarios Considered: G2 Catchments (Estuaries)

For estuaries with significant WWTW contributions.

#	Scenario	Description
1	Natural	Reference condition
2	Present	Present day flows and conditions
3	Scenario 1	Present day flows but all effluent from WWTW to be treated to DWS Special Standards
4	Scenario 2	Reduce inputs from the WWTW by 50% and treat the remainder to DWS Special Standards
5	Scenario 3	Reduce inputs from the WWTW by 75% and treat the remainder to DWS Special Standards
6	Scenario 4	Divert/recycle 100% of effluent from WWTW

Alternative future development scenarios for other estuaries (i.e. Langebaan, Sandvlei, Lourens).

Summary of Recommended Water Resource Classes

Determining the Water Resource Class

Description of the meaning for each Water Resource Class

Water Resource Class	Description
Class I	Minimally used
Class II	Moderately used
Class III	Heavily used

Guidelines for determining the IUA class based on ecological condition

	Percentage (%) of nodes in the IUA falling into the indicated groups				
	A or A/B	B or B/C	C or C/D	D	< D
Class I	60	40	20	1	-
Class II		60	30	5	-
Class III Either:			70	20	-

Comparison of Scenarios – Water Resource Classes

IUA Name	IUA Code	PES	Future ESBC	Future REC	Future No-EC	Future Climate Change ESBC	Future Climate Change REC	Future Climate Change No EC
Berg Estuary	A1	II	III	II	III	III	II	III
Langebaan	A2	II	III	II	III	III	II	III
West Coast	A3	III	III	III	III	III	III	III
Lower Berg	B4	III	III	III	III	III	III	III
Berg Tributaries	C5	II	III	II	III	III	II	III
Eerste	D6	III	III	III	III	III	III	III
Sir Lowry's	D7	III	III	III	III	III	III	III
Upper Berg	D8	III	III	III	III	III	III	III
Middle Berg	D9	III	III	III	III	III	III	III
Diep	D10	III	III	III	III	III	III	III
Peninsula	E11	II	III	II	III	III	II	III
Cape Flats	E12	III	III	III	III	III	III	III

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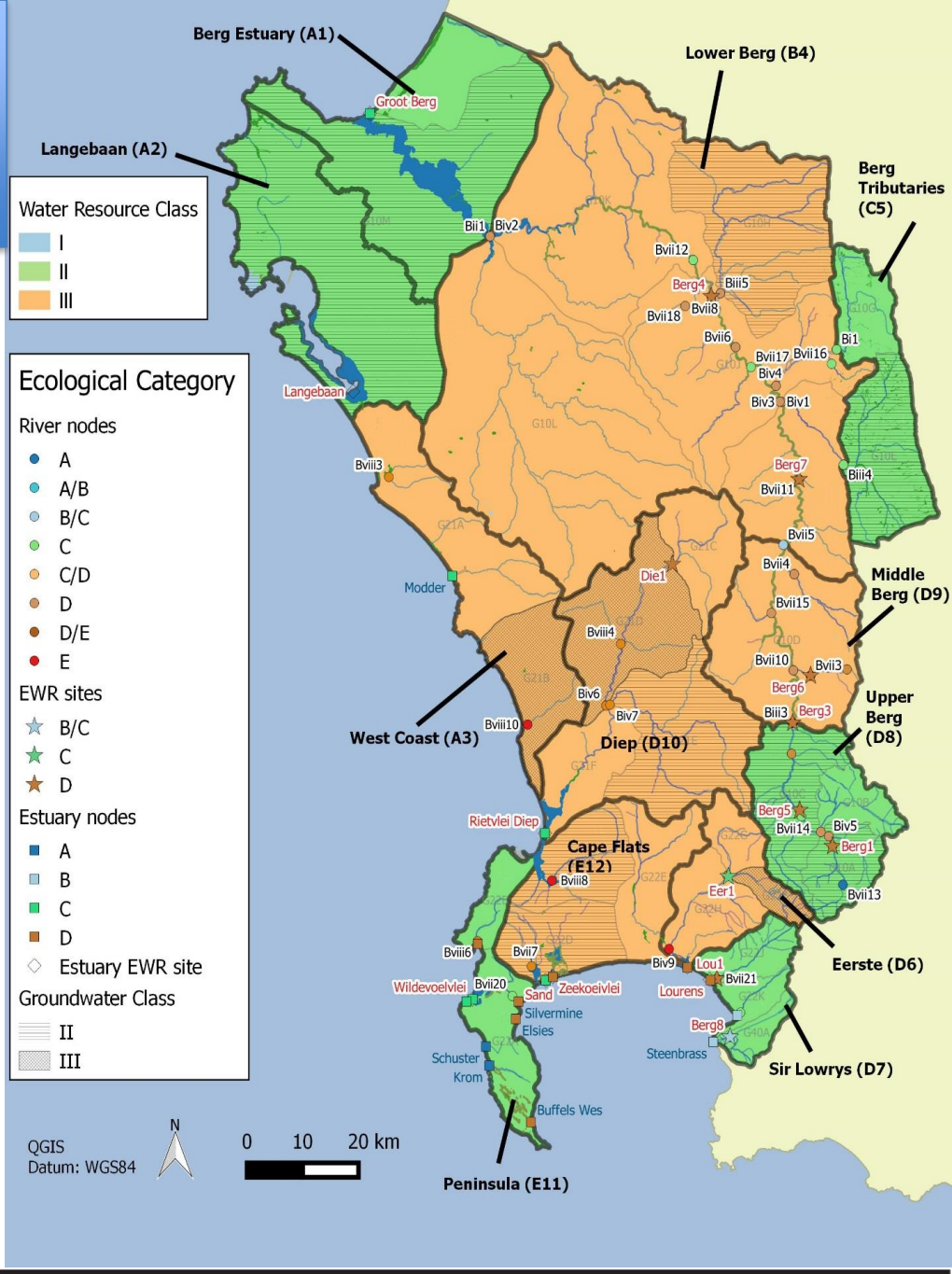
Water Resource Classes for the Berg Catchment

IUA Name	IUA Code	Recommended Class
Berg Estuary	A1	II
Langebaan	A2	II
West Coast	A3	III
Lower Berg	B4	III
Berg Tributaries	C5	II
Eerste	D6	III
Sir Lowry's	D7	II
Upper Berg	D8	III
Middle Berg	D9	III
Diep	D10	III
Peninsula	E11	II
Cape Flats	E12	III

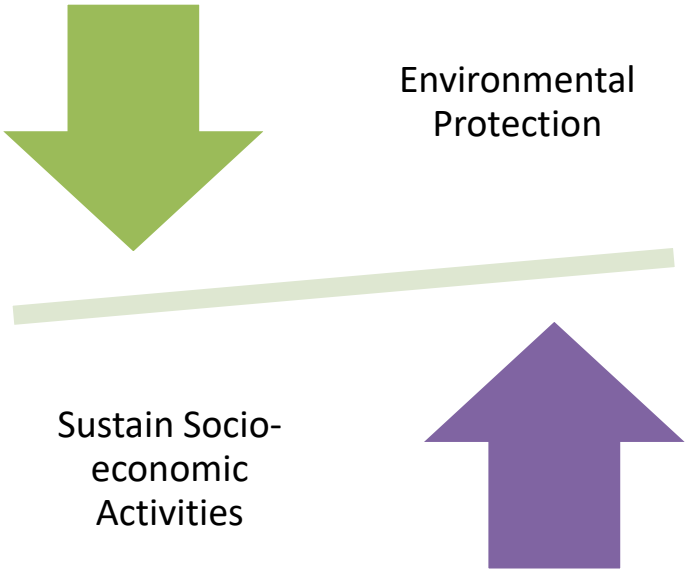


Methodology for Scenario Analysis

Scenario Evaluation Process

Aim of the scenario evaluation process:

- An appropriate balance between the level of environmental protection and the use of the water to sustain socio-economic activities

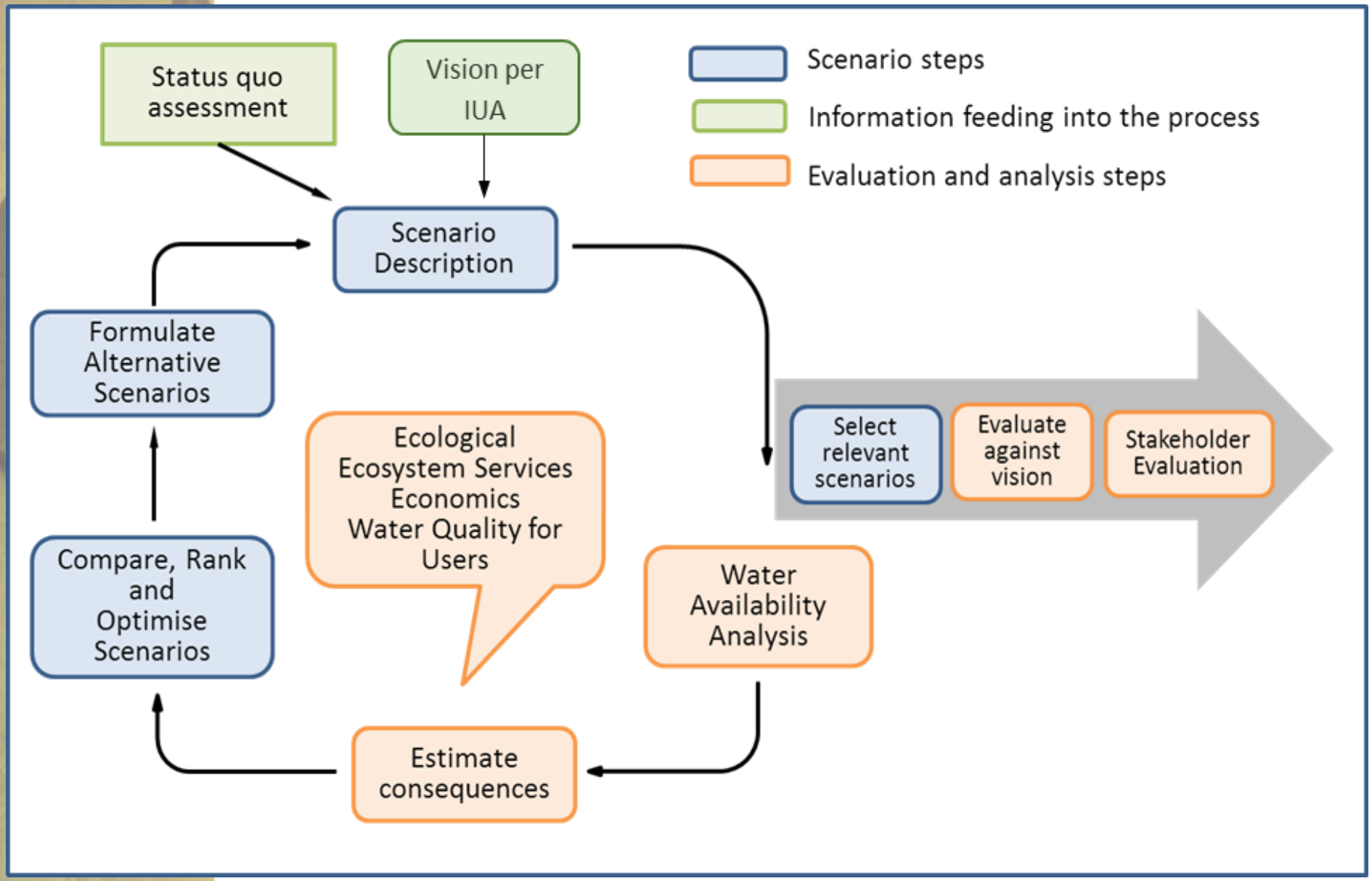


Balance must consider 3 main elements:

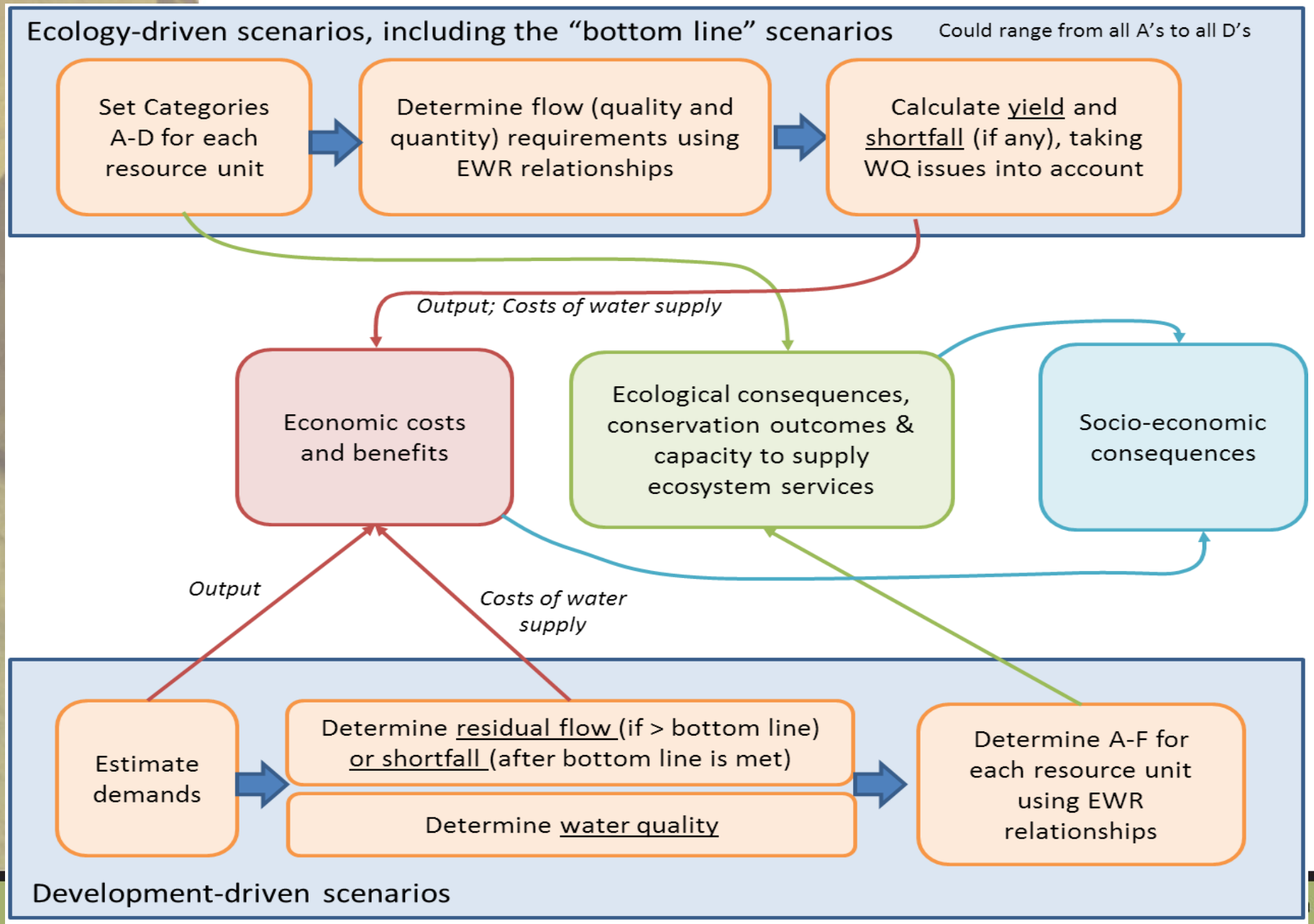
1. Ecology
2. Economic benefits
3. Societal benefits

Scenario evaluation process estimates consequences of the scenarios on the three main elements

Evaluation of Scenarios Methodology



Evaluation of Scenarios



Rivers

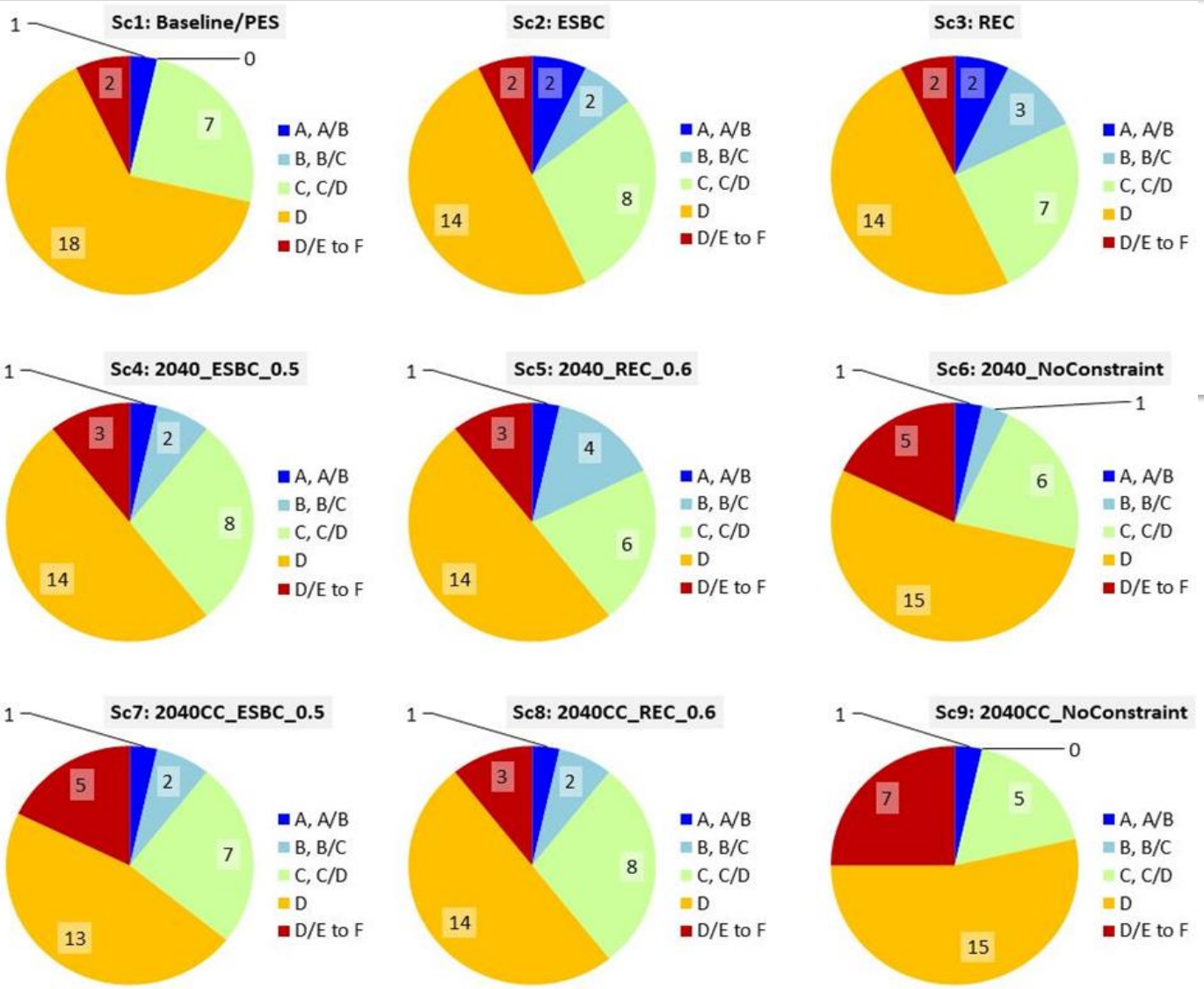
The balancing tool

- The balancing tool contains:
  - Baseline ecological conditions for rivers and estuaries
  - Modelled current day and natural flows (TOTAL i.e. with floods)
  - Modelled Reserve (E-flows) for a range of ecological conditions based on various Reserve studies
- Allows the user to toggle flow and see changes in ecological condition
- Reports surpluses and deficit in flow relative to current day

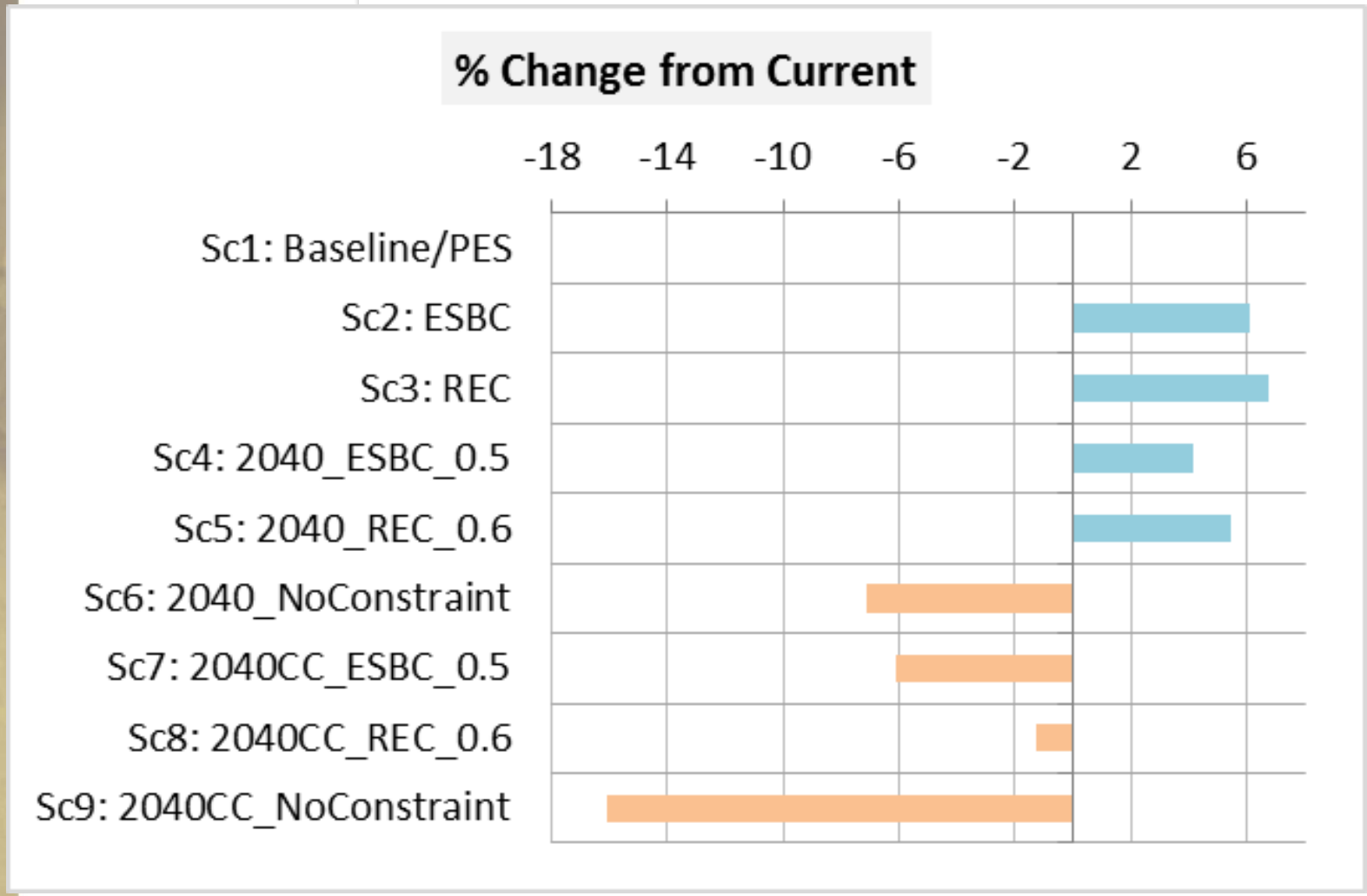
Scenario Results – Ecological Condition and % MAR
Present Day and Future ESBC and REC

IUA Code	River	REC	Node code	Sc1: Baseline/PES				Sc2: ESBC				Sc3: REC				Sc4: 2040_ESBC_0.5				Sc5: 2040_REC_0.6			
				EC	Wet % nMAR	Dry % nMAR	MAR	EC	Wet nMAR	Dry % nMAR	MAR	EC	Wet % nMAR	Dry % nMAR	MAR	EC	Wet % nMAR	Dry % nMAR	MAR	EC	Wet % nMAR	Dry % nMAR	MAR
UB	Berg		Bvii13	A	98.3	98.7	83.3	A	98.3	98.7	83.3	A	98.3	98.7	83.3	A	98.3	98.7	83.3	A	98.3	98.7	83.3
	Berg EWR 1	C	Bviii1	C	36.1	42.2	50.4	C	45.9	28.8	90.7	B/C	54.9	40.8	101.5	C	47.0	28.8	93.7	B/C	55.8	40.8	103.7
	Franschhoek		Biv5	D	53.3	3.7	31.0	D	53.3	3.7	31.0	D	53.3	3.7	31.0	D	53.3	3.7	31.0	D	53.3	3.7	31.0
	Wemmershoek		Biii2	D	16.6	2.1	25.8	D	16.6	2.1	25.8	D	16.6	2.1	25.7	D	16.6	2.1	25.8	D	16.6	2.1	25.8
	Dwars		Bvii14	C	67.8	58.7	31.7	C	68.4	59.1	31.9	C	68.2	59.1	31.8	C	68.5	59.1	31.9	C	68.4	59.1	31.8
	Berg		Biii3	E	94.6	204.0	226.3	E	122.1	254.6	290.6	E	123.1	254.6	298.1	E	122.5	254.7	291.0	E	123.4	254.7	297.9
MB	Pombers EWR 6	C	Bviii11	D	1342.6	3063.1	6.7	D	1342.6	3063.1	6.7	D	1342.6	3063.1	6.7	D	1342.6	3063.1	6.7	D	1342.6	3063.1	6.7
	Kromme EWR 7	D	Bvii3	D/E	89.9	1.9	16.5	D/E	89.9	1.9	16.5	D/E	89.9	1.9	16.5	D/E	89.9	1.9	16.5	D/E	89.9	1.9	16.5
	Berg		Bvii10	D	75.2	143.6	245.9	D	100.4	189.9	310.2	D	101.3	189.9	317.6	D	100.8	189.9	310.5	D	101.6	189.9	317.4
	Doring		Bvii15	D	38.3	0.0	2.9	D	38.2	0.0	2.9	D	38.1	0.0	2.9	D	38.1	0.0	2.9	D	38.1	0.0	2.9
	Kompanjies		Bvii4	D	43.7	0.5	18.3	D	43.7	0.5	18.3	D	43.7	0.5	18.3	D	43.7	0.5	18.3	D	43.7	0.5	18.3
	Berg EWR 3	D	Bvii5	D	32.8	17.9	266.7	B/C	94.3	98.0	578.8	B/C	95.2	98.0	586.8	B/C	95.3	98.2	581.9	B/C	96.1	98.2	588.8
BT	Berg		Biii4	C	97.2	128.2	69.1	C	97.2	128.2	69.1	C	97.2	128.2	69.1	C	97.2	128.2	69.1	C	97.2	128.2	69.1
	Berg		Bi1	C	30.3	33.2	29.6	C	30.4	33.2	29.7	C	30.4	33.2	29.8	C	30.6	33.2	30.5	B/C	30.8	33.2	30.8
	Klein Berg		Bvii16	C	23.8	35.0	2.7	C	23.9	35.0	2.8	C	23.9	35.0	2.8	C	24.1	35.0	2.9	C	24.2	35.0	2.9
LB	Klein-Berg		Bvii11	D	27.1	0.0	277.4	A/B	48.9	40.6	341.5	A/B	49.7	40.6	349.0	B/C	40.4	37.6	284.3	B/C	41.0	37.6	290.7
	Vier-en-Twintig		Biv1	D	67.4	106.6	332.3	D	83.7	129.5	399.0	D	84.3	129.5	404.9	D	90.0	146.5	397.3	D	90.7	147.2	402.2
	Leeu		Biv3	D	78.8	126.8	54.7	D	79.0	126.8	55.1	D	79.0	126.8	55.3	D	79.5	126.8	56.3	D	79.7	126.8	56.7
	Vier-en-twintig		Biv4	D	26.4	13.1	49.5	D	26.4	13.1	49.7	D	26.4	13.1	49.8	D	26.6	13.1	50.5	D	26.7	13.1	50.9
	Sandspruit		Bvii17	C	85.8	83.1	8.2	C	85.8	83.1	8.2	C	85.8	83.1	8.2	C	85.8	83.1	8.2	C	85.8	83.1	8.2
	Berg EWR 4	D	Bvii6	D	58.4	82.1	449.5	D	69.0	96.6	516.7	D	69.5	96.6	522.9	D	73.1	107.3	517.1	D	73.6	107.6	522.7
	Matjies		Biii5	D	75.7	70.6	26.8	D	75.7	70.6	26.8	D	75.7	70.6	26.8	D	75.7	70.6	26.8	D	75.7	70.6	26.8
	Berg		Bvii8	D	56.2	73.1	475.6	D	66.7	87.9	542.9	D	67.1	87.8	549.0	D	70.7	98.5	543.2	D	71.2	98.9	548.8
	Moreesburgspruit		Bvii18	D	100.0	100.0	3.3	D	100.0	100.0	3.3	D	100.0	100.0	3.3	D	100.0	100.0	3.3	D	100.0	100.0	3.3
	Berg EWR 5	D	Bvii12	D	40.1	35.2	445.3	C	55.0	59.5	521.9	C	55.4	59.5	528.0	C	60.2	77.9	517.4	C	60.9	79.2	523.4
	Sout		Bii1	D	99.6	100.0	15.6	D	99.6	100.0	15.6	D	99.6	100.0	15.6	D	99.6	100.0	15.6	D	99.6	100.0	15.6
	Berg		Biv2	D	36.7	24.8	453.1	C/D	50.7	47.8	529.5	C/D	51.0	47.8	535.6	D/E	39.3	18.6	506.4	D/E	40.5	21.2	512.7
	Berg Estuary	C	Bxi1	C	37.5	25.4	468.7	B/C	51.3	48.2	545.2	B/C	51.7	48.2	551.3	C	40.1	19.2	522.0	C	41.3	21.8	528.4

Scenario Results – Ecological Condition for Berg River Present Day and Future ESBC and REC



Scenario Results – Overall Ecological Condition (G1)



Target Ecological Condition (TEC) for River EWR sites

EWR Site	Node	IUA	Quat	Name	PES	TEC	% nMAR (Reserve – excludes flood flows)
Berg1	Bviii1	D8	G10A	Upper Berg River	C	C	31%
Berg3	Bvii5	D8	G10D	Lower Berg River	D	D	33%
Berg4	Bvii6	B4	G10J	Heuningberg, upstream of Misverstand Dam	D	D	21%
Berg5	Bvii12	B4	G10J	Nuwedrif, downstream of Misverstand Dam	D	D	24%
Berg6	Bvii3	D9	G10D	Kromme River	D	C	22%
Berg7	Bviii11	D9	G10D	Pombers River	D/E	D	14%
Berg8	Bvii22	B4	G40A	Steenbras River	B/C	B/C	14%
Die1	Bv1	D10	G21D	Diep River	E	D	14%
Eer1	Biii6	D6	G22F	Jonkershoek River	C	C	23%
Lou1	Bvii21	D7	G22J	Lourens River	D	D	15%

Water Quality

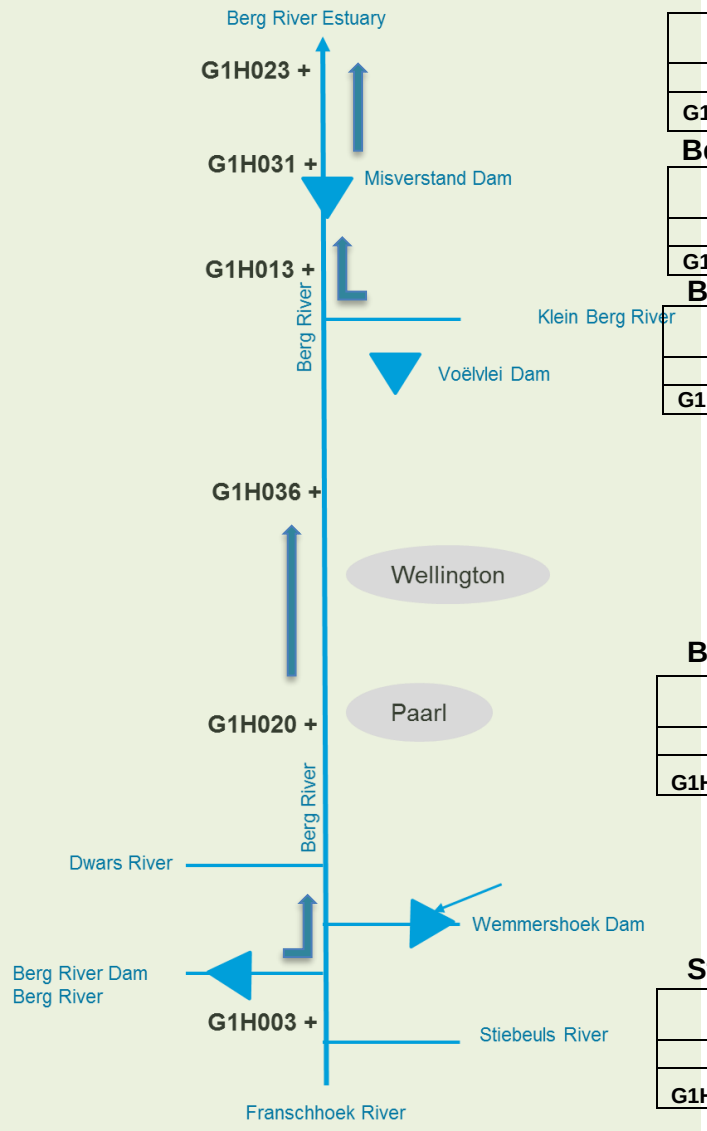
Scenario Analysis – Status Quo

Table 2.17. Water quality criteria used to assess the present water quality status.

Variable	Units	Bound	Ideal	Sensitive user	Acceptable	Sensitive user	Tolerable	Sensitive user
Alkalinity ($CaCO_3$)	mg/l	Upper	20	AAq	97.5	AAq	175	AAq
Ammonia (NH_3-N)	mg/l	Upper	0.015	Eco	0.044	Eco	0.073	Eco
Calcium (Ca)	mg/l	Upper	10	Dom	80	BHN	80	BHN
Chloride (Cl)	mg/l	Upper	40	In2	120	In2	175	In2
EC	mS/m	Upper	30	In2	50	In2	85	Eco
Fluoride (F)	mg/l	Upper	0.7	Dom	1	Dom	1.5	Dom
Magnesium (Mg)	mg/l	Upper	70	Dom	100	Dom	100	Dom
NO_3 (NO_3-N)	mg/l	Upper	6	Alr	10	Alr	20	Alr
pH	units	Upper	≤ 8	In2	<8.4	In2		
		Lower	≥6.5	Air, Aag, In2	>8.0	Air, Aag, In2		
Potassium (K)	mg/l	Upper	25	Dom	50	Dom	100	Dom
PO_4-P (Rivers)	mg/l	Upper	0.025	Eco	0.075	Eco	0.125	Eco
PO_4-P (Dams)	mg/l	Upper	0.005	Eco	0.015	Eco	0.025	Eco
SAR	mmol/l	Upper	2	Alr	8	Alr	15	Alr
Sodium (Na)	mg/l	Upper	70	Alr	92.5	Alr	115	Alr
Sulphate (SO_4)	mg/l	Upper	80	In2	165	In2	250	In2
TDS	mg/l	Upper	200	In2	350	In2	800	In2
Si	mg/l	Upper	10	In2	25	In2	40	In2

Note on sensitive users: Air = Agriculture: Irrigation users, AAq = Agriculture: Aquaculture users, BHN = Basic human needs users, Dom = Domestic users, Eco = Aquatic ecosystems, In2 = Industrial 2 users

Scenario analysis – Status Quo



Berg at Jantjiesfontein

		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	IUA	50	95	50	95	50	95	50	95	50	95	50	95	50	95
G1H023Q01	A1														

Berg at Misverstand

		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4		
Station	IUA	50	95	50	95	50	95	50	95	50	95	50	95	50	95	
G1H031Q01	B4															

Berg at Drieheuwels

		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4		
Station	IUA	50	95	50	95	50	95	50	95	50	95	50	95	50	95	
G1H013Q01	B4															

Berg in Paarl

		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	IUA	50	95	50	95	50	95	50	95	50	95	50	95	50	95
G1H020Q01	D7														

Stiebeuels River

		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	IUA	50	95	50	95	50	95	50	95	50	95	50	95	50	95
G1H003Q01	D7														

Scenario Assessment methodology

- Qualitative assessment
- Based on the relationship between flow and water quality concentrations
- Envisaged changes in flow (Scenarios)
- Continued impacts of point sources and non-point sources

Scenario Results – Potential water quality impacts (G1)

Scenario	Upper Berg	Middle Berg	Lower Berg
Scenario 1 (PES)	↔	↔	↔
Scenario 2 (ESBC)	↑	↑	↑
Scenario 3 (REC)	↑	↑	↑
Scenario 4 (ESBC-FI)	↔	↔	↓
Scenario 5 (REC-FI)	↑	↑	↓
Scenario 6 (No EC-FI)	↑	↑	↓↓
Scenario 7 (ESBC-CC)	↑	↑	↓↓
Scenario 8 (REC-CC)	↑	↑	↓↓
Scenario 9 (No EC-CC)	↓↑	↓↑	↓↓

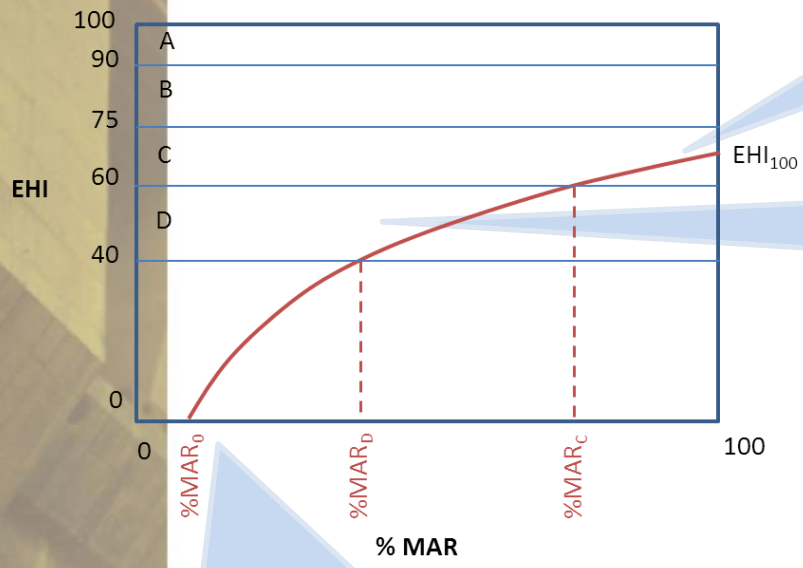
↔ No change

↑ Improvement

↓ Deterioration

Estuaries

Estuaries



3. It is often not possible to restore health to 100% of natural through restoration of flow alone due to other non-flow related impacts

1. Relationship between health and flow is logarithmic – health declines increasingly rapidly as %MAR declines

2. The ability of an estuary to support biodiversity drops to zero before MAR drop to zero

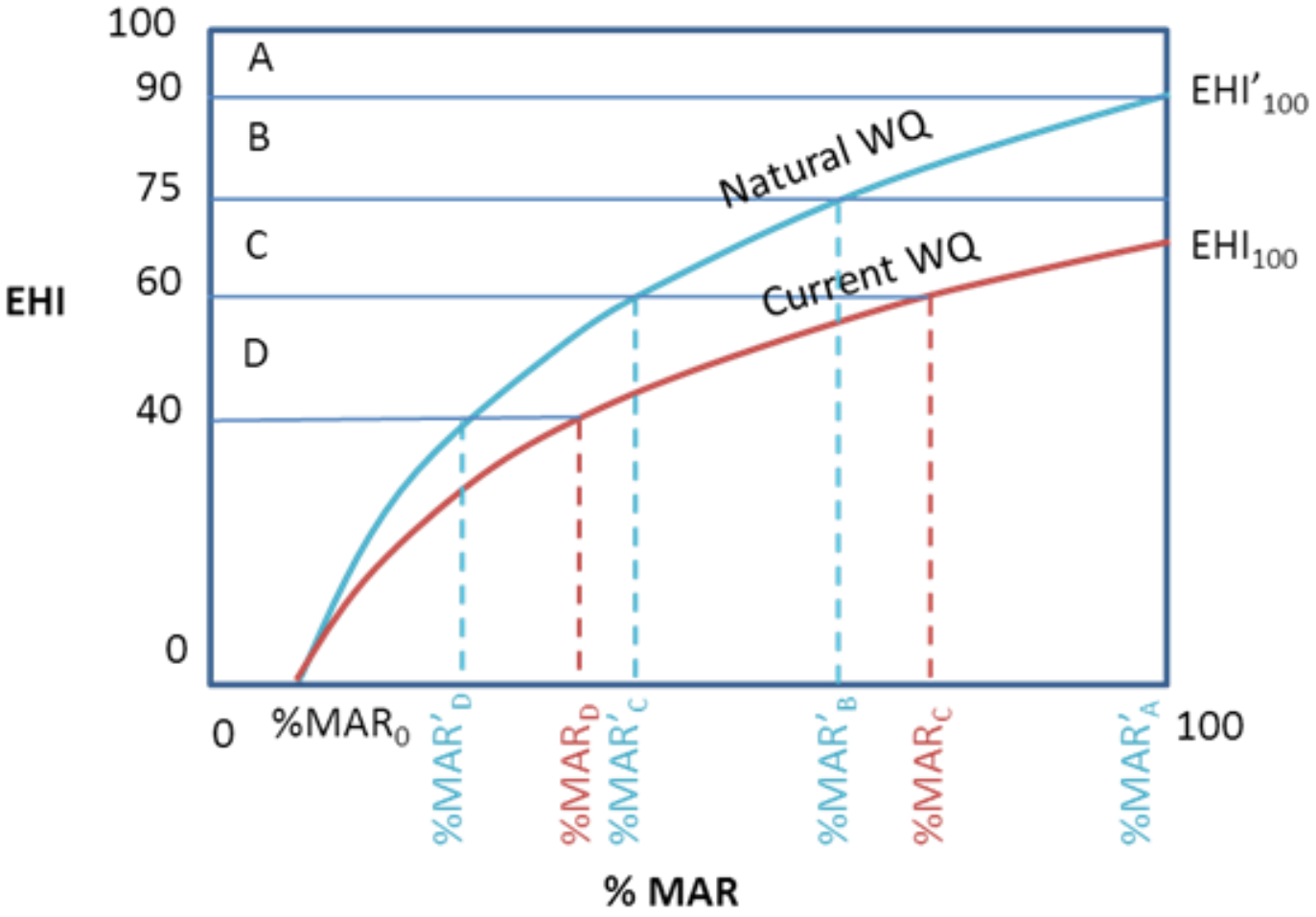
A. Models were developed which allowed us to project likely changes in estuary health from A to E category as flows decline based on data from Reserve determination studies for individual estuaries

B. Proportional changes in the size of macrophyte, invertebrate, fish and bird populations were also estimated using matrices developed using data from Reserve determination studies for individual estuaries

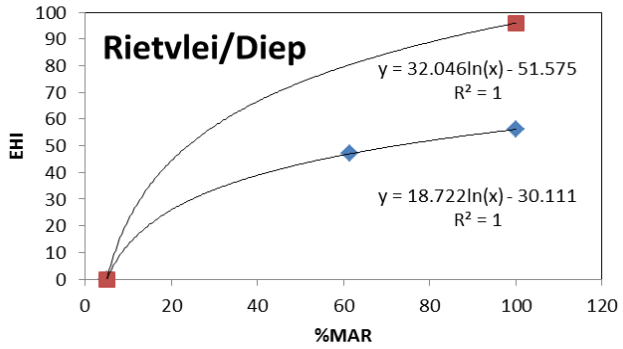
		Assigned Ecological Category					
		A	B	C	D	E	F
PES	A	1.0	0.9	0.7	0.5	0.3	0.1
	B	1.2	1.0	0.8	0.6	0.4	0.1
	C	1.4	1.2	1.0	0.7	0.4	0.1
	D	1.9	1.7	1.4	1.0	0.6	0.2
	E	3.2	2.8	2.3	1.7	1.0	0.3
	F	10.4	9.0	7.3	5.4	3.2	1.0

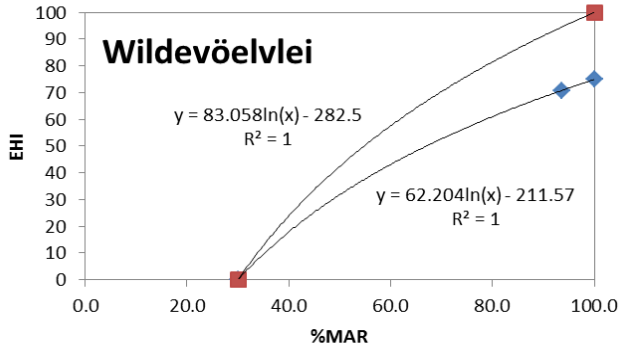
Determining EWRs for Estuaries

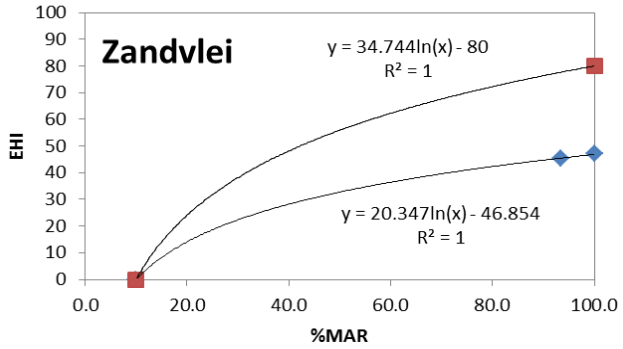
Model relationship between Estuary Heath Index (EHI) and changes in Mean Annual Runoff (MAR) and Water Quality

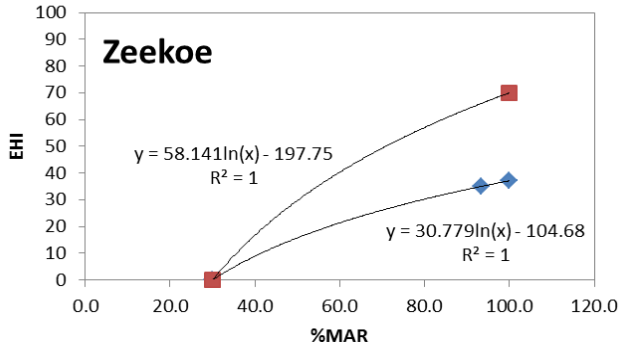


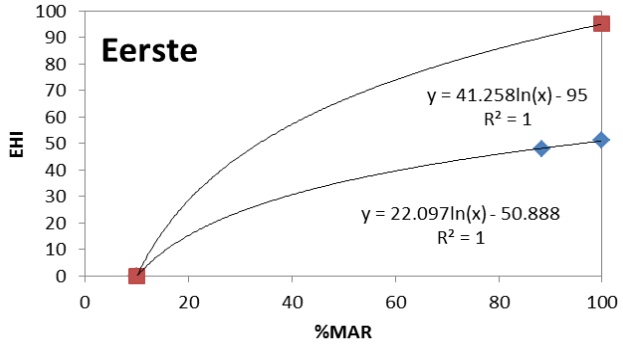
Summary of Estuary Flow Scenario Results (G2)

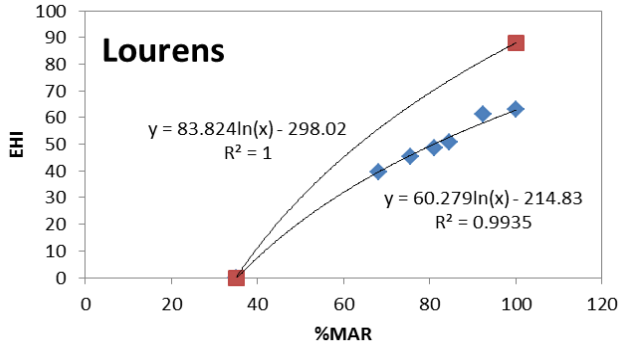












Estuary Scenario Results - Example

Langebaan Lagoon

Scenario	WCDM wellfield abstraction (million m³/a)	Dispersed abstraction (million m³/a)	Total abstraction (million m³/a)
Base case	0	4.94	4.94
Scenario 1	1.35	6.53	7.88
Scenario 2	3.5	6.53	9.83
Scenario 3	5.5	6.53	12.03
Scenario 4	7	6.53	13.53
Scenario 5	12	6.53	18.53

	Drawdown at Langebaan Lagoon (m)		Aquifer Flux to Lagoon (million m3/a)			% change from Base case
	LAU	UAU	LAU	UAU	LAU+UAU	
Base case	n/a	n/a	-0.6	-5.1	-5.7	-
Scenario 1	<0.1	<0.1	-0.6	-5.1	-5.7	-1
Scenario 2	<0.1	<0.1	-0.6	-5	-5.6	-3
Scenario 3	<0.1, increasing to 0.1-0.5 ~680m from water	<0.1	-0.6	-5	-5.6	-4
Scenario 4	<0.1, increasing to 0.1-0.5 ~500m from water	<0.1	-0.6	-5	-5.6	-4
Scenario 5	<0.1, increasing to 0.1-0.5 500m from water	<0.1	-0.6	-5	-5.6	-6%

Estuary Scenario Results - Example

Langebaan Lagoon

Component	Present	Sc1	Sc2	Sc3	Sc4	Sc 5
Hydology	**99**	**99**	**99**	**99**	**99**	99
Hydrodynamics and mouth condition	95	95	95	95	95	91
Water quality	95	95	95	95	95	95
Physical habitat alteration	92	92	92	92	92	92
Habitat health score	**95**	**95**	**95**	**95**	**95**	**94**
Microalgae	90	90	90	90	90	90
Macrophytes	90	90	88	88	85	85
Invertebrates	90	90	90	90	90	90
Fish	50	50	50	50	50	50
Birds	50	50	50	50	50	50
Biotic health score	**74**	**74**	**74**	**74**	**73**	**73**
Estuary Health Score	**85**	**85**	**84**	**84**	**84**	**84**
Ecological Category	**B**	**B**	**B**	**B**	**B**	**B**

Estuary Scenario Results - Example

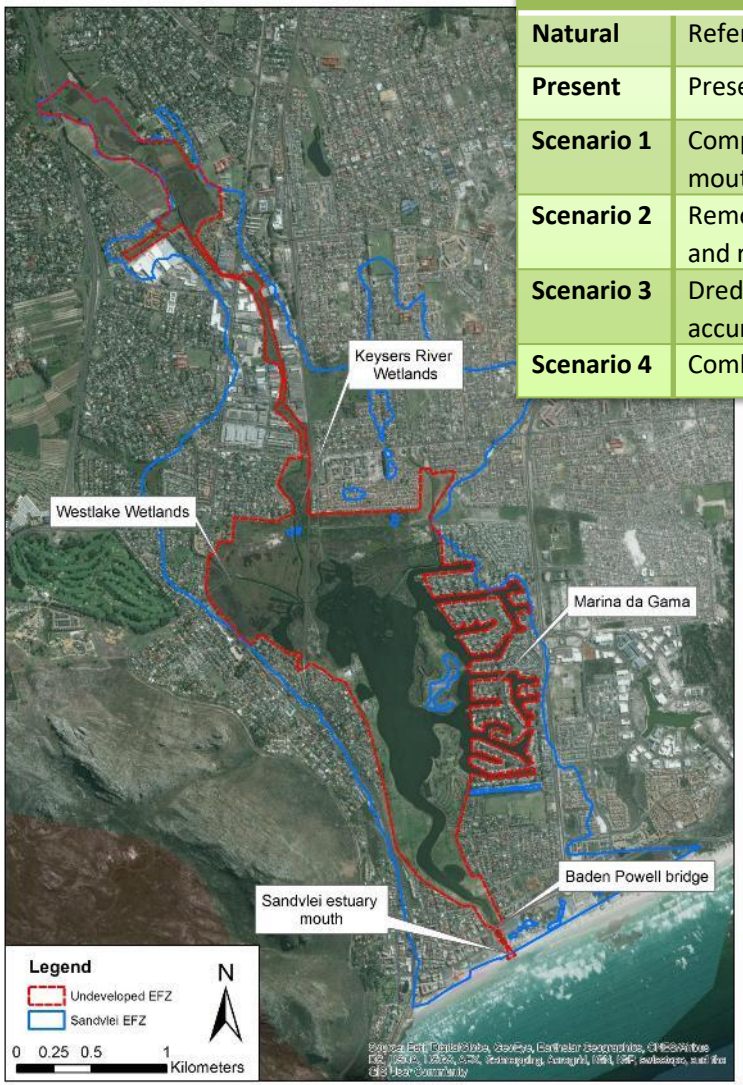
Diep/Rietvlei Estuary

Scenario name	Description	MAR (million m^3/a)	Percentage of natural flows
Natural	Reference condition	60.804	100%
Present	Present day flows	57.957	95%
Scenario 1	Present day flows + special WWTW standards	57.957	95%
Scenario 2	50% reduction in contribution from WWTW + special standards	47.627	78%
Scenario 3	75% reduction in contribution from WWTW+ special standards	42.462	70%
Scenario 4	Zero input from WWTW	37.297	61%

Component	Present	Sc1	Sc2	Sc3	Sc 4
Hydrology	59	59	59	59	59
Hydrodynamics and mouth condition	83	83	81	85	64
Water quality	38	39	40	42	47
Physical habitat alteration	30	30	30	30	30
Habitat health score	52	53	52	54	50
Microalgae	45	45	45	48	50
Macrophytes	30	32	35	38	40
Invertebrates	16	20	20	24	40
Fish	40	40	45	55	30
Birds	61	61	63	64	61
Biotic health score	38	40	42	46	44
Estuary Health Score	45	46	47	50	47
Ecological Category	D	D	D	D	D

Estuary Scenario Results - Example

Zandvlei Estuary



Scenario name	Description	MAR (million m^3/a)	Percentage of natural flows
Natural	Reference condition	31.68	100%
Present	Present day flows	29.58	93%
Scenario 1	Complete removal of the rubble weir and other obstructions (pipelines) at mouth of the estuary to allow improved tidal flushing	29.58	93%
Scenario 2	Remove bank stabilisation (concrete banks in lower reaches of the estuary and reshape banks) to create more shallow water marginal habitat	29.58	93%
Scenario 3	Dredge the upper reaches of the vlei to -2.0 m MSL to remove accumulated silt and organic material	29.58	93%
Scenario 4	Combination of interventions for Scenario 1 and 2	29.58	93%

Component	Present	Sc1	Sc2	Sc3	Sc4
Hydrology	93	93	93	93	93
Hydrodynamics and mouth condition	20	40	20	20	40
Water quality	43	49	43	45	47
Physical habitat alteration	10	15	20	10	25
Habitat health score	41	49	44	42	51
Microalgae	45	61	50	45	65
Macrophytes	25	35	35	25	35
Invertebrates	68	83	75	68	85
Fish	45	55	50	40	55
Birds	63	72	70	65	75
Biotic health score	49	61	56	49	63
Estuary Health Score	45	55	50	45	57
Ecological Category	D	D	D	D	D

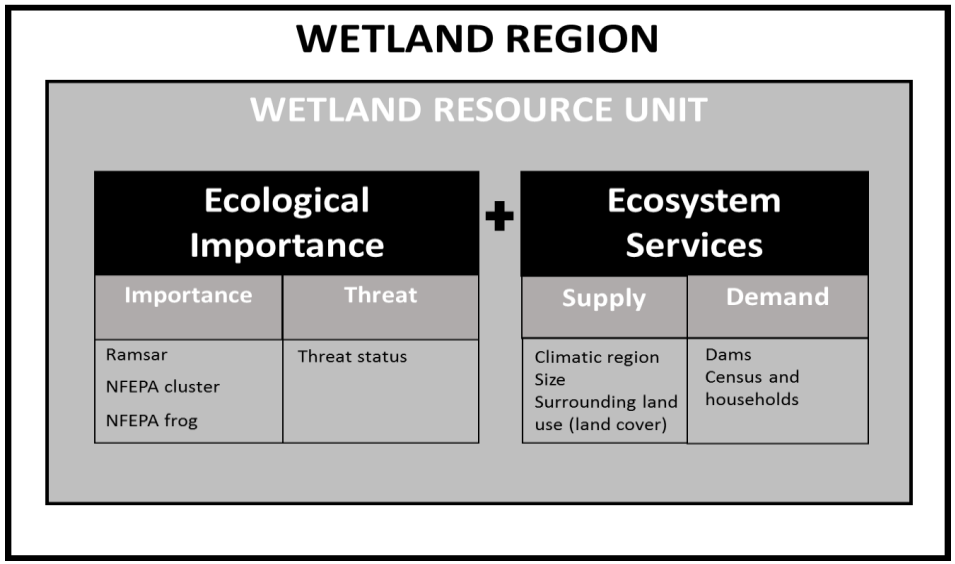
Target Ecological Condition (TEC) for Estuaries

Estuary Node	IUA	Quat	Name	PES	REC	EIS	Minimum %MAR with Current WQ	Minimum %MAR with Improved WQ
Bxi1	A1	G10M	Berg River Estuary	D	C	H	46	33
Bxi3	A2	G10M	Langebaan Estuary	B	A	VH	94	94
Bxi12	A3	G21A	Modder Estuary	C	C	M	n/a	33
Bxi7	D10	G21F	Rietvlei/Diep Estuary	D	C	H	n/a	33
Bxi9	E12	G22K	Zandvlei Estuary	D	C	H	n/a	56
Bxi20	E12	G22D	Zeekoe Estuary	E	D	U	110	60
Bxi10	E11	G22B	Hout Bay Estuary	E	D	U	35	26
Bxi11	E11	G22A	Silvermine Estuary	D	D	U	35	26
Bxi19	E11	G22A	Elsies Estuary	E	D	U	35	26
Bxi18	E11	G22A	Buffels Wes Estuary	F	D	U	66	67
Bxi17	E11	G22A	Krom Estuary	A	A	U	95	95
Bxi16	E11	G22A	Schuster Estuary	A	A	U	95	95
Bxi15	E11	G22A	Bokramspruit Estuary	C	C	U	65	42
Bxi14	E11	G22A	Wildvoelvlei Estuary	D	C	M	79	62
Bxi3	D6	G22H	Eerste Estuary	E	D	M	61	26
Bxi4	D7	G22J	Lourens Estuary	D	D	U	69	56
Bxi6	D7	G22K	Sir Lowry's Pass Estuary	E	D	U	35	26
Bxi6	D7	G40A	Steenbras estuary	B	B	U	97	35

Wetlands

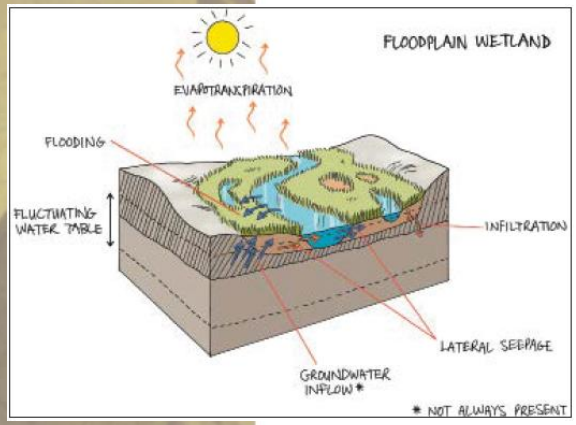
Identification of Priority Wetlands

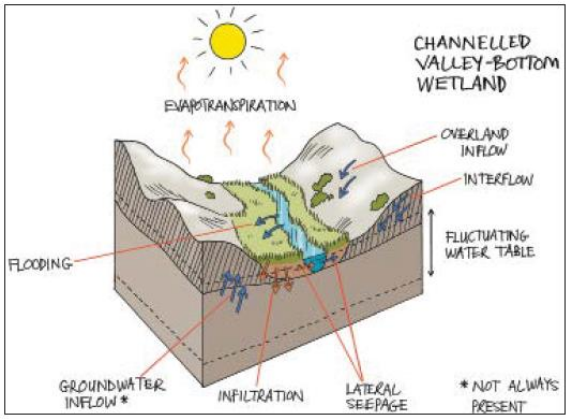
- Wetland Resource Units will be assessed qualitatively at individual river/estuary nodes in terms of impacts from surface and groundwater usage
- Wetland Resource Units will be assessed qualitatively at the catchment scale for all scenarios in terms of indirect impacts

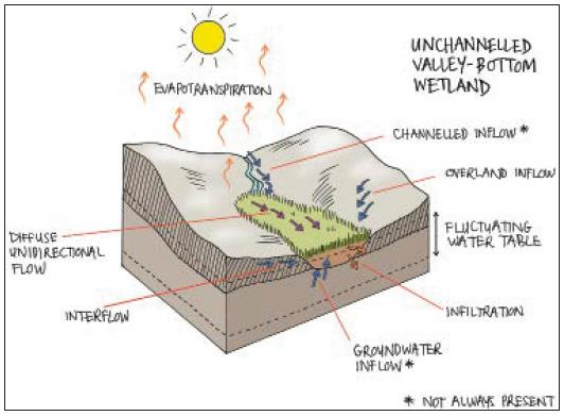


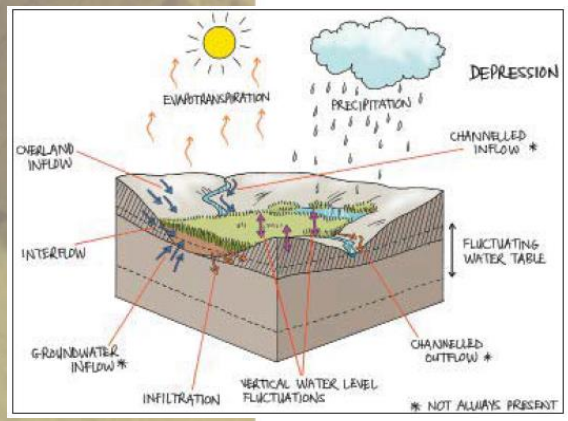
- Specific impacts/thresholds for individual priority wetlands to be investigated during the development of RQOs.

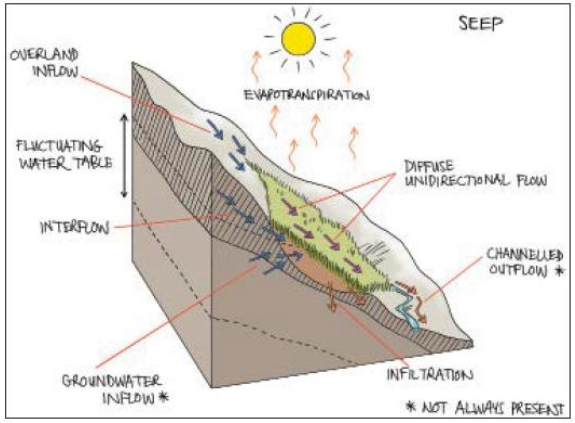
Identification of Priority Wetlands

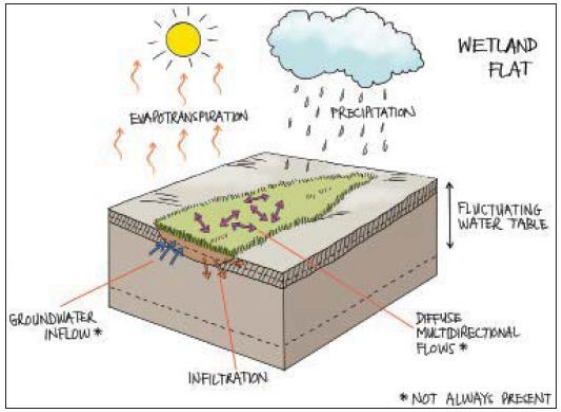








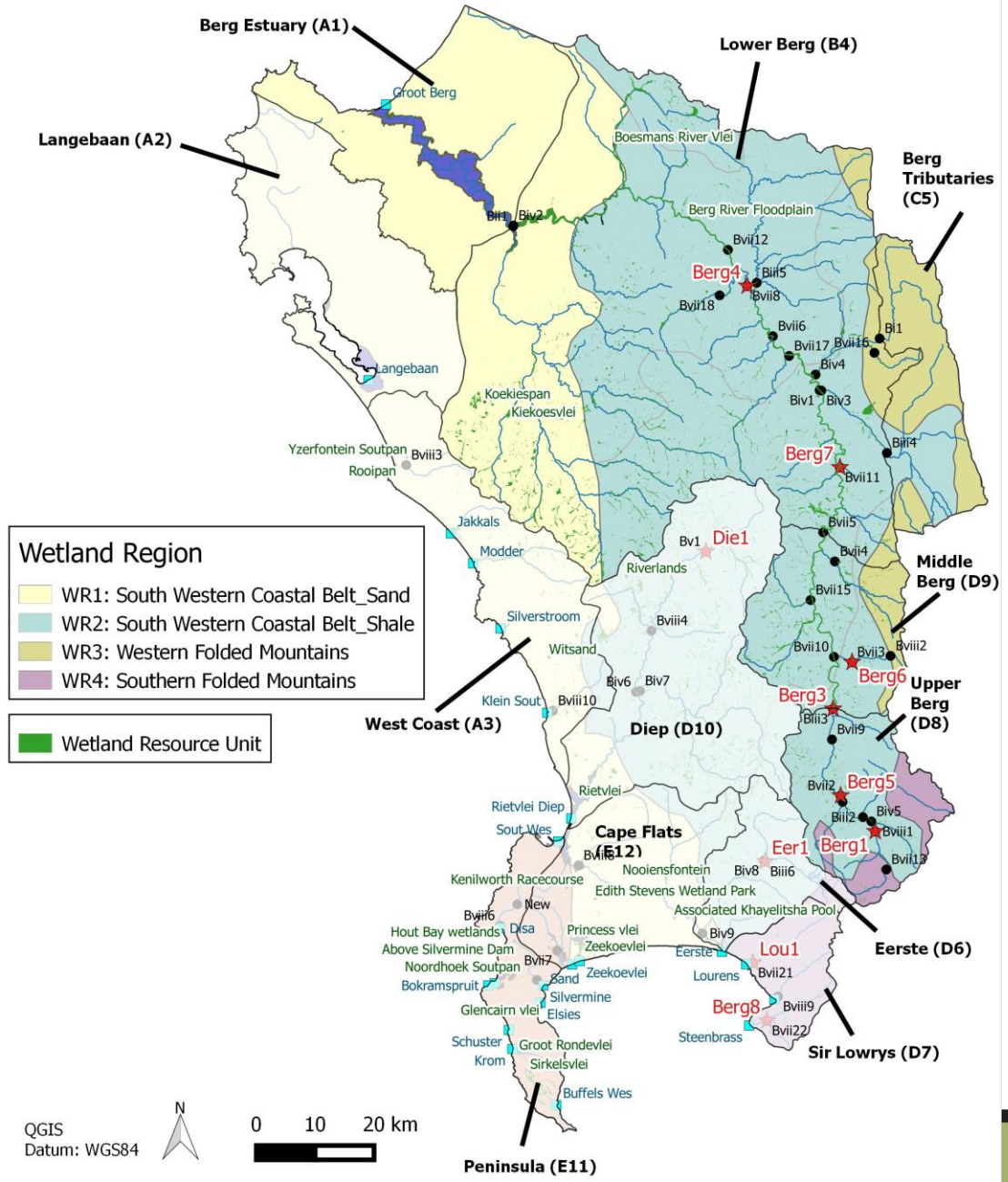




Surface/groundwater usage impacts

Indirect impacts

G1 Scenarios



Surface water usage impacts:

- Berg River Floodplain wetlands threatened by water abstraction due to reduction of flow in the future scenarios
- Climate change increases this impact

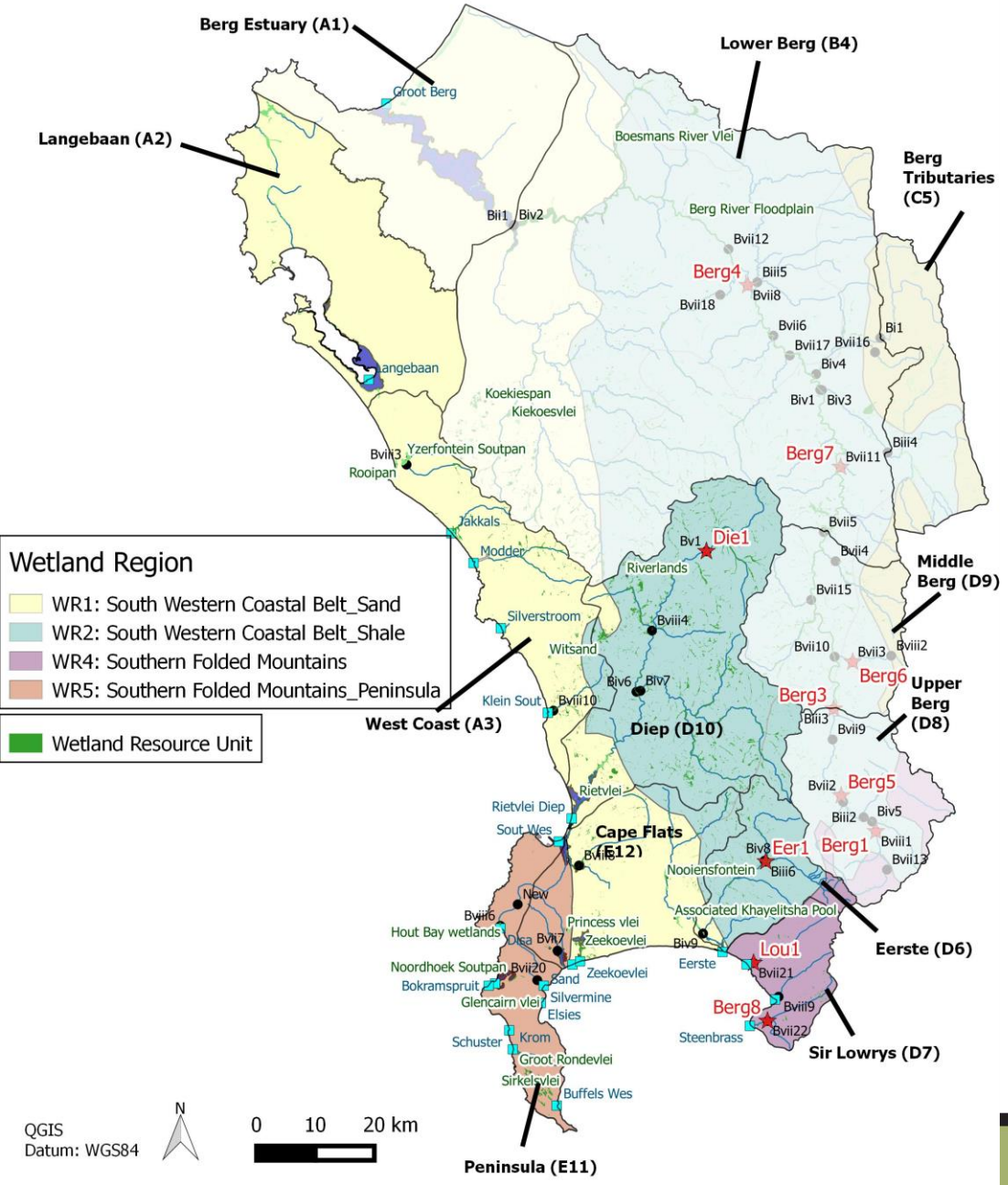
Groundwater usage impacts:

- Increased abstraction of Langebaan Road Wellfield impacts Berg River Floodplain
- Uncertain extent of impact to Geelbek wetlands due to Elandsfontein

Indirect impacts:

- Future scenarios with no catchment management results in transformation of wetland habitats, increased stormwater flow etc.
- Future scenarios with catchment management results in less transformation

G2 Scenarios



Surface water usage impacts:

- Wetlands associated with estuary scenarios
- Rietvlei floodplain wetlands need to maintain overtopping of banks
- Wildvoelvlei needs to maintain seasonality
- Zeekoevlei and Rondevlei need to maintain seasonality

Groundwater usage impacts:

- Currently seep and depression wetlands associated with the heavily used Atlantis and Malmesbury GRU may be impacted.
- Only hypothetical sites for Cape Flats, but in general use of the GRU would impact flat and depression wetlands by reducing seasonality

Indirect impacts:

- Increased hardened surfaces will increase stormwater flow to wetlands, and habitats may be transformed

Groundwater

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

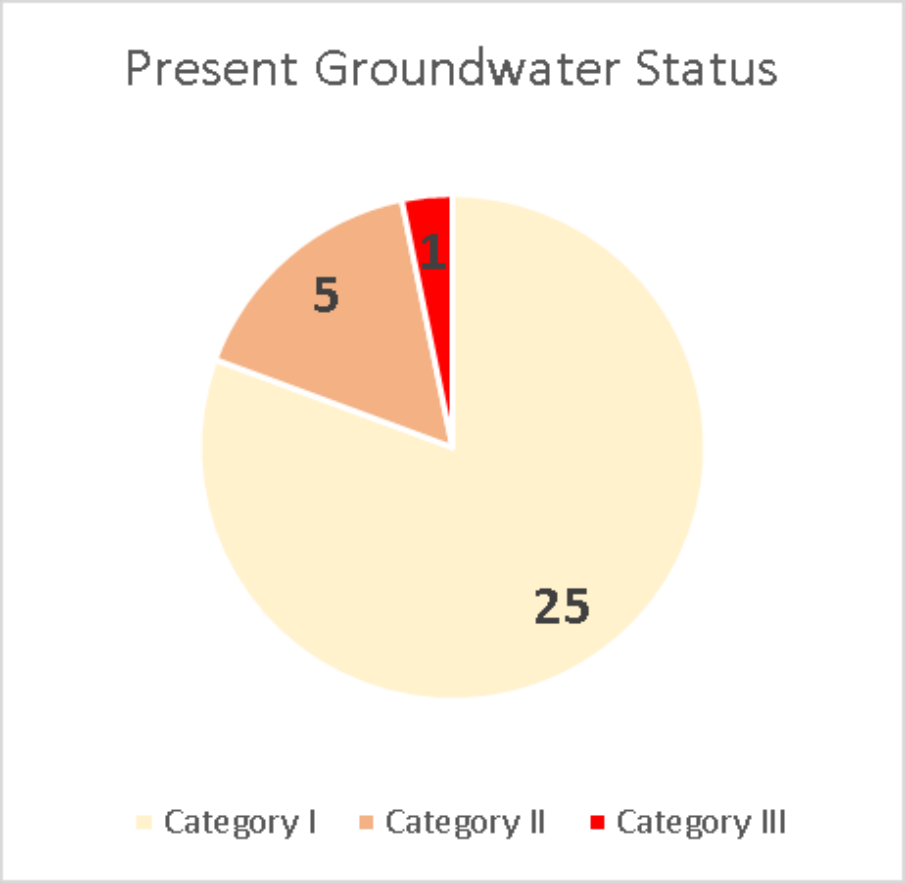
- Definition for groundwater status relates to alteration from pre-development state: informed by use/recharge ('stress') ratio
- Level of 'stress' used to determine the resulting groundwater status per water resources classification scenario, resulting from increases in groundwater use for future development,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

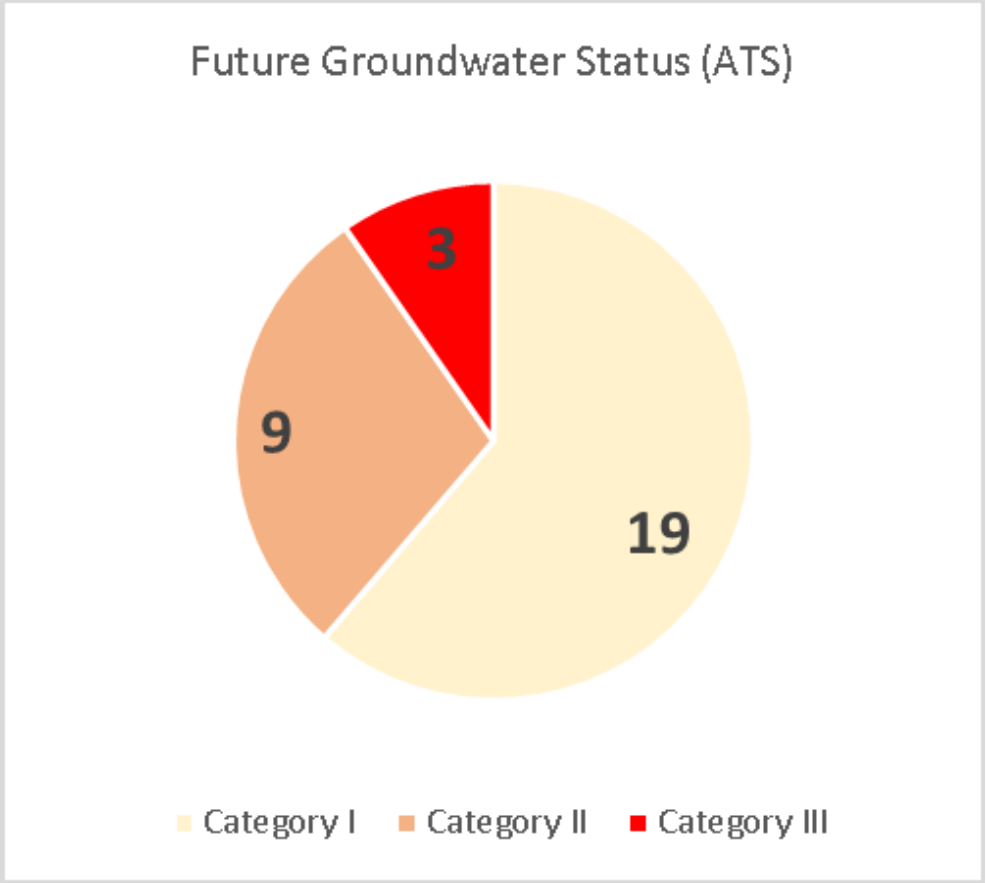
Groundwater Status Category		Generic Description	Use/ Recharge (Stress)
I	Minimally used	The water resource is minimally altered from its pre-development condition	≤20%
II	Moderately used	Localised low level impacts, but no negative effects apparent	20-65%
III	Heavily used	The water resource is significantly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

(modified from Dennis *et al*, 2013)

Scenario consequences on groundwater condition

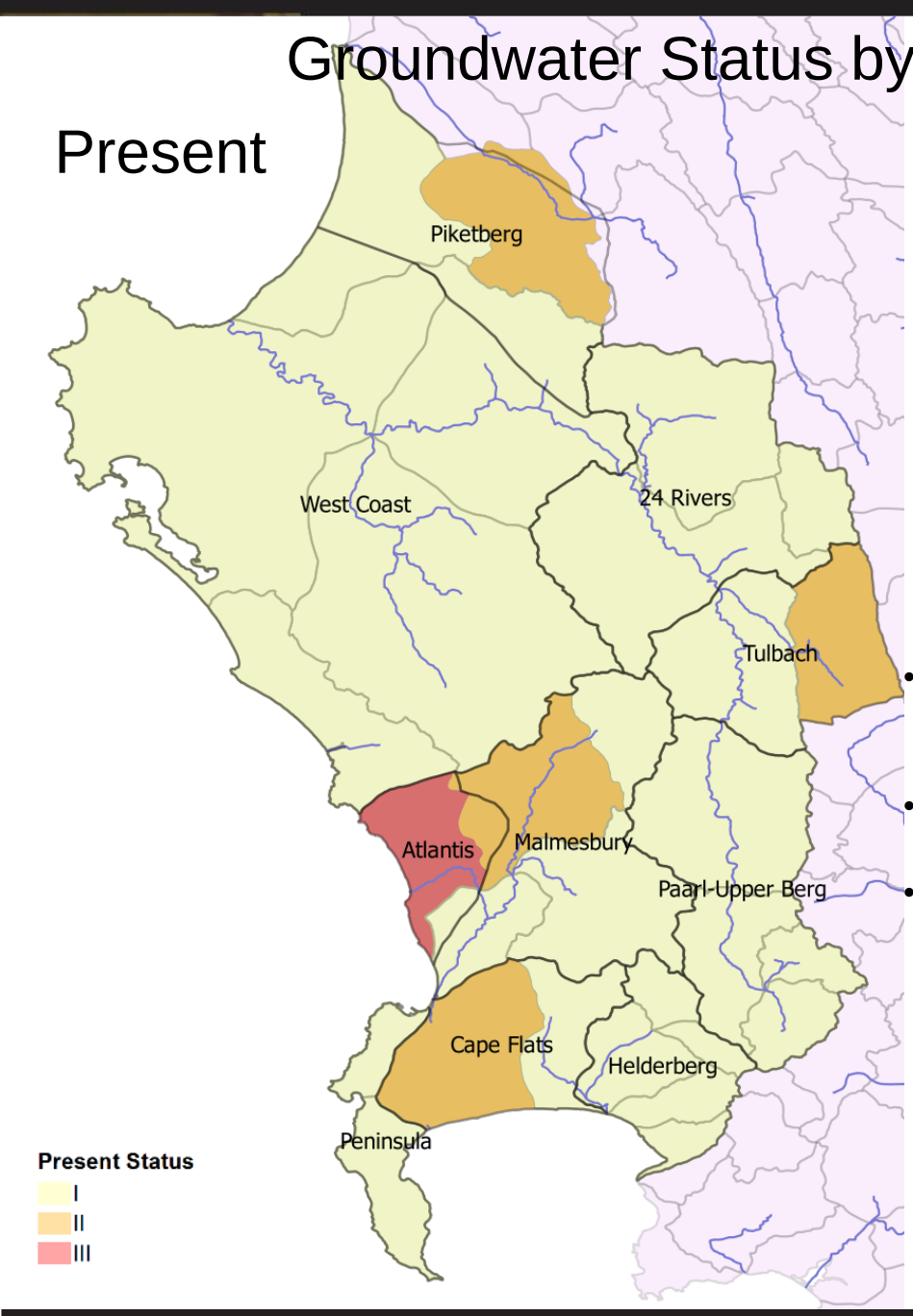
- Results: maximum impact of planned development according to All Towns water demand projections
- Groundwater use from 370 to 445 million m^3/a



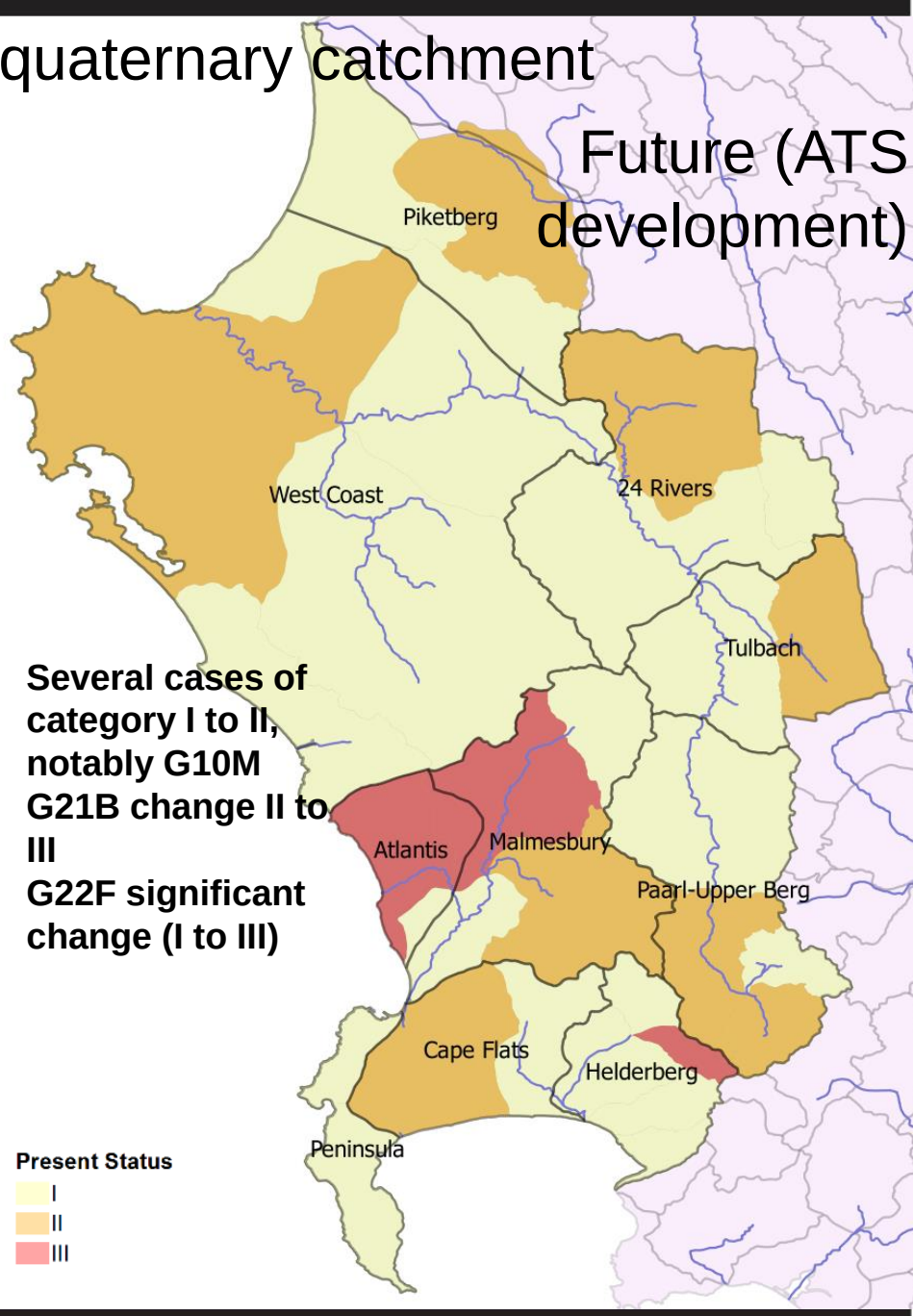


Groundwater Status by quaternary catchment

Present



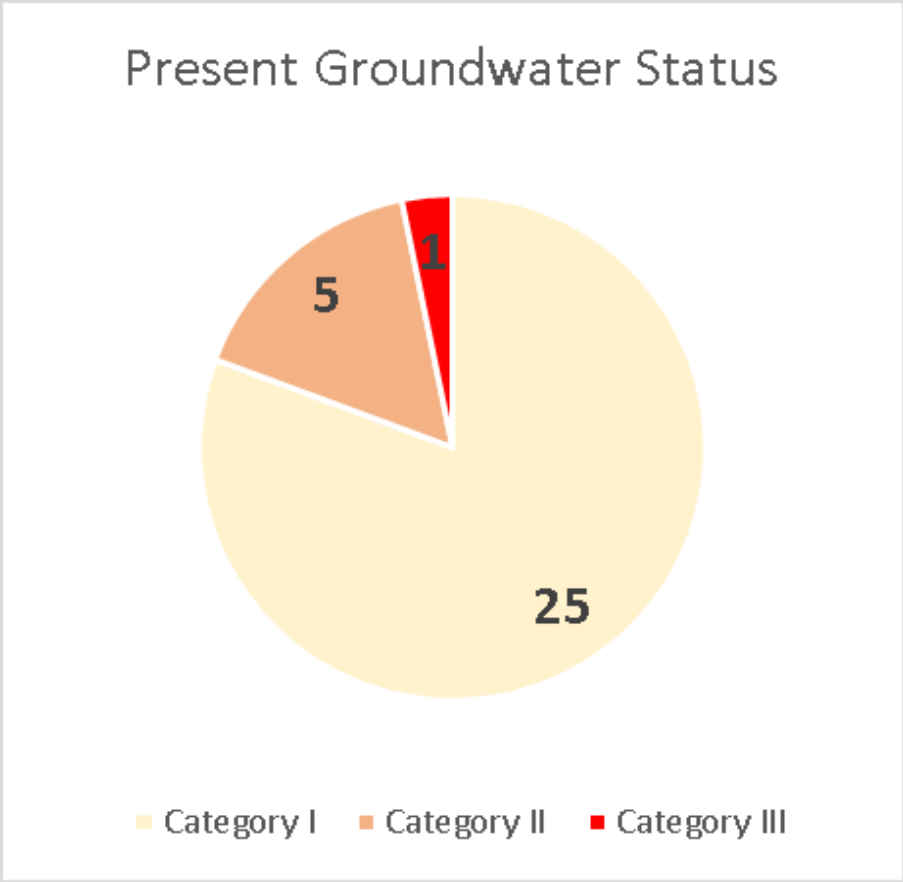
Future (ATS development)

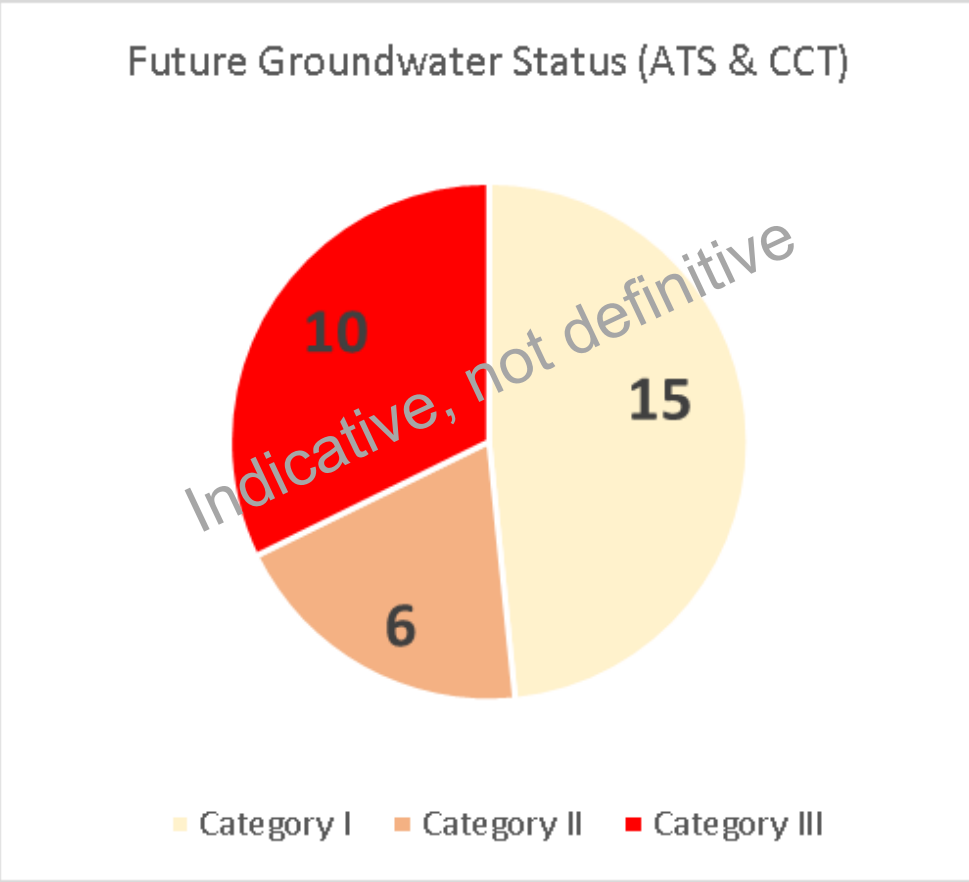


- **Several cases of category I to II, notably G10M**
- **G21B change II to III**
- **G22F significant change (I to III)**

Scenario consequences on groundwater condition

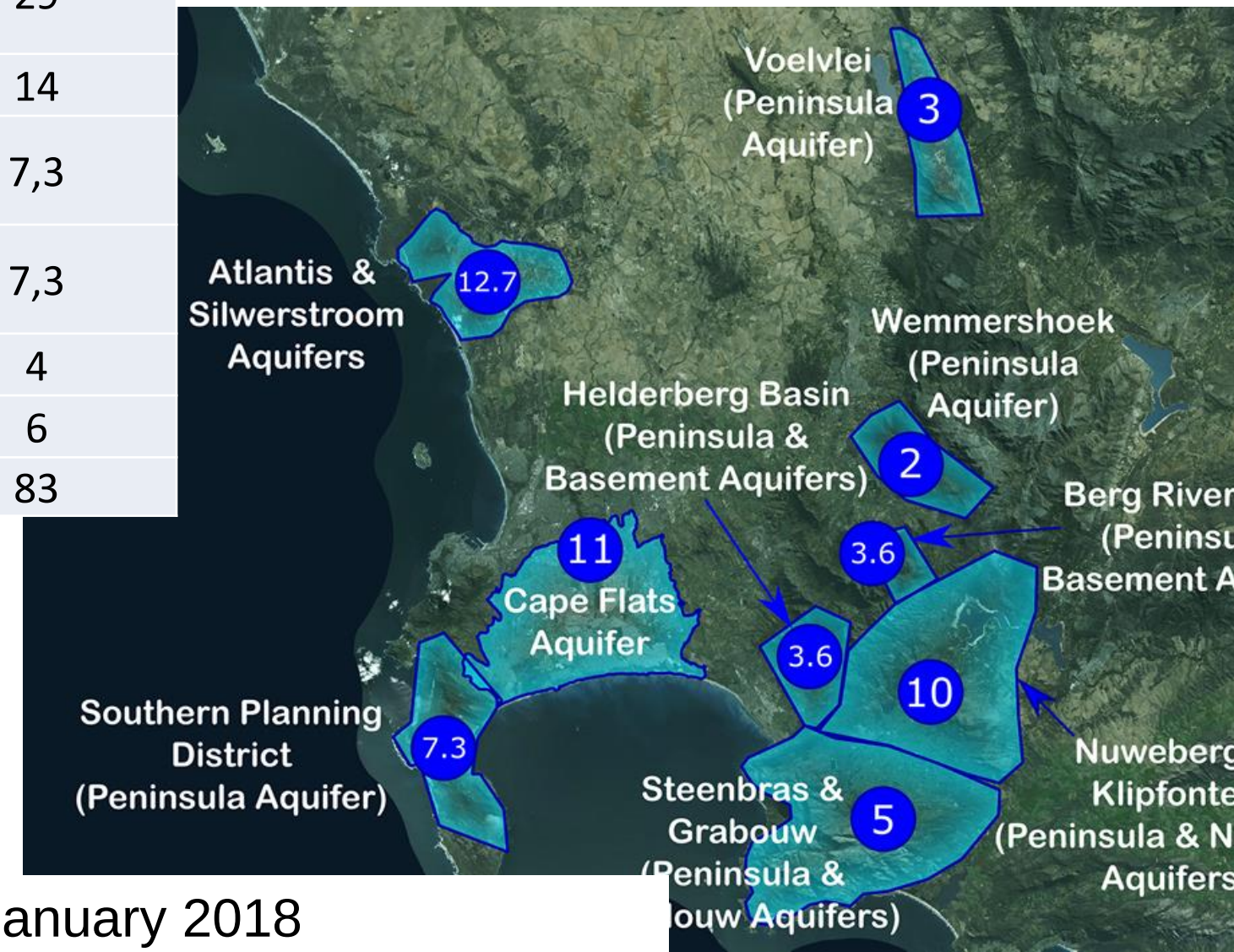
- Results: maximum impact of planned development according to All Towns water demand projections and CCT developments
- Groundwater use from 370 to 542 million m^3/a





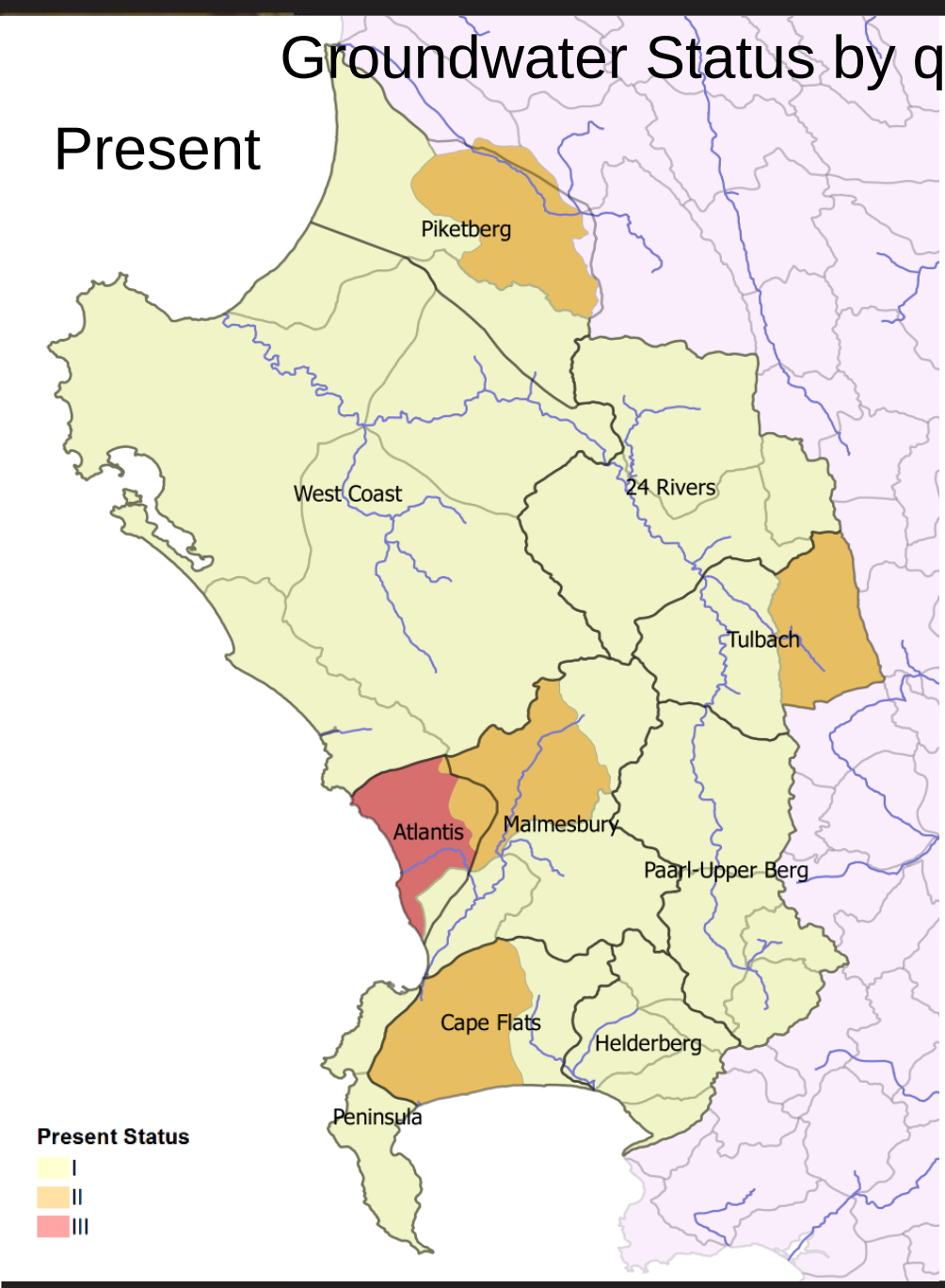
CCT GW use (Umvoto, 2018)

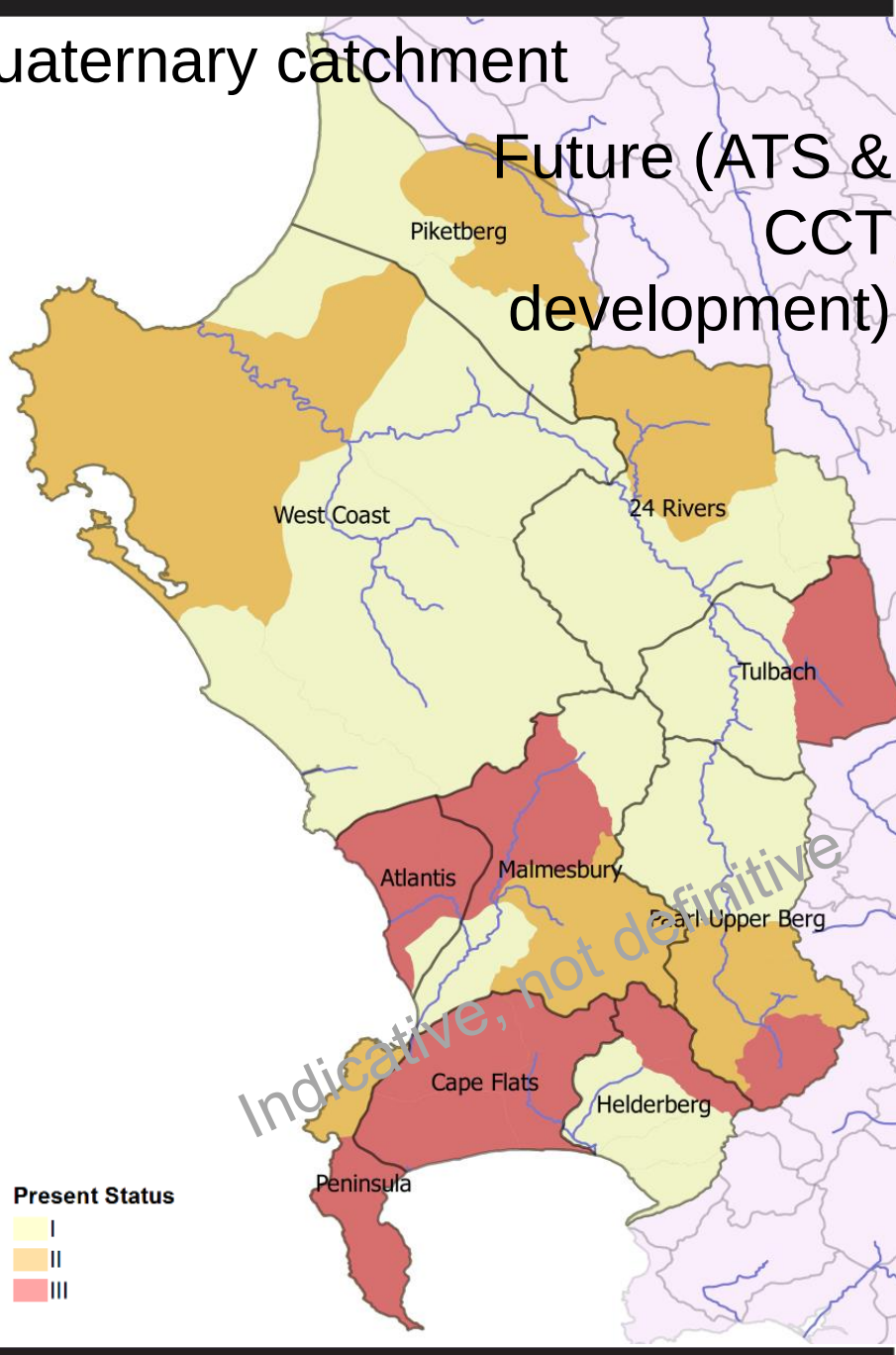
Project/Aquifer	Phase 3 (hm^3/a)
CFA	30
Atlantis & Silwerstroom	29
SPD	14
Helderberg Basin	7,3
Berg River Valley	7,3
Wemmershoek	4
Voelvlei	6
Total	83



From Umvoto, January 2018

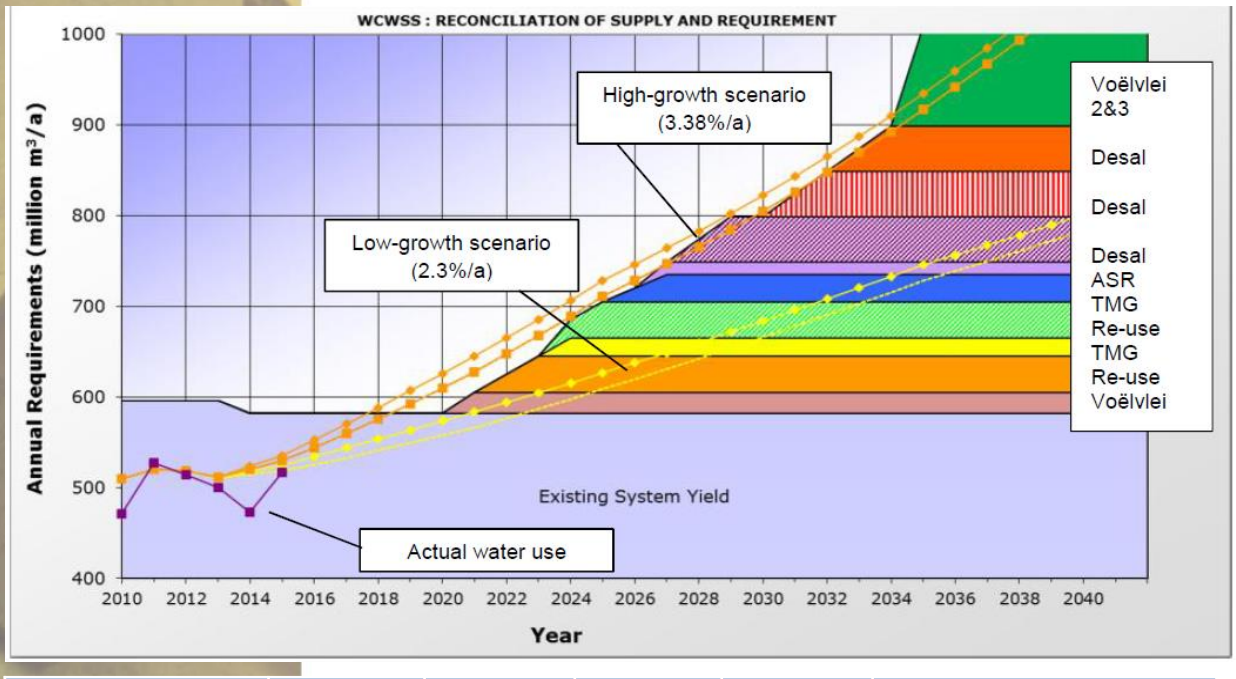
Groundwater Status by quaternary catchment





Impact on Water Availability and Yield

Current and Future Demands from the WCWSS



"Planning Scenario" of the WCWSS Reconciliation Strategy

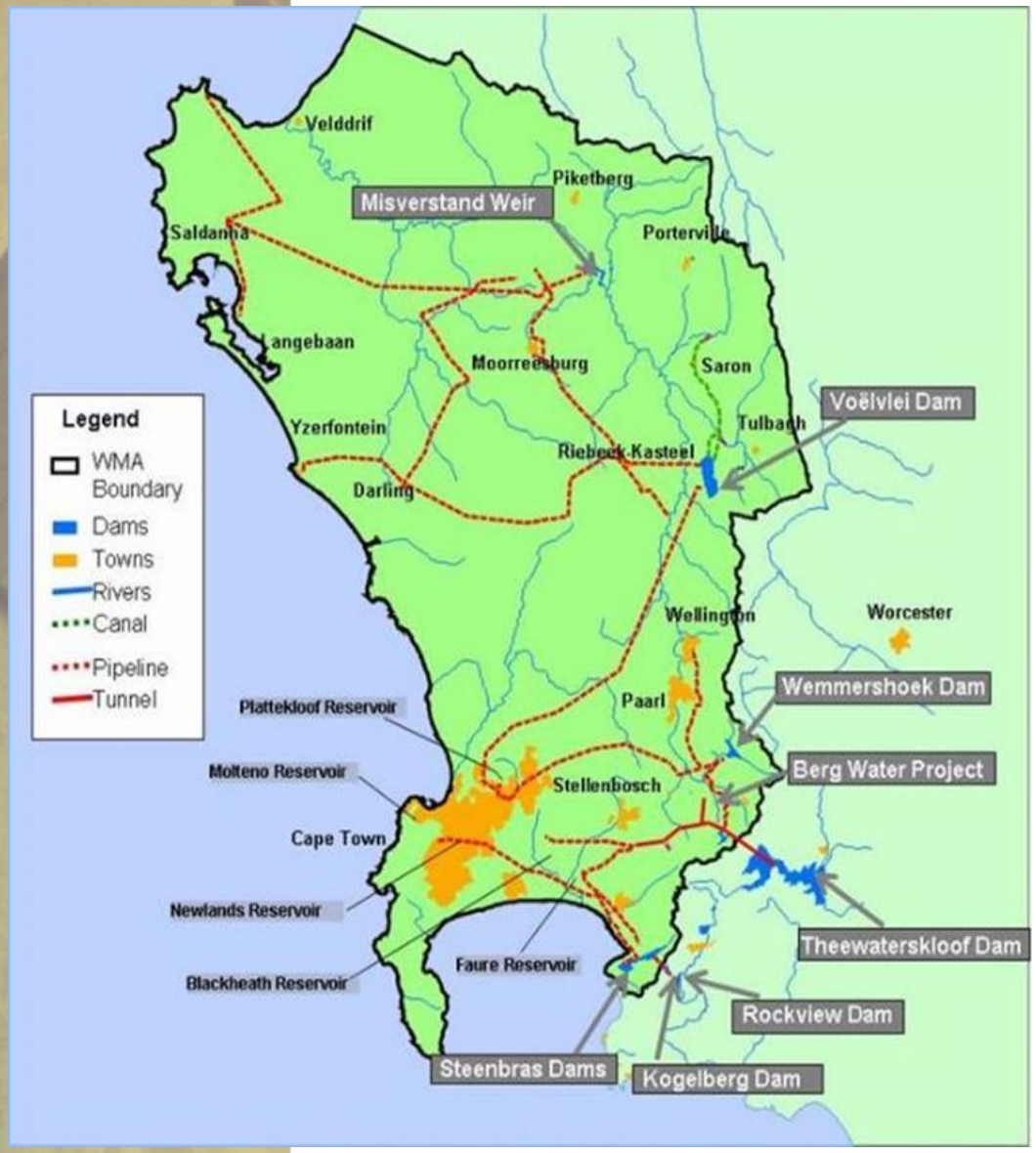
Bulk Water Supply Intervention	Yield (million m³/a)
Berg River-Voëlvlei Dam Diversion	23
Wastewater Re-Use - 1	40
TMG Aquifer - 1	20
Wastewater Re-Use - 2	40
TMG Aquifer - 2	30
West Coast Aquifer Recharge	14
Seawater Desalination - 1	50

New Bulk water supply interventions for WCWSS needed by 2039/40

Water Requirement Sector (million m³/a)	2017/18	2018/19	2019/20	2020/21	2039/40 Medium-Growth Urban (2.8%/a)
CoCT + Other Municipalities	193	210	275	330	560
Agriculture	93	110	135	190	210
Losses	11	12	14	20	20
Total	297	332	424	520	790

Progression of projected annual water requirements from 2017/17 to 2039/40

Model Configuration for WCWSS Scenarios



EWRs for River Nodes

EWR Site	Node	Name	PES	REC	ESBC
Berg1	Bviii1	Upper Berg River	C	C	D
Berg3	Bviii5	Lower Berg River	D	D	D
Berg4	Bvii8	Heuningberg, upstream of Misverstand Dam	D	D	D
Berg5	Bvii18	Nuwedrif, downstream of Misverstand Dam	D	D	D

Minimum flow at Estuary

- REC = 0.6 m^3/s
- ESBC = 0.5 m^3/s

Future Infrastructure:

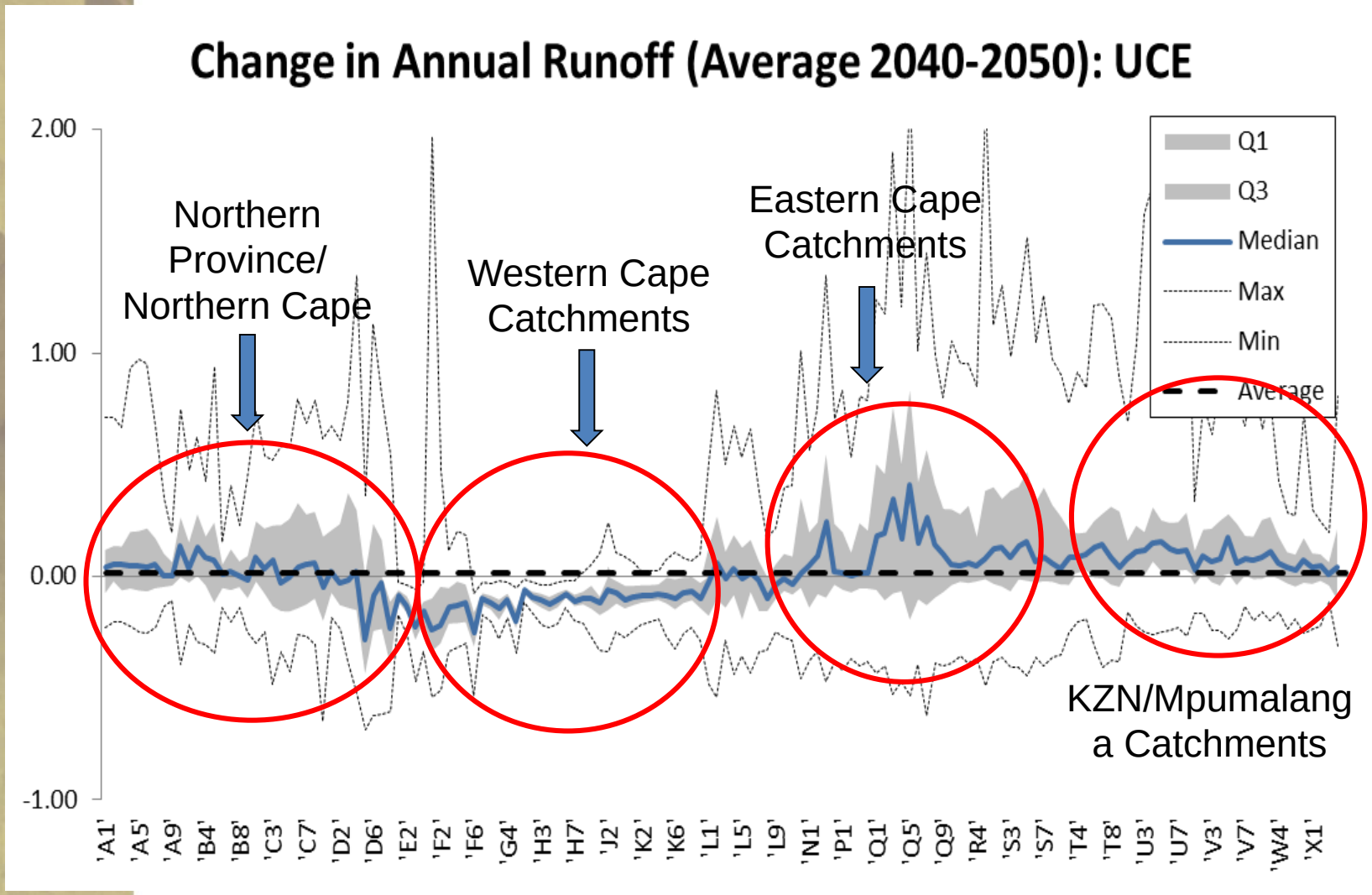
- Voëlvlei Augmentation Scheme
- West Coast Managed Aquifer Recharge
- Fully utilised WWTW return flows

Hydrology:

- Current (1920 to 2004)
- Climate change impacts by 2040 (10^{th} percentile dry scenario)

Result = Firm Yield of System

Climate Change Impacts (Cullis et al.2015)



Range of potential impacts on MAR for Secondary Catchments for the Unconstrained Emissions Scenario (UCE) (Cullis et al 2015)

Scenario Results for WCWSS and Berg River Estuary

Scenario Name	Summer lowflow requirement at the estuary (m^3s^{-1})	Historic Firm Yield (Million.m^3)	Change in Historic Firm Yield from baseline (Million.m^3)	Estuary MAR (1928-2004) (Million.m^3)	Percentage of natural MAR reaching estuary
Current Infrastructure Development Scenarios - WCWSS					
Scenario 1 (PES)	0.5	535	0	464	50%
Scenario 2 (ESBC)	0.5	469	-84	545	58%
Scenario 3 (REC)	0.6	466	-87	551	59%
Future (2040) Scenarios – WCWSS + Voelvlei Augmentation, West Coast Managed Aquifer Recharge, and full reuse of WWTWs					
Scenario 4 (ESBC-FI)	0.5	679	0	552	56%
Scenario 5 (REC-FI)	0.6	674	- 5	528	57%
Scenario 6 (No EC-FI)	0.0	775	+ 96	415	45%
Future (2040) Infrastructure Development Scenarios including Climate Change impacts on hydrology					
Scenario 7 (ESBC-CC)	0.5	599	- 80	442	47%
Scenario 8 (REC-CC)	0.6	596	- 83	447	48%
Scenario 9 (No EC-CC)	0.0	716	+ 37	299	32%

Ecosystem Goods, Services and Attributes

Main ecosystem services used in analysis

Category of service	Types of values	Description of EGSA	Independent variables related to estuary condition
Goods (Provisioning services) 	Subsistence fishing	Invertebrates and fish collected on a subsistence basis for consumption or bait	Invertebrate abundance Freshwater fish abundance Estuary line- and net fish abundance
Services (Regulating services) 	Nursery value	Contribution to marine fish catches due to the nursery habitat provided by estuaries	Abundance of estuary-dependent marine fish
Attributes (Cultural services) 	Tourism value & property value	A river, wetland or estuary's contribution to recreation/tourism appeal of a location	Overall health Line fish abundance Water quality

Impact on EGSAs: Berg River Estuary for Different Scenarios

Scenario	Ecological Condition of the estuary (Current WQ)	Sub-sistence Fishing	Nursery Value	Tourism value & property value	Property value (estuary premium, annualised)	Total	NPV change in EGSAs (R million)
Sc 1 (PES)	C	0.2	8.1	31.1	11.0	50.4	0.0
Sc 2 (ESBC)	B/C	0.3	8.9	32.7	11.0	52.8	42.3
Sc 3 (REC)	B/C	0.3	8.9	32.7	11.0	52.8	42.3
Sc 4 (ESBC-FI)	DC	0.2	8.1	31.1	11.0	50.4	0.0
Sc 5 (REC-FI)	C	0.2	8.1	31.1	11.0	50.4	0.0
Sc 6 (No EC-FI)	C/D	0.2	6.9	29.5	9.4	46.0	-78.9
Sc 7 (ESBC-CC)	C	0.2	8.1	31.1	11.0	50.4	0.0
Sc 8 (REC-CC)	C	0.2	8.1	31.1	11.0	50.4	0.0
Sc 9 (No EC-CC)	D	0.2	5.7	28.0	7.7	41.5	-157.7

Net present value (NPV) of the change in the EGSAs value for the REC (from PES) (NPV: 30 years @ 6% discount rate)

Impact on EGSAs: G2 Catchments (REC scenario)

ESTUARY	Property Value (R million/a)	Tourism Value (R million/a)	Total Value (R million/a)	PES	REC	Change in Value	Change in Total EGSA Value (R million/a)	NPV of Change in EGSAs (R million)
Langebaan	26.99	136.6	163.59	A	A	1	0.0	0.0
Rietvlei/ Diep	32.71	62.4	95.11	D	D	1	0.0	0.0
Wildevoël-vlei	0.19	29.6	29.79	D	D	1	0.0	0.0
Sand	4.74	98.5	103.24	D	C	1.4	41.3	731.2
Zeekoe	1.62	8.2	9.82	E	D	1.8	7.9	139.1
Eerste	1.76	8.9	10.66	E	D	1.8	8.5	151.0
Lourens	0.50	33	33.50	D	D	1	0.0	0.0
TOTAL	**39.81**	**377.2**	**445.71**				**57.7**	**1 021.3**

Net present value (NPV) of the change in the EGSAs value for the REC (from PES) (NPV: 30 years @ 6% discount rate)

Overall Economic Cost/Benefit of Scenarios

Overall Net Economic Costs/Benefits: G1 Catchments

Net Economic Benefit for Berg River (WCWSS) Scenarios.

By 2040 it is assumed that the only viable additional water supply option will be desalination of seawater (ultimate marginal cost).

Estimated capital cost for additional water supply = **R18 / m³**

NPV of EGSA calculated over 20 years with 6% annual increase.

Classification scenario	NPV of water supply costs without/with CC R millions	NPV of EGSA direct value changes R millions
PES to No EC		- 48.7 to - 97.5
ESBC	0 – 6,190	+18.5
REC	432 – 7,170	+18.5

Overall Net Economic Costs/Benefits: G2 Catchments

Overall Net Economic Benefit of proposed REC scenario for the significant estuaries and IUAs in the G2 catchments.

NPV of EGSA benefits for Estuaries in REC = **R 1 021 million**

Cost saving from increase re-use of water (22 million m^3/a) as compared to alternative (i.e. desalination) = **R 110 million**

Infrastructure costs to meet dry-season shortfalls = **- R 31 million**

Net economic benefit of REC scenario (G2) = **+ R 1 100 million**

Recommended Water Resource Classes

Determining the Water Resource Class

Description of the meaning for each Water Resource Class

Water Resource Class	Description
Class I	Minimally used
Class II	Moderately used
Class III	Heavily used

Guidelines for determining the IUA class based on ecological condition

	Percentage (%) of nodes in the IUA falling into the indicated groups				
	A or A/B	B or B/C	C or C/D	D	< D
Class I	60	40	20	1	-
Class II		60	30	5	-
Class III Either:			70	20	-

Comparison of Scenarios – Water Resource Classes

IUA Name	IUA Code	PES	Future ESBC	Future REC	Future No-EC	Future Climate Change ESBC	Future Climate Change REC	Future Climate Change No EC
Berg Estuary	A1	II	III	II	III	III	II	III
Langebaan	A2	II	III	II	III	III	II	III
West Coast	A3	III	III	III	III	III	III	III
Lower Berg	B4	III	III	III	III	III	III	III
Berg Tributaries	C5	II	III	II	III	III	II	III
Eerste	D6	III	III	III	III	III	III	III
Sir Lowry's	D7	III	III	III	III	III	III	III
Upper Berg	D8	III	III	III	III	III	III	III
Middle Berg	D9	III	III	III	III	III	III	III
Diep	D10	III	III	III	III	III	III	III
Peninsula	E11	II	III	II	III	III	II	III
Cape Flats	E12	III	III	III	III	III	III	III

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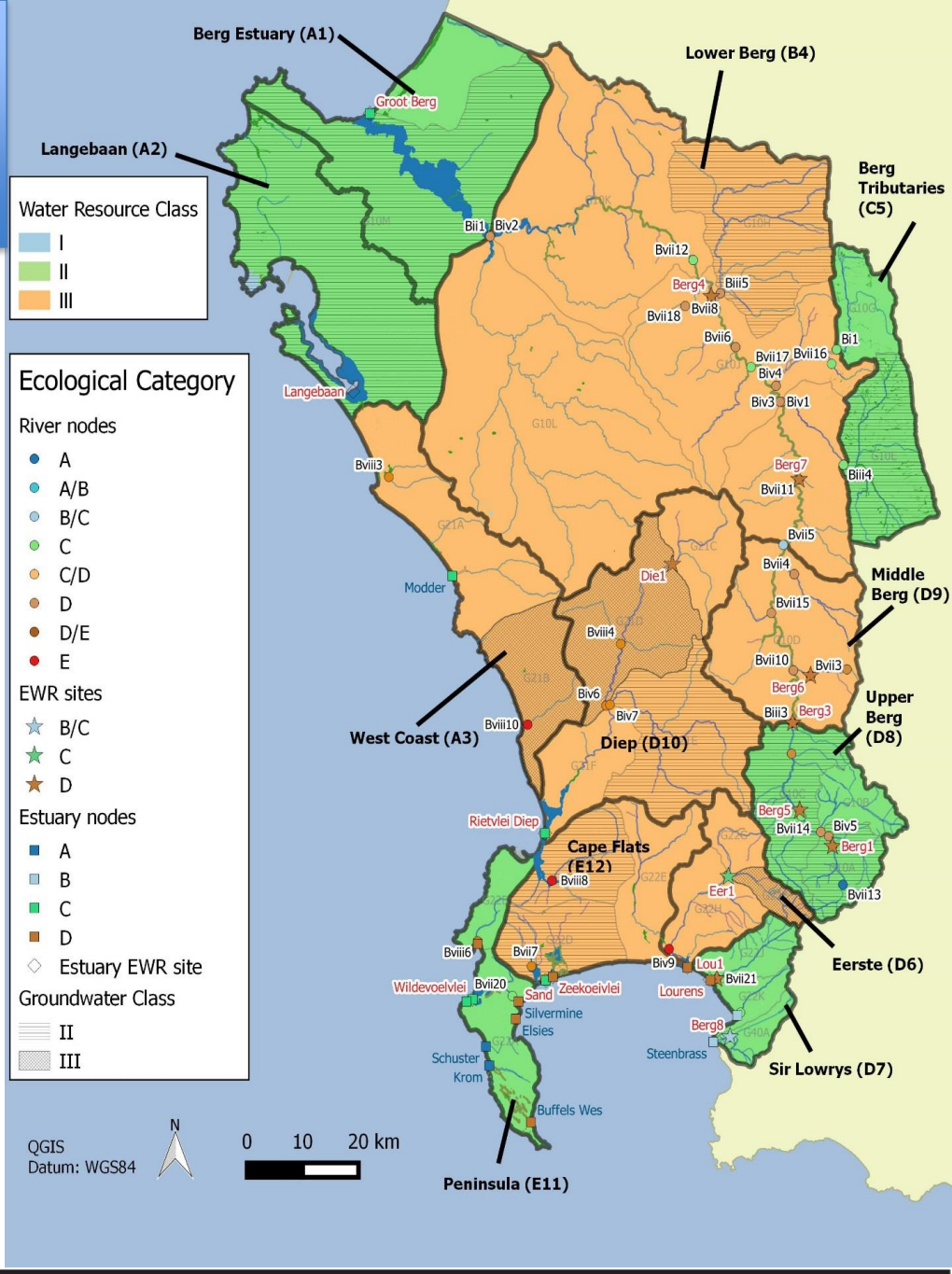
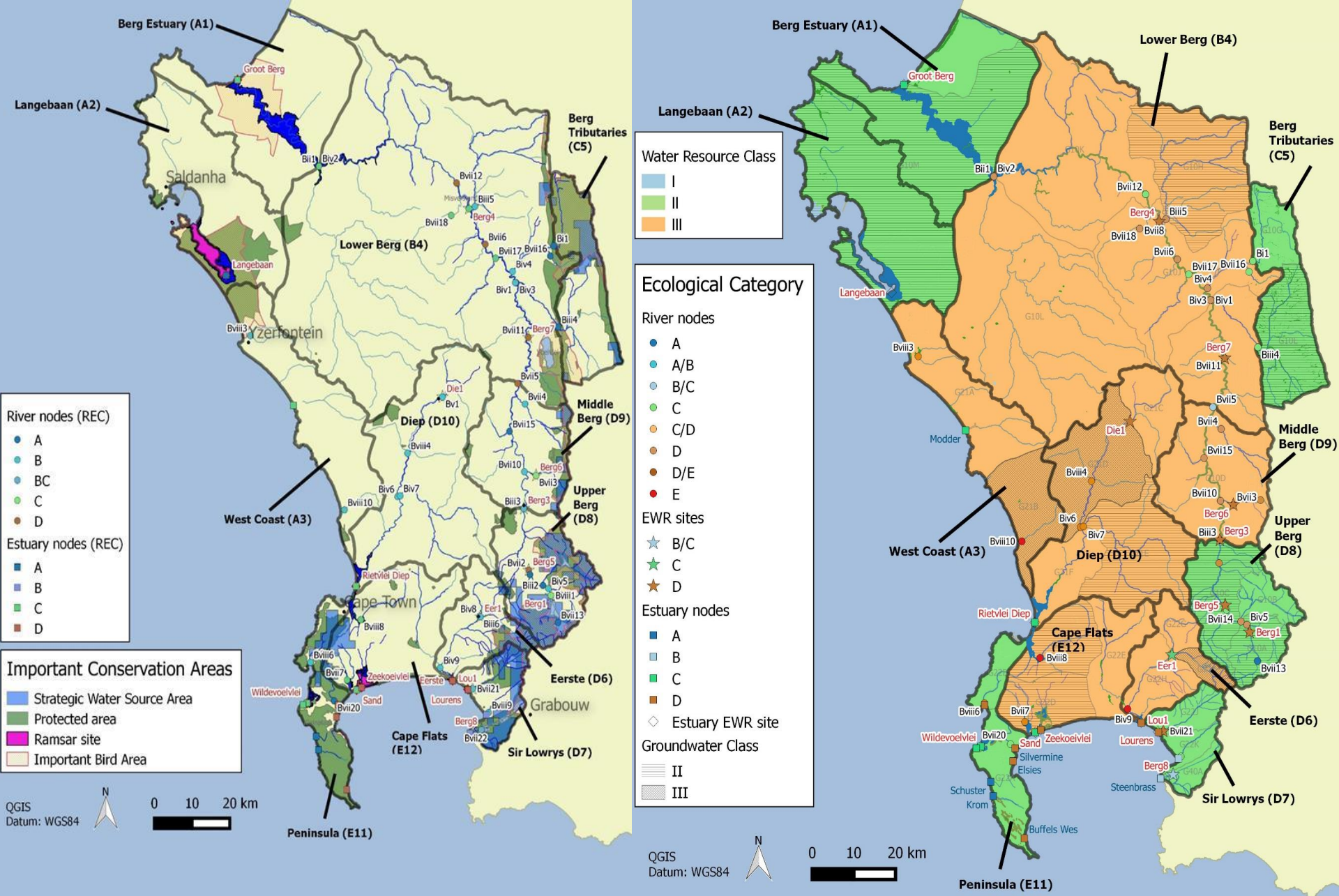
Water Resource Classes for the Berg Catchment

IUA Name	IUA Code	Recommended Class
Berg Estuary	A1	II
Langebaan	A2	II
West Coast	A3	III
Lower Berg	B4	III
Berg Tributaries	C5	II
Eerste	D6	III
Sir Lowry's	D7	II
Upper Berg	D8	III
Middle Berg	D9	III
Diep	D10	III
Peninsula	E11	II
Cape Flats	E12	III





Management Considerations for Water Resource Classes

Discussion

Estuary Scenarios (G2)

Impact on Ecosystem Health and Biodiversity: G2 Catchments

Zeekoevlei Estuary

Scenario name	Description	MAR* (million m^3/a)	Percentage of natural flows	Effluent from Cape Flats WWTW (million m^3/a)
Natural	Reference condition	18.36	100%	-
Present	Present day flows	17.14	93%	42.49
Scenario 1	Scenario 1 (Present flow, Treat effluent from WWTW to Special Standards)	17.14	93%	42.49
Scenario 2	Scenario 2 (50% reduction in vol of WWTW inputs, treat remainder to Special standards)	17.14	93%	21.25
Scenario 3	Scenario 3 (75% reduction in vol of WWTW inputs, treat remainder to Special standards)	17.14	93%	10.62
Scenario 4	Scenario 4 (Divert/recycle 100% of effluent from WWTW)	17.14	93%	-
Scenario 5	Scenario 5 Flows as for Sc 1 but facilitate access by marine and estuarine fish into Zeekoevlei and Rondevlei through construction of a fish ladder	17.14	93%	42.49
Scenario 6	Scenario 6 Flows as for Sc 4 but facilitate access by marine and estuarine fish into Zeekoevlei and Rondevlei through construction of a fish ladder	17.14	93%	-

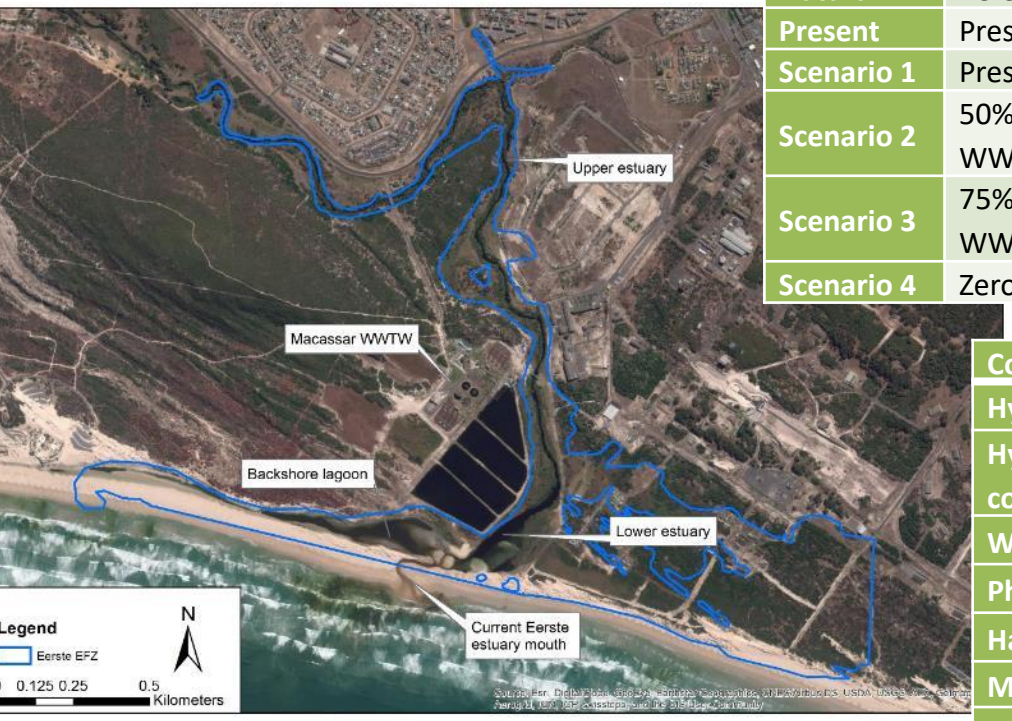
Impact on Ecosystem Health and Biodiversity: G2 Catchments

Zeekoevlei Estuary

Component	Present	Sc1	Sc2	Sc3	Sc4	Sc 5	Sc 6
Hydrology	51	51	82	89	93	51	93
Hydrodynamics and mouth condition	20	20	20	20	10	20	10
Water quality	24	22	25	25	26	22	26
Physical habitat alteration	10	10	10	10	10	10	10
Habitat health score	26	26	34	36	35	26	35
Microalgae	25	25	25	25	35	25	35
Macrophytes	25	25	25	25	35	25	35
Invertebrates	10	10	10	10	11	10	11
Fish	5	5	10	20	25	5	30
Birds	52	52	52	52	52	55	65
Biotic health score	23	23	24	26	32	24	35
Estuary Health Score	25	25	29	31	33	25	35
Ecological Category	E	E	E	E	E	E	E

Impact on Ecosystem Health and Biodiversity: G2 Catchments

Eerste River Estuary

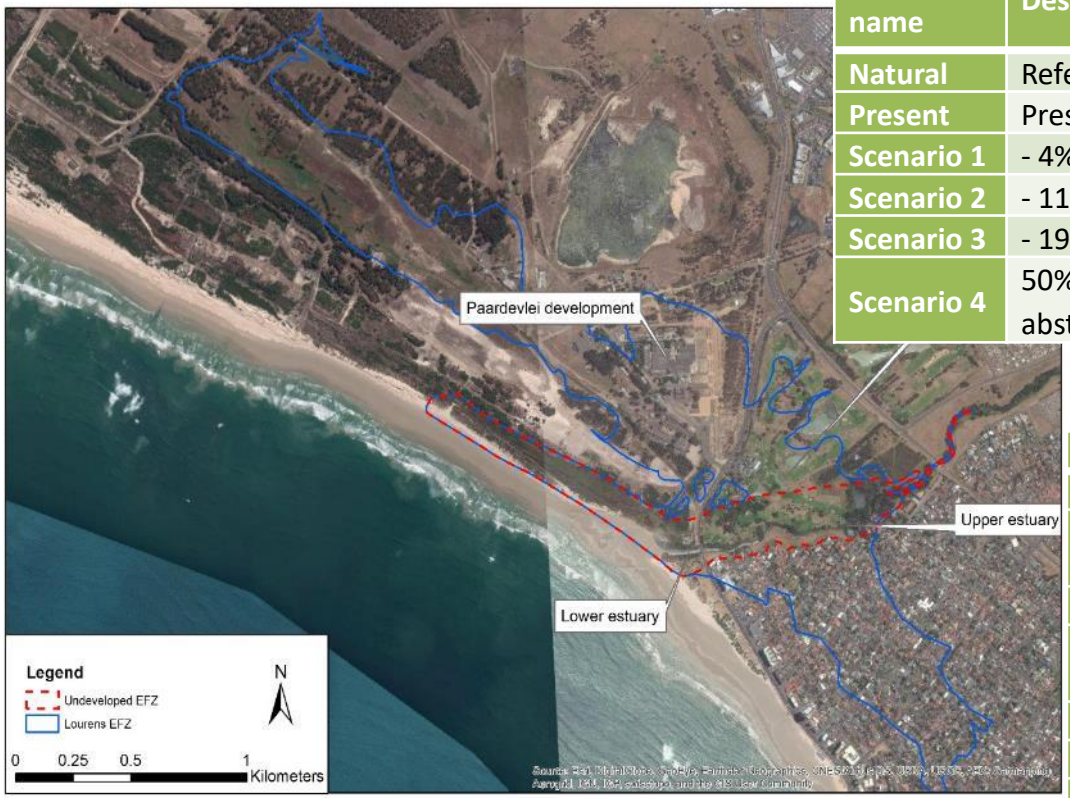


Scenario name	Description	MAR (million m³/a)	Percentage of natural flows
Natural	Reference condition	114.81	100%
Present	Present day flows	176.45	154%
Scenario 1	Present day flows	176.45	154%
Scenario 2	50% reduction in contribution from WWTW	138.95	121%
Scenario 3	75% reduction in contribution from WWTW	119.39	104%
Scenario 4	Zero input from WWTW	101.44	88%

Component	Present	Sc1	Sc2	Sc3	Sc4
Hydrology	35	35	39	43	40
Hydrodynamics and mouth condition	74	74	80	80	89
Water quality	21	26	30	33	42
Physical habitat alteration	30	30	30	30	30
Habitat health score	40	41	45	46	50
Microalgae	25	25	30	30	35
Macrophytes	35	35	40	40	45
Invertebrates	10	10	15	20	25
Fish	5	5	20	50	50
Birds	65	65	70	75	75
Biotic health score	28	28	35	43	46
Estuary Health Score	34	35	40	45	48
Ecological Category	E	E	E	D	D

Impact on Ecosystem Health and Biodiversity: G2 Catchments

Lourens River Estuary



Scenario name	Description	MAR (millio m^3/a)	Percentage of natural flows
Natural	Reference condition	70.027	100%
Present	Present day conditions	59.221	85%
Scenario 1	- 4% from Present	56.793	81%
Scenario 2	- 11% from Present	52.887	76%
Scenario 3	- 19% from Present	47.769	68%
Scenario 4	50% reduction in abstraction from present	64.621	92%

Component	Present	Sc1	Sc2	Sc3	Sc4
Hydrology	85	81	76	68	92
Hydrodynamics and mouth condition	76	69	57	51	90
Water quality	53	52	51	50	58
Physical habitat alteration	30	30	25	20	30
Habitat health score	61	58	52	47	67
Microalgae	45	45	45	40	65
Macrophytes	25	25	25	20	35
Invertebrates	39	36	34	25	45
Fish	40	40	40	30	65
Birds	53	50	48	45	65
Biotic health score	40	39	38	32	55
Estuary Health Score	51	49	45	40	61
Ecological Category	D	D	D	E	C