Determination of Water Resources Classes and Associated Resource Quality Objectives in the Berg Catchment

October 2017

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Ecological Sustainable Base Configuration Scenario Report

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Reports that will be produced as part of this Study are indicated below.

Bold type indicates this report

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1	RDM/WMA9/00/CON/CLA/0116	Inception Report
2	RDM/WMA9/00/CON/CLA/0216	Stakeholder Identification and Mapping
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4	RDM/WMA9/00/CON/CLA/0416	Resource Units and IUA Delineation
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8	**RDM/WMA9/00/CON/CLA/0317**	**Ecological Base Configuration Scenarios**
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16	RDM/WMA9/00/CON/CLA/0618	Draft Project Close Out Report
17	RDM/WMA9/00/CON/CLA/0718	Final Project Close Out Report.

List of Abbreviations

1999EC	Ecological Condition 1999
2014EC	Baseline Ecological Condition 2014
CD: WE	Chief Directorate: Water Ecosystems
DAFF	Department of Agriculture, Forestry and Fisheries
DWA	(Previous) Department of Water Affairs
DWAF	(Previous) Department of Water Affairs
DWS	Department of Water and Sanitation
EC	Ecological Category
EGSA	Ecological goods, services and attributes
EIS	Ecological importance and sensitivity
ER	Ecoregion
ES	Ecological Sensitivity
ESBC	Ecologically sustainable base configuration scenario
EWR	Ecological water requirements
HGM	Hydrogeomorphic Unit
IUA	Integrated Unit of Analysis
Lati	Latitude
Long	Longitude
MAR	Mean annual runoff
NFEPA	National Freshwater Ecosystem Priority Areas
nMAR	natural Mean Annual Runoff
NWA	National Water Act
NWRCS	National Water Resources Classification System
PES	Present Ecological Status
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RI	Recurrence Interval
SQ	Sub-quat
TMG	Table Mountain Group
U	unclassified
WARMS	Water Authorisation Registration and Management System
WC/WDM	Water conservation and water demand management
WRCS	Water Resource Classification System
WR2012	Water Resources of South Africa 2012
WMA	Water Management Area
WRU	Wetland resource unit

Executive Summary

INTRODUCTION

The Chief Directorate: Water Ecosystems of the Department of Water and Sanitation (DWS) has commissioned a study to determine Water Resource Classes and associated Resource Quality Objectives (RQOs) for all significant water resources in the Berg Catchment.

In terms of the deliverables required for the water resource class determination phase of this study, the following separate (but linked) reports will be required, of which this is the third:

1. Linking the Value and Condition of the Resource report
2. Quantification of the EWR and changes in ecological EGSAs
3. **Ecological Base Configuration Scenarios report**
4. Evaluation of Classification Scenarios report

This report is a sub-set (Step 4a) of the fourth step of the classification procedure as prescribed by DWS (DWAF, 2007). The objective of Step 4a is to set up the Ecologically Sustainable Base Configuration (ESBC) scenario and to develop a tool (pre-yield model tool, called the **basin configuration tool** in this report) used to evaluate a range of scenarios to be considered in terms of determining the recommended water resource classification. The ESBC scenario considers the minimum environmental flow at the river nodes that sustains the lowest acceptable D-conditions for water resources basin-wide.

The scenarios framework, including the ESBC scenario, was first described in the Linking Value and Condition of Water Resource report and have been refined as shown in Table E1.

Table E1. Description of configuration scenarios

#	Scenario	Abbreviation	Description
1	Maintain Present Ecological Status (“Baseline”)	PES	River, wetland and estuary systems are maintained in their present condition, or where currently in an E or F, improved to a D as far as possible. The implications for water supply are tested under both: (a) the current level of economic development and (b) projected demands under a high growth scenario
2	Ecologically Sustainable Base Configuration (ESBC) Scenario (also called the “Bottom-line” Scenario)	ESBC	The maximum volume of water is made available for abstraction from the system for economic activities, with the provision that all water resources are just maintained in a D category (the ecological “bottom line”). The implications for water supply are tested under both: (a) the current level of economic development and (b) projected demands under a high growth scenario
3	Recommended Ecological Categories (RECs)	REC	The RECs determined for rivers, wetlands and estuaries based on present health and conservation importance (but without any consideration of socio-economic effects) are applied in this scenario. The implications for water supply are tested under both (a) the current level of economic development and (b) projected demands under a high growth scenario

#	Scenario	Abbreviation	Description
4	High future demands	High Dev	This development-focussed scenario presents the situation where the water demand for the future level of economic development (assuming high growth in future water demands) are met. The resulting ecological categories are not constrained and may result in ECs of worse than a D category.
6	Climate change (10%)	CC(10)	The shifts that climate change might cause to the ecological conditions of nodes across the Study Area was assessed by modelling catchment streamflow changes relative to current day for the 90th percentile case selected from the "drying" side of the spectrum of outcomes a wide range of climate change impact models for different emission scenarios (Cullis et al, 2015) covering the whole of Southern Africa. For every node the proportional mean monthly streamflow changes under the CC(10) scenario were super-imposed on the current day mean monthly streamflow values at that node. These changed nodal mean monthly streamflow values were then input to the basin configuration tool.

Establishing the ESBC scenario aims to route flows through the network of biophysical and allocation nodes such that the flow requirements necessary to comply with the minimum ecological conditions (i.e. D-condition) are met in the rivers basin-wide and at the estuaries. This is achieved by first putting the estuary flow requirements in place (i.e. for D-condition), and then working in an upstream direction from the estuary through the node network setting flows in place to ensure that the necessary flows are routed down the system to maintain this. The bottom line condition of each node is then established as either a D or whichever higher category is required to maintain all the downstream nodes in at least a D (Figure E1).

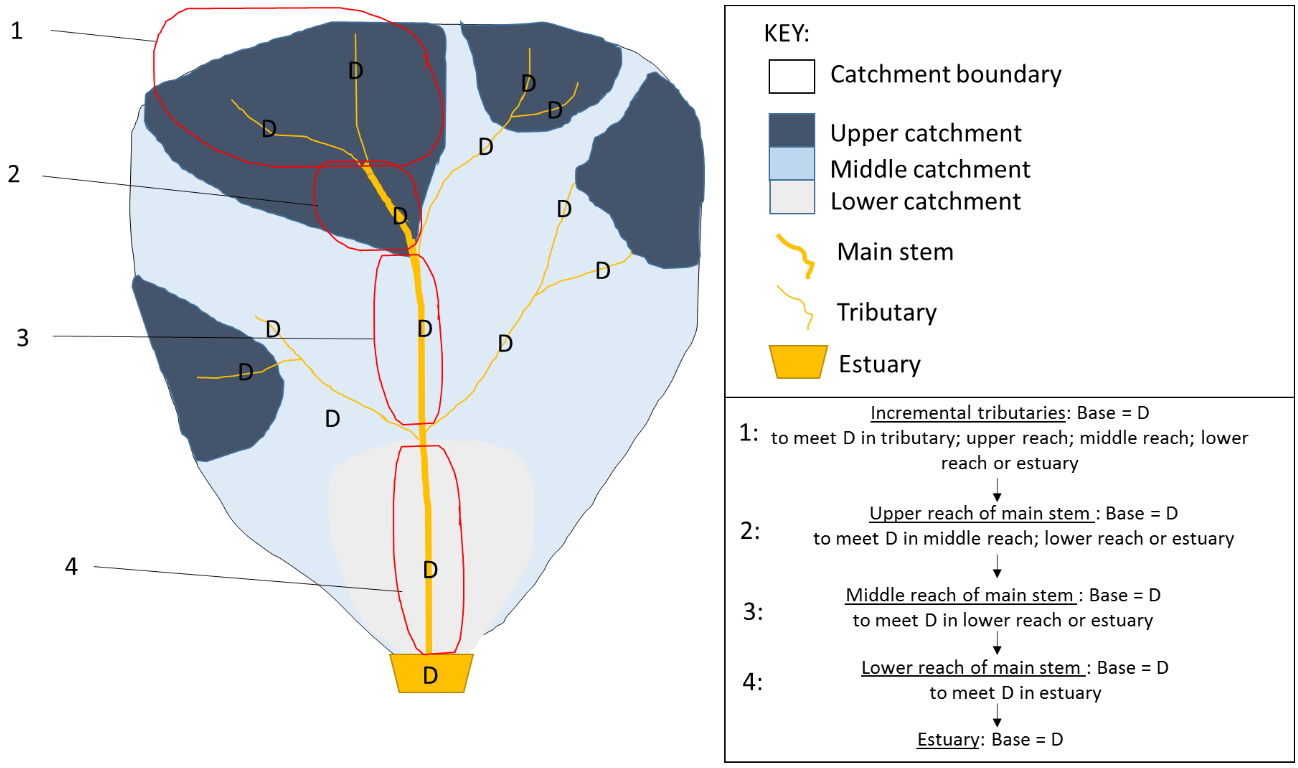

Figure E1. Schematic illustrating a downstream dependence on upstream condition for a hypothetical, simplified catchment (adapted from DWAF, 2007b)

USE OF BASIN CONFIGURATION TOOL TO SET THE ESBC

In order to set up the ESBC and other scenarios a "**basin configuration tool**" was developed in Excel. Average monthly flows for Natural, Current and each of the ecological categories were used and flows are routed from one node to the next in a downstream direction. This was set up so that if a particular ecological category was chosen for a node, the monthly flows associated with that category were selected and routed to the next node (and so on down the system), in order to assess whether those flows would provide what was required for chosen ecological categories at downstream nodes.

The tool reports "surpluses" and "deficits" at each node for the category specified annually, monthly, and for wet and dry seasons, relative to current. If a chosen category upstream does not provide the required flows at a downstream node, the deficit or surplus can be reported and / or the category can be changed until the requirement is met. In the subsequent scenario analysis, the yield model, and groundwater models will be used to assess how the deficits could be remedied, and the concomitant socio-economic effects of the outcome thereof. In the case of surpluses, once verified in the hydrological and yield model, the potential benefits of the water thus available for abstractive uses can be assessed. This is done as part of the scenarios evaluation phase and in some cases involves additional analysis of potential impacts on yield.

COMPARING THE ESBC TO CURRENT DAY FLOWS

The volumes resulting from the Ecologically Sustainable Base Configuration are reported as surpluses or deficits relative to current day at each node according to groups of Integrated Units of Analysis (IUAs).

The results of setting up the balancing tool and running the ESBC scenario revealed some significant challenges that will need to be addressed during the scenarios evaluation phase. These include:

- Elevated current day flows during the dry season due to the Berg River being used to convey releases for downstream users including both irrigation and urban and industrial.
- Elevated current day flows during the dry season due to return flows from treatment plants.
- Significant differences in the flow requirements for river and estuary nodes.

In these cases the Berg River catchment (including the coastal catchments in G2) is different to other catchments were particularly in that it is significantly impacts by development and manged flows. These issues were noted during the Status Quo Assessment and will be addressed during the scenario analysis.

The initial analysis of the ESBC scenario, as presented in this report, does however achieve its primary objectives which are to establish the balancing tool and identify the fact that there are areas of potential surplus and deficit resulting from a minimum sustainable ecological scenario that need to be considered.

PREPARATION OF OTHER DATA FOR SCENARIO ANALYSIS

In the next report, The Evaluation of Scenario Report, the surface water yield model will be adjusted in an attempt to surpass the deficits reported for the ESBC and also to meet the Reserve requirements of the other scenarios. So too, will the outcomes of the scenario analyses be evaluated in terms of their impacts on river ecological condition, water quality, availability of groundwater, impacts on wetlands, water supply and socio-economic outcomes of these. A short background to preparation of these other data is provided.

THE WAY FORWARD

After completing the ESBC scenario, the balancing tool will be used to set up the necessary ecological category (EC) requirements to achieve the specific objectives of the alternative proposed classification scenarios including the Present Ecological Scenario (PES), the Recommended Ecological Category (REC) scenario, as well as the high development and future climate change scenarios. The scenarios analysis will then consider the associated social, economic and environmental impacts of these alternative configuration scenarios in order to assess the overall impact and to agree with stakeholders on the final recommended classification scenario for each resource unit and the individual Integrated Units of Analysis (IUA).

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1 Introduction

1.1 Background

Chapter 3 of the National Water Act (NWA) lays down a series of measures which are together intended to ensure protection of the critical water resources of the country. In accordance with these measures, the Department of Water and Sanitation (DWS), in line with Section 12 of the NWA, established a Water Resources Classification System (WRCS) that is formally prescribed by Regulations 810 dated 17 September 2010.

The WRCS provides guidelines and procedures for determining Water Resource Classes, Reserve and Resource Quality Objectives (RQOs) for all water resources in the country.

Section 13 of the NWA states that "as soon as reasonable practicable after the Minister prescribed a system for classifying water resources, the Minister must, subject to subsection (4), by notice in the gazette, determine for all or part of every significant water resource:

- A class in accordance with the prescribed classification system; and
- Resource quality objectives based on the class determined in terms of paragraph (a).

In accordance with the above section of the NWA, the Chief Directorate: Water Ecosystems of the Department of Water and Sanitation (DWS) has commissioned a study to determine Water Resource Classes and associated Resource Quality Objectives (RQOs) for all significant water resources in the Berg Catchment as part of the Berg-Olifants Water Management Area (WMA) in the Western Cape.

The Berg River is the largest catchment in the Study Area, which also includes a number of smaller catchments such as the Diep, Kuils, Eerste, Lourens, Sir Lowry's, Steenbras, as well as various small catchments on the Cape Peninsula and along the West Coast. The study area is shown in Figure 1.1.

The 7-step WRCS procedure is prescribed in the WRCS Overview Report (DWAF, 2007) leading to the recommendation of the class of a water resource (the outcome of the Classification Process).

1.2 Objectives of the study

The main objectives of the Study are to undertake the following:

- Co-ordinate the implementation of the WRCS, as required in Regulation 810 in Government Gazette 33541, by classifying all significant water resources in the Berg Catchment.
- Determine RQOs using the DWS Procedures to Determine and Implement RQOs for all significant water resources in the Beg Catchment.

This report presents the Ecological Sustainable Base Configuration (ESBC) scenario for the study area and is part of a series of reports that will be prepared as part of determining the water resource classes:

1. Linking the Value and Condition of the Resource report
2. Quantification of the Ecological Water Requirements and changes in Ecological Goods, Services and Attributes (EGSA) report
3. **Ecologically sustainable base configuration scenario (ESBC) report (this report)**
4. Evaluation of Classification Scenarios report

Figure 1.1 Map of the study area.

1.3 Purpose of this report

The 7-step WRCS procedure is described in the WRCS Overview Report (DWAF, 2007a) and leads to the recommendation of the Class of a water resource (the outcome of the Classification Process).

This report is a sub-set (Step 4a) of the fourth step of the classification procedure as outlined by the DWS (DWAF, 2007a). The objective of Step 4a is to set up the Ecologically Sustainable Base Configuration (ESBC) scenario in preparation for the analysis of proposed alternative classification scenarios. A critical component of this is setting up the necessary tools used to establish the other configuration scenarios.

STEP 1: Delineate the units of analysis and describe the status quo of the water resources.
STEP 2: Link the value and condition of the water resource.
STEP 3: Quantify the Ecological Water Requirements and changes in non-water quality Ecosystem Goods, Services and Attributes.
STEP 4: Determine an Ecologically Sustainable Base Configuration scenario and establish the starter configuration scenarios.
STEP 5: Evaluate scenarios within the Integrated Water Resource Management (IWRM) process.
STEP 6: Evaluate the scenarios with stakeholders.
STEP 7: Gazette the class configuration.

Figure 1.2 7-Step Procedure to determine Water Resource Classes

The ESBC is the minimum environmental flow scenario that sustains the lowest acceptable D-conditions for all water resources basin-wide. In this report (and in the project from here on) it is suggested that the suffix *bottom line* is attached to the ESBC when describing this scenario, to avoid confusion between this and the baseline scenario that maintains PES (baseline) *viz.* ESBC (bottom line).

The ESBC and the other scenarios were first described in the *Linking Value and Condition of Water Resource* Report (DWS, 2017a) and have been refined in this report as described in the table below.

Table 1.1 Description of configuration scenarios

#	Scenario	Abbreviation	Description
1	Maintain Present Ecological Status ("Baseline")	PES	River, wetland and estuary systems are maintained in their present condition, or where currently in an E or F, improved to a D as far as possible. The implications for water supply are tested under both: (a) the current level of economic development and (b) projected demands under a high growth scenario
2	Ecologically Sustainable Base Configuration (ESBC) Scenario (also called the "Bottom-line" Scenario)	ESBC	The maximum volume of water is made available for abstraction from the system for economic activities, with the proviso that all water resources are just maintained in a D category (the ecological "bottom line"). The implications for water supply are tested under both: (a) the current level of economic development and (b) projected demands under a high growth scenario
3	Recommended Ecological Categories (RECs)	REC	The RECs determined for rivers, wetlands and estuaries based on present health and conservation importance (but without any consideration of socio-economic effects) are applied in this scenario. The implications for water supply are tested under both (a) the current level of economic development and (b) projected demands under a high growth scenario
4	High future demands	High Dev	This development-focussed scenario presents the situation where the water demand for the future level of development (assuming high growth in future water demands) are met. The resulting ecological categories are not constrained and may result in ECs of worse than a D category.
6	Climate change (10%)	CC(10)	The shifts that climate change might cause to the ecological conditions of nodes across the Study Area was assessed by modelling catchment streamflow changes relative to current day for the 90th percentile case selected from the "drying" side of the spectrum of outcomes a wide range of climate change impact models for different emission scenarios (Cullis et al, 2015) covering the whole of Southern Africa. For every node the proportional mean monthly streamflow changes under the CC(10) scenario were super-imposed on the current day mean monthly streamflow values at that node. These changed nodal mean monthly streamflow values were then input to the basin configuration tool.

In order to determine the configuration of ecological water requirements (EWRs) at all allocation nodes, a pre-yield screening model (called the **basin configuration tool** in this report) was set up to assess whether the present day flows are sufficient to meet these EWRs. This is described in more detail in Section 3.

Establishing the ESBC scenario aims to route flows (and their associated ecological conditions per node, (see Section 2) through the network of biophysical and allocation nodes, such that minimum D-condition flows are met in the rivers basin-wide and finally at the estuaries which represent the outlet of each catchment (Figure 1.3). Normally, even though flows are finally routed in a downstream direction, establishing this bottom-line configuration is approached first by putting the estuary requirements in place (D-condition), and then working in an upstream direction from the estuary through the node network setting flows in place to maintain this. The bottom line condition of each node is then established as either a D or whichever higher category is required to maintain all downstream nodes in at least a D condition.

Since EWRs are calculated from natural flows, the EWRs for the various ecological categories (EC) often exceed flows of the present day, reduced relative to natural by water demands basin-wide. This is especially the case in the Western Cape where water use is high during the peak growing season that coincides with the low flow periods during the dry season. That being the case, it is necessary to check that these bottom line EWRs can be met by flows of the present day. Inevitably deficits result where the EWRs exceed present day flows, normally during the dry season. In these cases it may be possible to increase flow supplied to a node in deficit (*viz.* with negative cumulative flow) to balance out the deficit.

The flows required to meet the ecological conditions of the bottom line scenario (EBSC) are compared to that of the present day using the pre-yield model (basin configuration tool) in Section 4. The results of this analysis will show deficits and surpluses of flow (water volumes) between the EWRs for the ESBC and present day flows. A deficit results when EWRs for the targeted ecological category (EC) exceed flows of the present day, a surplus occurs when present day flows exceed the EWRs for the target EC.

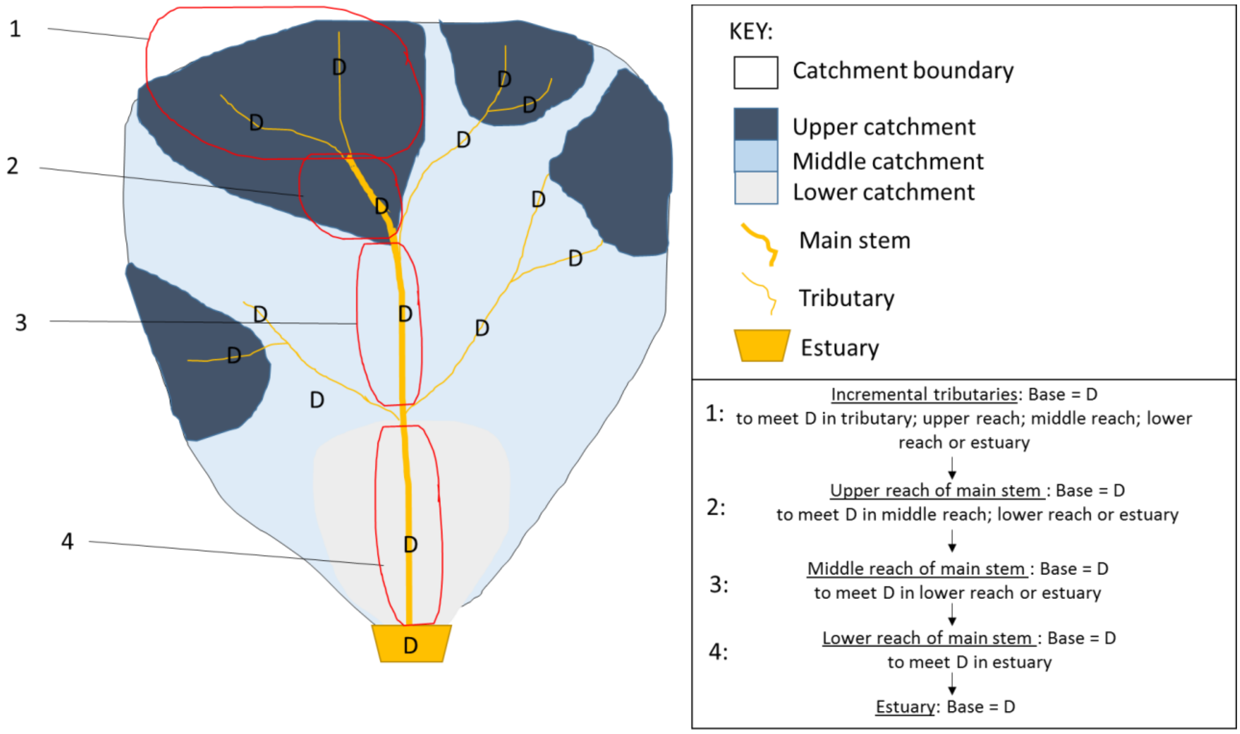

Figure 1.3 Schematic illustrating a downstream dependence on upstream condition for a hypothetical, simplified catchment (adapted from DWAF, 2007b)

In the Scenario analysis report, the surface water yield model will be adjusted in an attempt to surpass the deficits reported for the ESBC and also to meet the EWR requirements of the targeted ecological categories for the other scenarios, being higher or lower than the present ecological status (PES). So too, will the outcomes of the scenario analyses be evaluated in terms of their impacts on river ecological condition, water quality, availability of groundwater, impacts on wetlands, water supply and socio-economic outcomes.

A short background to preparation of these other date requirements is provided in Section 5 of this Report.

2 Integrated Units of Analysis and location of nodes used for analysis

2.1 Integrated Units of Analysis and Biophysical Nodes

Integrated Units of Analysis (IUAs) were determined for the study area based on a combination of hydrological, ecological and socio-economic factors. Twelve IUAs were identified and are shown in Figure 2.1 and in Table 2.1. In addition 45 biophysical river nodes were defined according to the procedures prescribed by DWS (DWAF, 2007f). Nineteen estuary nodes were also identified and eight of these were considered to be priority estuary nodes. The delineation of IUAs and identified of river and estuary nodes are described in the *Resource Units and Integrated Units of Analysis Delineation Report* (DWS, 2016b).

Table 2.1: Socio-economic zones, Integrated Units of Analysis (IUA)s delineated for the study area.

Socio-economic Zone	Zone Code	IUA Name	IUA Code	Quaternary Catchments
West Coast	A	Berg Estuary	A1	G30A, G10M
		Langebaan	A2	G10M
		West Coast	A3	G21A, G21B
Lower Berg	B	Lower Berg	B4	G10K, G10L. G10J, G10H, G10F
Tulbagh Fruit Area	C	Berg Tributaries	C5	G10G, G10E
Winelands	D	Eerste	D6	G22G, G22H, G22F
		Sir Lowry's	D7	G22J, G22K. G40A
		Upper Berg	D8	G10C, G10B, G10A
		Middle Berg	D9	G10D
		Diep	D10	G21C, G21D, G21E, G21F
Cape Town	E	Peninsula	E11	G22B, G22A
		Cape Flats	E12	G22C, G22D, G22E

2.2 Location of River and Estuary Nodes

A total of 46 river nodes and 22 estuary nodes have been identified in the Study Area (Figure 2.1).

The process for identification of these nodes is described in the Delineation Report and then further evaluated in the report on Ecological Water Requirements (EWRs) produced previously in this Study.

Additional information on all nodes are given in Table 2.2 including the location (quat), estimated ecological importance score (EIS), present ecological condition (PEC) and other information including the following:

- The estuary nodes are highlighted in blue
- The nodes with a significant contribution from groundflow are highlighted in green.
- The nodes associated with Reserve sites are indicated in **red**
- Whether the node is associated with specific wetlands, wetland types, or wetlands systems
- Additional information in terms of nodes linked with specific conservation sites or areas.

Table 2.2 List of nodes selected for the scenario analyses

IUA	Node	Quat	EIS	EC	Node type and considerations	Within conservation sites
A1	**Bxi1**	**G10M**	**H**	**D**	**Berg River estuary EWR site, linked to river node Biv2; Floodplain, Channelled Valley-bottom and Unchannelled Valley-bottom wetlands.**	**Berg River Estuary IBA**
A2	**Bxi3**	**G10M**	**VH**	**B**	**Langebaan estuary; Channelled Valley-bottom and Unchannelled Valley-bottom wetlands, significant groundwater contribution.**	**West Coast National Park IBA**
A3	Bxi12	G21A	M	C	Modder estuary	N/A
	Bviii3	G21A	H	D	Inflow to Yzerfontein salt pan; Depression wetland (Yzerfontein Salt Pan) as well as Unchannelled Valley-bottom wetlands.	N/A
	Bviii10	G21B	H	E	Sout River; Depression and Seep wetlands as well as Floodplain wetlands.	N/A
B4	Biv3	G10J	VH	D	Klein-Berg River, u/s of confluence with Berg; Channelled Valley-bottom wetlands.	N/A
	Biv1	G10J	M	D	Berg River, u/s of confluence Klein-Berg, d/s Voëlvlei canal; Seep wetlands as well as Channelled Valley-bottom and Floodplain wetlands.	N/A
	Bvii16	G10J	VH	A	Leeu River, gauge, 100% MAR.	N/A
	Bvii11	G10F	H	D	Berg River, u/s of Voëlvlei canal; Depression and Hillslope seep wetlands.	N/A
	Biv4	G10J	H	D	Vier-en-Twintig River, u/s of confluence with Berg; Depression wetlands as well as Channelled Valley-bottom, Unchannelled Valley-Bottom and Flat wetlands.	N/A
	Bvii17	G10J	M	C	Sandspruit River, gauge; Depression wetlands as well as Floodplain and Flat wetlands.	N/A
	Bvii6	**G10J**	**H**	**D**	**Berg River, d/s of EWR 4, above Misverstand Dam; Depression wetlands as well as Floodplain wetlands.**	N/A
	Biii5	G10J	M	D	Matjies River, gauge; significant groundwater contribution; Depression wetlands as well as Channelled Valley-bottom wetlands.	N/A
	Bvii8	G10J	M	D	Berg River, u/s Misverstand reservoir, d/s Matjies River; Depression wetlands as well as Floodplain wetlands.	N/A
	Bvii18	G10J	M	E	Morreesburg Spruit River, gauge; significant groundwater contribution; Depression wetlands as well as Flat and Channelled Valley-bottom wetlands.	N/A
	Bvii12	**G10K**	**H**	**D**	**Berg River, 3.5 km d/s Misverstand reservoir, at EWR 5; Depression wetlands and Floodplain wetlands.**	N/A
	Bii1	G10L	M	D	Sout River, u/s of confluence with Berg; Depression wetlands as well as Floodplain, Flat, Channelled Valley-bottom and Unchannelled Valley-bottom.	N/A
	Biv2	G10L	H	D	Berg River, u/s of confluence with Sout, head of estuary; Hillslope seep wetlands as well as Floodplain, Flat and Unchannelled Valley-bottom wetlands.	N/A
C5	Biii4	G10E	VH	C	Klein Berg River, gauge; Channelled Valley-bottom, Unchannelled Valley-bottom and Flat wetlands.	SWSA
	Bi1	G10G	VH	A	Vier-en-Twintig River, gauge, pristine wilderness 100%.	NFEPA Fish1; Winterhoek MCA
D6	**Biii6**	**G22F**	**H**	**C**	**Jonkershoek River, Eer1 EWR site**	**N/A**
	Biv8	G22G	H	D	Klippies River	N/A
	Biv9	G22H	H	E	Kuils River, u/s confluence Eerste; significant groundwater contribution; Depression and Seep wetlands as well as Floodplain wetlands and Valley-bottom wetlands.	N/A
	Bxi3	**G22H**	**M**	**E**	**Eerste estuary EWR site, linked to river nodes Biii6, Biv8 and Biv9; Floodplain wetlands.**	**N/A**
D7	**Bvii21**	**G22J**	**H**	**C**	**Lourens River, Somerset West; Seep (Paardevlei) and Depression wetlands as well as Valley-bottom wetlands.**	NFEPA Fish1, SWSA; Lourens River
	Bxi4	**G22J**	**U**	**D**	**Lourens estuary, linked to river node Bvii21; Floodplain wetlands.**	**N/A**
	Bviii9	G22K	H	C	Sir Lowry's Pass River; Depression and Seep wetlands as well as Valley-bottom wetlands.	NFEPA Fish1, SWSA
	Bxi5	**G22K**	**U**	**E**	**Sir Lowry's Pass estuary EWR site, linked to river node Bviii9**	**N/A**
	Bvii22	G40A	VH	C	Steenbras River, at EWR 8, u/s of estuary mouth; significant groundwater contribution; Seep wetlands as well as Valley-bottom wetlands.	SWSA; Hottentots Holland MCA

IUA	Node	Quat	EIS	EC	Node type and considerations	Within conservation sites
	Bxi6	**G40A**	**U**	**B**	**Steenbras estuary EWR site, linked to river node Bvii22**	**Hottentots Holland MCA**
D8	Bvii13	G10A	VH	A	Berg River, gauge u/s Berg River dam, 100% MAR.	NFEPA Fish2; SWSA
	Bviii1	**G10A**	**H**	**C**	**Berg River, d/s of Berg River dam EWR 1**	SWSA
	Biv5	G10A	H	D	Franschoek River, u/s of confluence with Berg.	N/A
	Biii2	G10B	VH	D	Wemmershoek River, u/s of confluence with Berg; significant groundwater contribution; Depression and Hillslope seep wetlands as well as Channelled Valley-bottom wetlands.	NFEPA Fish1; SWSA
	Bvii14	G10C	VH	C	Dwars River, gauge.	SWSA
	Bvii2	G10C	H	D	Berg River, Berg Water Project pump station; Depression wetlands as well as Floodplain and Channelled Valley-bottom wetlands.	SWSA
	Biii3	G10C	H	E	Berg River, gauge; Depression and Hillslope seep wetlands as well as Floodplain, Channelled Valley-bottom and Unchannelled Valley-bottom wetlands.	SWSA
D9	**Bviii11**	**G10C**	**H**	**D**	**Pombers River, EWR 7 u/s of confluence with Kromme; Flat, Channelled Valley-bottom, Unchannelled Valley-bottom and Floodplain wetlands**	**N/A**
	Bvii3	**G10D**	**H**	**D**	**Kromme River, North of Wellington, EWR 6; Hillslope seep wetlands as well as Flat, Channelled Valley-bottom and Unchannelled Valley-bottom wetlands.**	**NFEPA Fish2; SWSA**
	Bvii10	G10D	H	D	Berg River, d/s of confluence Kromme, gauge; significant groundwater contribution; Hillslope seep and Depression wetlands as well as Floodplain, Channelled Valley-bottom, Unchannelled Valley-bottom and Flat wetlands.	NFEPA Fish2; SWSA
	Bvii15	G10D	VH	D	Doring River, gauge; significant groundwater contribution; Depression wetlands as well as Unchannelled Valley-bottom (Klein Sand vlei and Sand River vlei) and Floodplain wetlands.	SWSA
	Bvii4	G10D	H	D	Kompanjies River, gauge; Hillslope seep and Depression wetlands as well as Channelled Valley-bottom and Floodplain wetlands.	SWSA
	Bvii5	**G10D**	**H**	**D**	**Berg River, gauge and u/s of EWR 3; Depression (Blouvlei) and Seep wetlands.**	**SWSA**
D10	**Bv1**	**G21D**	**H**	**D**	**Diep River; significant groundwater contribution; Depression and Seep wetlands as well as Flat wetlands.**	NFEPA Fish2
	Bviii4	G21D	H	D	Swart River, u/s of confluence with Diep; significant groundwater contribution; Depression wetlands as well as Unchannelled Valley-bottom wetlands.	NFEPA Fish2
	Biv6	G21D	H	D	Diep River; significant groundwater contribution ; Depression and Seep wetlands as well as Valley-bottom wetlands.	NFEPA Fish2
	Biv7	G21E	H	D	Mosselbank River; significant groundwater contribution; Depression and Seep wetlands as well as Floodplain and Valley-bottom wetlands.	N/A
	Bxi7	**G21F**	**H**	**D**	**Rietvlei/Diep estuary EWR site, linked to river nodes Bv1, Bviii4, Biv6, Biv7; Floodplain and Valley bottom wetlands (Rietvlei) as well as Depression wetlands.**	N/A
E12	Bviii8	G22C	M	F	Elsieskraal River, u/s of confluence Black; Depression as well as Valley-bottom wetlands.	N/A
	Bvii7	**G22D**	**H**	**D**	**Keysers River, at EWR site; Depression (Princessvlei) and Seep wetlands as well as Floodplain and Valley-bottom wetlands.**	**N/A**
	Bxi9	**G22D**	**H**	**D**	**Sand estuary EWR site, linked to river node Bvii7; Depression as well as Floodplain wetlands.**	**SWSA, False Bay Nature Reserve**
	Bxi20	**G22D**	**U**	**E**	**Zeekoe estuary; Depression (Zeekoevlei and Rondevlei) and Seep wetlands as well as Floodplain wetlands.**	**SWSA, False Bay Nature Reserve**
E11	Bviii6	G22B	H	D	Hout Bay River, at EWR site; Seep wetlands as well as Floodplain and Valley-bottom wetlands.	SWSA, NFEPA Fish1
	Bxi10	**G22B**	**U**	**E**	**Hout Bay estuary EWR site, linked to river node Bviii6**	SWSA, Table Mountain National Park
	Bvii20	G22A	U	C	Silvermine River, Fish Hoek, 100% MAR; Seep wetlands.	NFEPA Fish1
	Bxi11	G22A	U	D	Silvermine estuary EWR site, linked to river node Bvii20	N/A
	Bxi13	G22A	M	D	Goeiehoop estuary	N/A
	Bxi14	**G22A**	**M**	**D**	**Wildevoelvlei estuary; Depression wetlands (Noordhoek Salt Pan and Pick n Pay Reedbeds) as well as Valley-bottom wetlands.**	Table Mountain National Park

IUA	Node	Quat	EIS	EC	Node type and considerations	Within conservation sites
	Bxi15	G22A	U	D	Bokramspruit estuary (micro-estuary); Depression wetlands as well as Valley-bottom wetlands.	N/A
	Bxi16	G22A	U	A	Schuster estuary (micro-estuary); Seep wetlands as well as Valley-bottom wetlands.	NFEPA Fish1, Table Mountain National Park
	Bxi17	G22A	U	A	Krom estuary (micro-estuary); Seep wetlands as well as Valley-bottom wetlands.	Table Mountain National Park
	Bxi18	G22A	U	F	Buffels Wes estuary (micro-estuary); Seep wetlands as well as Valley-bottom wetlands.	Table Mountain National Park
	Bxi19	G22A	U	E	Elsies estuary (micro-estuary); Depression wetlands as well as Valley-bottom wetlands.	SWSA

With IUA = Integrated Unit of Analysis; IBA = Important Bird Area; Quat = Quaternary catchment; EIS = Ecological Importance and Sensitivity; EC = Ecological Category; SWSA: Strategic Water Source Area, MCA = Mountain Catchment Area; N/A = Not applicable; NFEPA: National Freshwater Priority Area

Note: EWR sites in red; blue highlights estuary nodes and green highlights river nodes with significant groundwater contribution

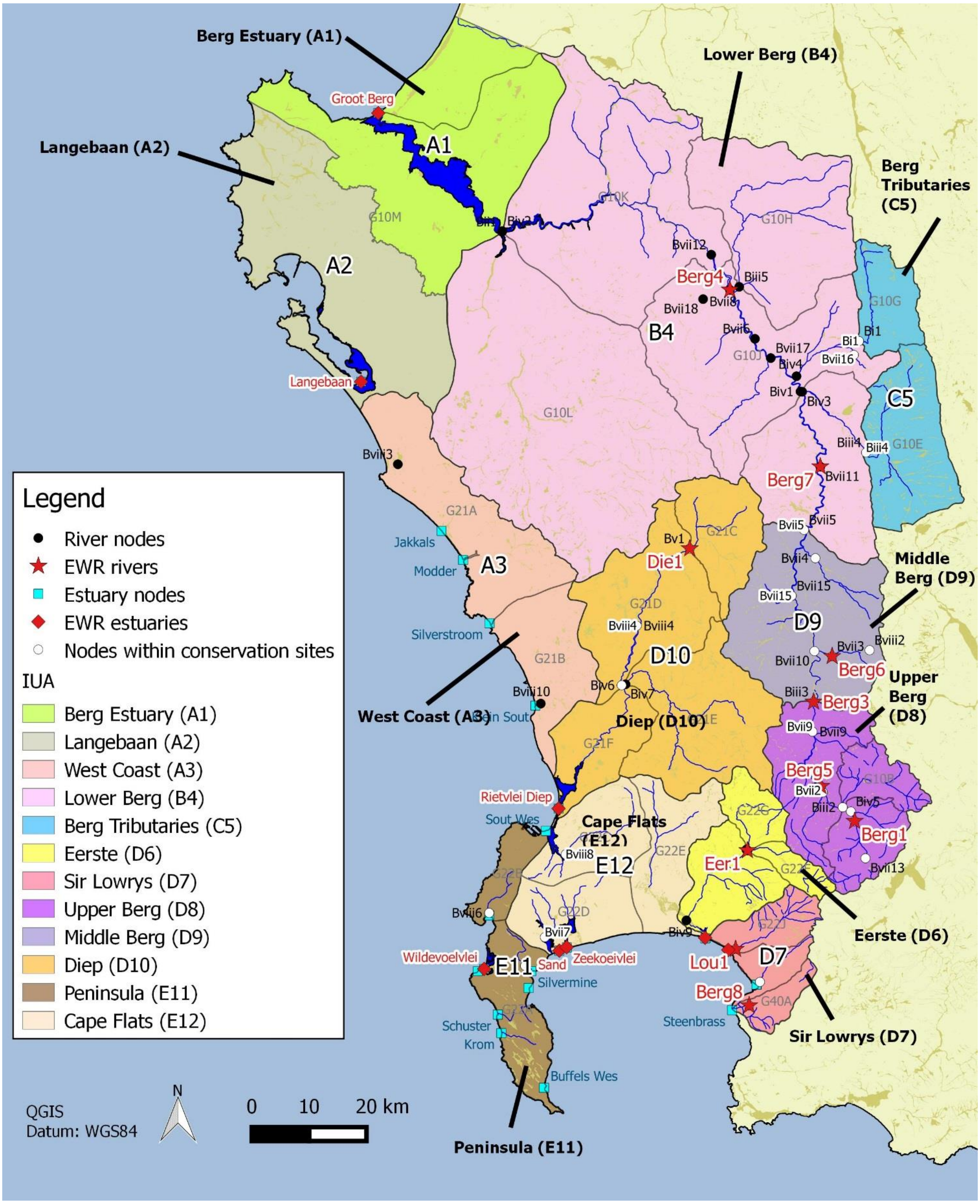

Figure 2.1 Integrated Units of Analysis (IUAs) and biophysical nodes for the Berg catchment.

3 Base Configuration Scenario Tool

3.1 Introduction

In order to set up the ESBC and other scenarios a "**basin configuration tool**" was developed in Excel.

Average monthly flows for Natural, Current (present day) and each of the ecological categories were used and flows were routed from one node to the next in a downstream direction. This was set up so that if a particular ecological category was chosen for a node, the monthly flows associated with that category were selected and routed to the next node (and so on down the system), in order to assess whether those flows would provide what was required for chosen ecological categories at downstream nodes.

The tool reports "surpluses" and "deficits" at each node for the category specified annually, monthly, and for wet and dry seasons, relative to current. If a chosen category upstream does not provide the required flows at a downstream node, the deficit or surplus can be reported and / or the category can be changed until the requirement is met.

In the subsequent scenario analysis, the yield model, and groundwater models will be used to assess how the deficits could be remedied, what alternative water supply options are available and the concomitant socio-economic effects thereof. In the case of surpluses, once verified in the yield model, the potential benefits of the water thus available for abstractive uses can be assessed. This is done as part of the scenarios evaluation phase and in some cases involves additional analysis of potential impacts on yield.

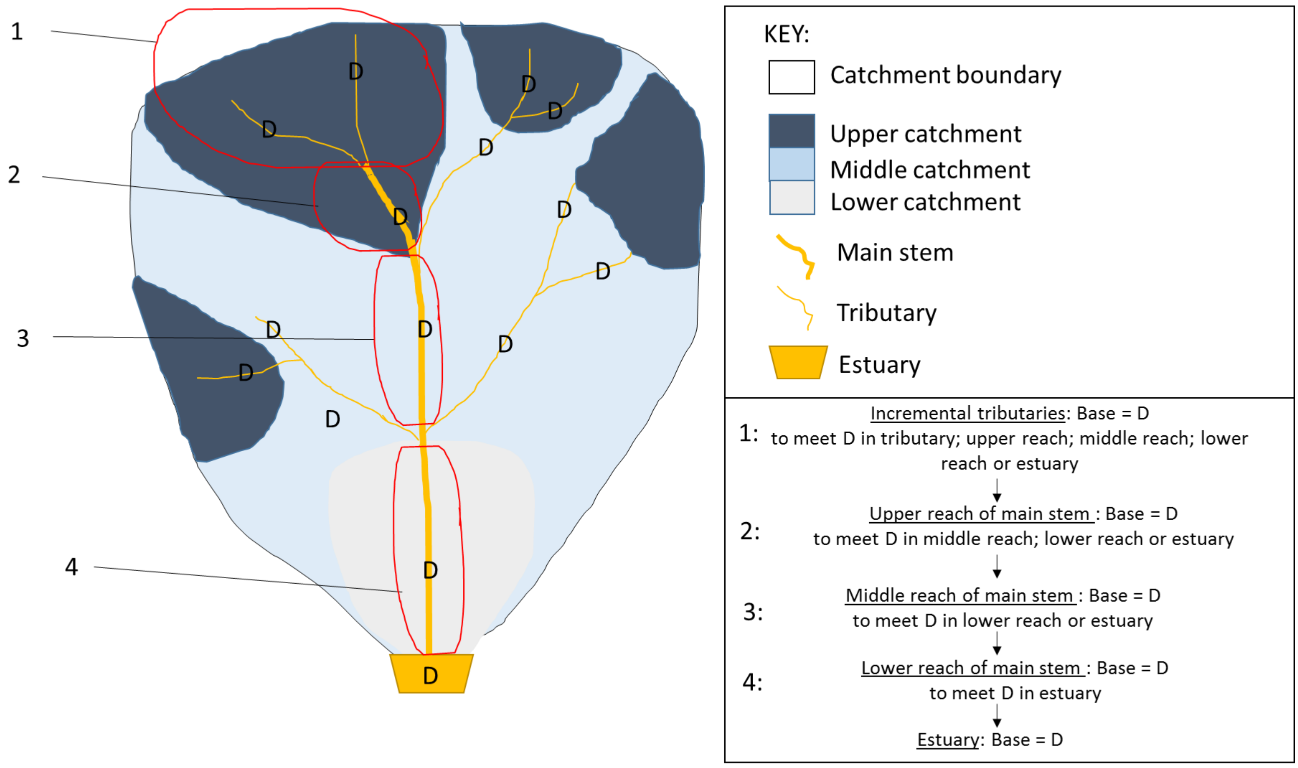

Figure 3.1 Schematic illustrating a downstream dependence on upstream condition for a hypothetical, simplified catchment (adapted from DWAF, 2007b)

3.2 The "Basin configuration tool"

The basin configuration tool (hereafter called the **tool**) is an EXCEL based model that was programmed to route flows through the river nodes to the estuaries; nodes represent various points of interest in the study area. As such the tool is a hydrological model that was created to model how changes in flow affect the ecological condition of rivers and estuaries, the two primary water resources where data from past Reserve studies are readily available. To achieve this, the tool calculates the ecological condition of rivers and estuaries (at the nodes) as the flows are increased or decreased, relative to flows of the current day.

It is important to note that Reserves (in terms of ecological water requirements - EWRs) for rivers and estuaries were calculated based on percentage change from natural flows, *viz.* NOT relative to current day.

There are various inputs into the tool, some of which are related to the background programming and are not discussed here. The following description deals with the main inputs included in the basin configuration tool and used to construct the ecological scenarios (at each node):

- The location of each node geographically in the study area relative to the other nodes, up- and downstream respectively
- The ecological condition of each node (river and estuary)
- Naturalized hydrological monthly time series' (cumulative and incremental flows), calculated as volumes in Million Cubic Meters (MCM)
- Current day hydrological monthly time series' (cumulative and incremental flows), calculated as volumes in Million Cubic Meters (MCM)
- Hydrological monthly Reserve (EWR) time series' (cumulative and incremental flows), calculated as volumes in Million Cubic Meters (MCM) for a range of ecological categories

The location of each node, relative to the others, is important in the tool as flows are linked together in a downstream direction toward their receiving estuary. In some cases, there are a large number of nodes that are linked together in a network in tributaries and river channels of various orders.

The nodes are listed in a downstream direction with the distal nodes listed first. The tool calculates the cumulative flows in a downstream direction for each node by taking into account nodes that deliver flow from upstream. In short, for each node, the tool calculates and reports what the cumulative current day flows are. This is the primary data source (**baseline**) against which all other flow calculations are made. The next main source of data for the flow calculations are the Reserve flows; provided for a range of ecological categories where rivers and estuaries in better condition maintain higher levels of flow.

3.3 Routing of flow requirements for each scenario

The Reserve flows were calculated using naturalized hydrological time series' at each node in the Desktop Model that calibrates Reserve flows based on flow sequences from Reserve studies, or the use of regional specific settings. The model only calculates intra-annual flows, *viz.* flows that include the small intra-annual floods (that occur every year) and excludes the larger inter-annual floods (1:2, 1:5, 1:10 etc.).

Therefore, in order to compare various Reserve flows to the naturalized and current hydrological time series', which are TOTAL flows (inclusive of all floods), it was necessary to first put back the inter-annual floods into the Reserve hydrological time series' prior to any comparative calculations.

The starting point for calculations that compare the hydrological outcome of setting Reserve flows at a location of interest (node) therefore are naturalized, current day and Reserve TOTAL flow time series.

The other important data source in the tool, and necessary for scenario evaluation, is the present ecological status (baseline) of each node. This is the baseline ecological condition of each (river and estuary) node, taken from the 2014 PES EIS data base (DWS 2014a), in the Western Cape these data were derived from field based studies, or the relevant Reserve study, or from updates made during the study (DWS, 2017).

3.4 Linking flow requirements to ecological condition

The links between flow and ecological condition were programmed into the tool based on a number of standard assumptions common to environmental flow studies in general, including:

- Ecological conditions were ranked into groups designated different ecological categories (Kleynhans and Louw 2007, Table 3.1)
- Current day and Reserve flows were ranked into groups designated different flow categories, based on their % differences to naturalized flow
- Changes in flow were linked to changes in ecological condition in a non-linear manner such that rivers/estuaries in good ecological condition were more responsive to changes in flow, whereas rivers/estuaries in poor ecological condition were less responsive to changes in flow
    - the premise being that poor ecological conditions often result from a combination of impacts, not just flow alone, and where this is the case an improved ecological condition requires multiple interventions, not flow manipulation alone

3.5 User interface and scenario analysis

The interface of the tool is:

- a list of nodes, associated with
    - incremental nodes that contribute flow at that point
    - river names
    - their location per quaternary and integrated unit of analyses
    - the present ecological status (baseline ecological condition)
    - the recommended ecological category at river and estuary Reserve study sites
- a program button per node that allows the user to change flow routed at each node from
    - current day, or
    - Reserve flows for different ecological categories

The user works from the various estuaries in an upstream direction, loading different flow volumes at each node and while doing so, the tool calculates how the cumulative flows at each node downstream changes, relative to current day flow, and calculates whether this relative change is sufficient, when compared to the flow sustaining the baseline ecological condition (current day), to improve the ecological condition of the water resource at that node, if flows are increased relative to current day, or degrade in response to decreases in flow.

As flow, and resulting ecological conditions change, the results calculated to per node include:

- Current ecological condition
- Scenario ecological condition
- Current day seasonal (wet and dry seasons) average monthly flow volume as a percentage of natural (current day)
- Scenario seasonal (wet and dry seasons) average monthly flow volume as a percentage of natural (current day)
- Surplus/deficit seasonal (wet and dry seasons) flow volumes relative to current day

Table 3.1 **Ecological categories and associated PES scores (Kleynhans et al., 2008)**

Ecological Category	PES % Score	Description of the habitat
A	92-100	Still in a Reference Condition.
A/B	87-92	
B	82-87	Slightly modified from the Reference Condition. A small change in natural habitats and biota has taken place but the ecosystem functions are essentially unchanged.
B/C	77-82	
C	62-77	Moderately modified from the Reference Condition. Loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
C/D	57-62	
D	42-57	Largely modified from the Reference Condition. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
D/E	37-42	
E	22-37	Seriously modified from the Reference Condition. The loss of natural habitat, biota and basic ecosystem functions is extensive.
E/F	17-2	
F	0-17	Critically/Extremely modified from the Reference Condition. The system has been critically modified with an almost complete loss of natural habitat and biota. In the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

In the tables of results from the tool, colouring is used to guide description and highlight changes. The ecological condition classes are coloured in the standard fashion, blue for better conditions, and red for poorer conditions, and green and orange in between (see below). Other shading is used for the percentages of flow relative to natural mean annual runoff (nMAR) in the tables that follow). Here, light pink indicates a small change from natural, light orange a greater change, then darker orange and finally red to indicate a large degree of change in flow, relative to natural. Lastly, the surplus or deficit volumes per node, are also colour coded where light pink indicates a deficit and light blue indicates a surplus. Very small changes from natural or current day respectively, are not colour coded. Nodes in bold text are estuary nodes.

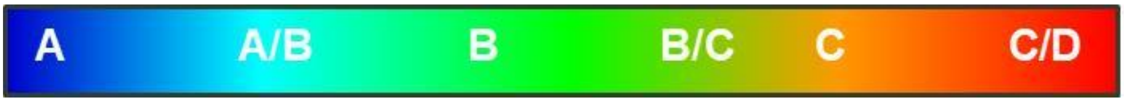

Illustration of the distribution of Ecological Categories on a continuum of change.

Illustration of the distribution of percentages of flow relative to natural.

Illustration of the distribution of deficit or surplus flows.

4 Results of the ESBC scenario

4.1 Introduction

The average seasonal flow volumes resulting from the ESBC are reported as surpluses or deficits relative to current day flow at each node in the study area. The results are presented separately for the nodes in the Berg River catchment (G1) and the additional coastal catchments (G2 and G40A). The results are reported in these large hydrological groupings, rather than at the level of individual IUAs as these nodes are generally hydrologically connected and these connections bridge across the divide between IUAs.

Ultimately the overall ecological impact associated with the ESBC and the other scenarios will be reported at the IUA level when taking in to account additional factors such as social and economic impacts, groundwater impacts, wetlands and the cost of additional infrastructure will be evaluated at the IUA level.

For each grouping of IUAs, the results from the balancing tool for the ESBC configuration are shown indicating the potential surplus and deficit water availability at each node. The descriptions focus on changes in hydrology and the resulting changes in river and estuary ecological condition, relative to that of the current day for each scenario. In some instances and at certain IUAs, other mention was made of wetlands, conservation areas of importance or certain worthy socio-economic factors, as appropriate.

4.2 Berg River catchments (G1)

The ESBC results and comparison with current day flows for river and estuary nodes in the Berg River catchments (G1) are shown in **Table 4.1**. The modelled scenario flow regime:

- meets and exceeds the seasonal flow requirements for a D at all the nodes, apart from at Biii3, the Berg River through the town of Paarl, Biv3, the Klein Berg, and Bvii17, the Sandspruit Rivers, where increasing flow did not improve the ecological conditions up from an E in the former, and a D/E in the two latter cases,
- results in slight dry season deficits in flow volume at Biv5, the Franschhoek River, Biii2, the Wemmershoek River, Bvii5 and Bvii11, the lower foothills of the Berg River, Biv4, the Vier-en-Twintig River, Bvii12, the Berg River downstream of Misverstand Dam, Biv2, the Berg River downstream of the Sout River, and Bxi1, the Berg River estuary,
- creates a large wet season surplus volume (in terms of the volume required to meet the ecological condition relative to current day volumes) at various points along the Berg River and most tributaries, and in the estuary,
- current day flows were kept at six nodes, Bvii13 the upper Berg, Bi1 the upper Vier-en-twintig, Leeu, Bvii16 the Leeu, Biii5 the Matjies River, Bvii18 the Mooressburgspruit River, and Bii1 the Sout River, either because routing Reserve flows through these nodes reduced their ecological condition or that of nodes downstream, or due to the node being selected as a water source area that requires maintaining 100% of natural flow,
- in this example, Reserve flows were routed at most nodes which, in many cases, dramatically changes the seasonal distribution of flow down the river as, being based on natural, the Reserve flows have much lower volumes in the dry season when compared with the current day flows that are strongly regulated to sustain irrigation releases made during the dry season that surpass natural.

Table 4.1 Ecologically sustainable base configuration (ESBC) scenario for river and estuary nodes in the Berg River basin (G1)

QUAT	Node	River	CURRENT			SCENARIO					Notes
			Current EC	Seasonal flow % Nat		Scenario EC	Seasonal flow % NAT		Seasonal deficit / surplus (MCM)		
				WET	DRY		WET	DRY	WET	DRY	
G10A	Bvii13	Berg	A	98.3	98.7	A	98.3	98.7	0.00	0.00	Kept current day, water source area flowing close to natural, inflow to Berg River dam, no abstraction
G10A	Bviii1	Berg	C	38.1	666.2	A/B	58.0	59.8	6.56	30.04	Improved condition due to seasonal reversal away from current day, where irrigation releases surpass natural dry season flows
G10A	Biv5	Franschhoek	D	93.2	3.7	C	34.2	26.4	10.33	-0.26	
G10B	Biii2	Wemmershoek	D	34.3	2.1	C	32.1	20.2	2.74	-0.39	
G10C	Bvii14	Dwars	C	74.7	58.7	D	32.3	22.9	9.20	0.25	
G10C	Biii3	Berg	E	52.9	204.0	E	48.0	43.8	35.35	19.28	No improvement up from E possible with increased flow alone
G10C	Bviii11	Pombers	D	223.9	3063.1	C	16.5	18.1	2.35	0.83	
G10D	Bvii3	Kromme	D	97.5	1.9	C	18.5	15.9	6.20	-0.04	
G10D	Bvii10	Berg	D	55.4	143.6	D	47.2	41.8	46.25	13.86	
G10D	Bvii15	Doring	D	73.8	0.0	C	35.9	20.8	0.94	-0.02	
G10D	Bvii4	Kompanjies	D	82.2	0.5	C	38.0	16.6	6.07	-0.06	
G10D	Bvii5	Berg	D	58.4	17.9	C	44.5	42.3	64.36	-1.58	
G10F	Bvii11	Berg	D	59.0	0.0	A/B	44.0	43.6	68.99	-3.31	Improved condition due to reserve flows now in dry season where previously dry
G10J	Biv1	Berg	D	62.7	106.6	D	43.3	55.5	89.22	8.32	
G10E	Biii4	Klein Berg	C	78.6	128.2	D	34.4	24.2	23.18	2.12	
G10J	Biv3	Klein-Berg	D	48.8	126.8	D/E	31.9	24.1	19.38	2.27	No improvement up from DE possible with increased flow alone
G10G	Bi1	Vier-en-Twintig	C	21.2	33.2	C	21.2	33.2	0.00	0.00	Kept current day
G10J	Bvii16	Leeu	C	9.2	35.0	D	9.2	35.0	0.00	0.00	Kept current day
G10J	Biv4	Vier-en-twintig	D	30.4	13.1	C	27.8	32.9	12.45	-0.61	
G10J	Bvii17	Sandspruit	C	88.9	83.1	D/E	31.2	21.9	3.29	0.03	No improvement up from DE possible with increased flow alone
G10J	Bvii6	Berg	D	55.3	82.1	D	40.1	48.3	111.90	7.66	
G10J	Biii5	Matjies	D	84.1	70.6	D	84.1	70.6	0.00	0.00	Kept current day, needed to maintain D or higher in Berg River
G10J	Bvii8	Berg	D	56.5	73.1	D	42.1	50.5	119.99	5.55	
G10J	Bvii18	Moreesburg Spruit	d	100.0	100.0	D	100.0	100.0	0.00	0.00	Kept current day, needed to maintain D or higher in Berg River
G10K	Bvii12	Berg	D	55.9	35.2	C/D	46.6	57.4	112.08	-0.95	
G10L	Bii1	Sout	D	99.4	100.0	D	99.4	100.0	0.00	0.00	Kept current day, needed to maintain D or higher in Berg River
G10L	Biv2	Berg	D	56.2	24.8	C/D	46.3	61.0	115.31	-3.12	
G10M	Bxi1	Berg estuary	C	56.9	25.4	B/C	44.3	47.9	129.57	-0.13	Improved condition due to cumulative higher flows in dry season

4.3 Coastal catchments (G2)

The ESBC results and comparison with current day flows for river and estuary nodes in the coastal catchments (G2) are shown **Table 4.2**. The modelled scenario flow regime:

- meets and exceeds the seasonal flow requirements for a D at all the nodes, apart from at Bviii18, the Elsieskraal River through Pinelands, where increasing flow did not improve the ecological conditions up from an F,
- results in slight dry season deficits in flow volume at Biv8, the Klippies River, Biii6, the Eerste River, Bvii21, the Lourens River and Bxi9, the Lourens estuary,
- results in slight wet season deficits in flow volume at Bviii10, the Klein Sout River, and Biv7, the Mosselbank River,
- creates wet season surplus flow volumes at various other rivers and estuaries,
- Reserve flows were routed down all rivers into all estuaries, and in most cases this dramatically changed the seasonal distribution of flow down the river as, being based on natural, the Reserve flows have much lower volumes in the dry season when compared with the current day flows that are buffered by waste water treatment releases, most obviously surpassing natural dry season flows.

Table 4.2 Ecologically sustainable base configuration scenario for river and estuary nodes in the Coastal basin (G2)

QUAT	Node	River	CURRENT			SCENARIO					Notes
			Current EC	Seasonal flow % Nat		Scenario EC	Seasonal flow % NAT		Seasonal deficit / surplus (MCM)		
				WET	DRY		WET	DRY	WET	DRY	
G21A	Bviii3	Yzerfontein	D	63.3	46.9	D	54.2	54.2	0.04	0.00	
G21B	Bviii10	KleinSout	E	47.5	139.9	D	95.8	95.8	-0.58	0.08	
G21D	Bv1	Diep	E	72.3	27.4	D	60.2	60.2	0.73	-0.05	
G21D	Bviii4	Swart	D	62.9	157.1	D	54.2	54.2	0.17	0.04	
G21E	Biv7	Mosselbank	D	25.2	84.3	C/D	54.2	54.2	-3.67	0.12	
G21D	Biv6	Diep	D	68.2	96.6	D	92.0	88.1	1.96	0.17	
G21F	Bxi3	Rietvlei-Diep estuary	E	79.3	425.7	D	70.0	68.3	9.62	3.47	
G22C	Bviii8	Elsieskraal	F	87.4	76.5	F	44.0	44.0	2.70	0.09	No improvement up from F possible with increased flow alone, is a concrete canal
G22C	Bxi4	Sout (Wes) estuary	F	157.8	887.6	D	44.0	44.0	21.94	6.01	
G22B	Bviii6	Hout Bay	D	92.6	198.2	D	40.8	40.8	4.32	0.32	
G22A	Bxi5	Wildevoëlvlei estuary	D	124.2	509.6	B	55.7	55.7	2.42	0.53	Reduced upstream flows result in improved EC.
G22A	Bvii20	Silvermine	C	91.9	89.4	C/D	40.8	40.8	0.89	0.03	
G22D	Bvii7	Keysers	D	96.4	74.7	D	66.2	66.2	0.62	0.01	
G22A	Bxi6	Sand estuary	D	98.1	74.0	D	66.2	66.2	4.39	0.04	
G22A	Bxi7	Zeekoei	E	215.8	2138.1	A/B	66.2	66.2	18.13	6.28	Reduced upstream flows result in improved EC.
G22G	Biv8	Klippies	D	119.3	20.0	C	62.0	62.0	2.86	-0.31	
G22F	Biii6	Eerste (Jonkershoek)	C	78.8	56.4	C	62.0	62.0	2.40	-0.12	
G22H	Biv9	Kuils	E	188.3	1655.7	B	62.0	62.0	16.04	5.64	Reduced upstream flows result in improved EC.
G22H	Bxi8	Eerste estuary	E	114.6	308.6	D	62.0	62.0	33.28	6.83	
G22J	Bvii21	Lourens	D	96.7	19.7	C	67.3	67.3	7.13	-0.65	
G22J	Bxi9	Lourens estuary	C	98.4	19.6	A/B	67.3	67.3	8.60	-0.78	Reduced upstream flows result in improved EC.
G22K	Bviii9	Sir Lowry's Pass*	C	84.8	96.5	C/D	40.8	40.8	6.10	0.32	
G40A	Bvii22	Steenbras	C	47.8	45.4	D	20.7	20.7	4.81	0.16	

4.4 Challenges with flow regulation and return flows

Flows in the Berg River (G1) are much higher than natural flows at many of the river and estuary nodes. This is due to the releases made from reservoirs to meet irrigation and other demands downstream, such as the West Coast District Municipality which abstracts water at Misverstand weir, as well as the impact of return flows from irrigation use along the river and from waste water treatment works (WWTW).

This situation also occurs at a number of the smaller estuaries such as the Diep, Sout, Hout Bay, Wildevoelvlei, Zeekoei, Kuils and Eerste are dominated by the return flows from wastewater treatment works. In these cases it may not be feasible to route Reserve flows at these locations as this would practically mean dampening the maintenance low flows during the dry season, effectively *shutting off* the releases made for irrigation or from WTWW, to revert natural seasonality whereby flows are lower in the dry season. The condition of the rivers and estuaries are maintained by current day flow regime. The current impact of return flows, particularly on the ecological conditions at the estuaries, results in the observation that flows may in fact need to be *reduced* in some locations to achieve an improved ecological condition.

This indicates a potential for synergies between future alternative water supply options, particularly through the treatment and re-use of effluent which will need to be considered as part of the future scenarios.

The results of the provisional analysis of the ESBC scenario also indicates a few cases where it is not possible to improve the current EC even with significant increases in flow without addressing other habitat or water quality issues. For example the Elsieskraal River is largely a concrete canal with condition F.

These and other issues relating to the impact of the ESBC scenario will need to be addressed during the scenarios evaluation phase as well as in terms of the final recommended water resource class and associated resource quality objectives, where alternative management scenarios may be required.

5 Preparation of other data for the classification scenario analyses

5.1 Yield modelling and Water Supply Augmentation

5.1.1 Definition of surface water yield/water supply

In a water resources augmentation planning context, surface water yield is generally expressed as the maximum annual withdrawal at a specific annual assurance of supply (as %) (also expressed as recurrence interval in years of failure of supply). However, for this study, yield is defined as the average annual water supply. This definition meets the requirements of the basin configuration tool methodologies used for the ecological condition determinations under the different scenarios formulated for this study, as well as for the concomitant economic analyses.

5.1.2 Quantifying surface water yield/water supply

For the WCWSS, the latest configuration of the WRYM system yield model will be used and, for the rest of the Study area, the WR2012 Pitman model configuration, as refined for this study, will be used to simulate 90 years of monthly streamflows at each node of interest in each IUA in order to quantify surface water yield/water supply.

5.1.3 Scaling up or down to IUA level

The consequences of changes in surface water yields brought about each scenario are evaluated at the IUA scale. However, given that the simulated yield usually represents the integrated contributions of various components of the surface water system, while IUAs do not necessarily constitute logical surface water system units, the changes in yield will be either aggregated or disaggregated to the IUA scale, as the case may be. This process will also include spatial proportioning of domestic versus irrigation demands on surface resources.

5.1.4 Surface water options for meeting shortfalls or utilising surpluses

Simulation of specific scenarios can be expected to result in surface water supply shortfalls, after meeting the EC, at many nodes, while less frequently, surpluses may be expected to be indicated.

For each simulated scenario with surface water shortfalls after meeting the relevant EWRs, several options will be assessed for meeting the shortfall, including increased groundwater use where possible. Furthermore, various bulk surface water intervention options may be super-imposed on the configured models, as appropriate, in search of reconciling projected scenario surface water requirements with availability.

A list of potential surface water supply intervention options and potential implementation dates has been compiled, following the latest WCWSS Reconciliation Strategy study report, as well as the outputs of more recent water resource planning studies by DWS and relevant municipalities.

5.1.5 Inclusion of climate change

Potential changes to surface water availability due to climate change over the whole of South Africa have been projected by application of a wide range of climate change impact models for different emission scenarios (Cullis et al, 2015). The results for a “relatively dry” scenario (for example, the 10th percentile) were selected from the “drying” side of the spectrum of outcomes for the Berg Study area from the above study and super-imposed on the current-day scenario.

5.2 Groundwater

The scenarios to be assessed consider the impact of changing ecological status (and hence flow requirement), or changing water requirement (and hence ecological status). It is assumed in groundwater balance modelling, that if groundwater contribution to baseflow (GWBF) is maintained, there is no impact of increased groundwater use on GWBF, and hence groundwater’s contribution to meeting EWR (refer to ERW report). Groundwater’s role in scenario analysis is therefore to quantify the increased water demand that can be met by groundwater use. The increased demand may derive from demand driven scenarios, or from a surface water shortfall where surface water is required to meet a specific EWR in conservation driven scenarios.

To support scenario evaluation, a groundwater balance model has been established, and is described in the EWR report. The changing groundwater use, per scenario, also impacts the present status of groundwater (defined by use/recharge), and will be reported per scenario. The final Water Resources Class will therefore be related to a particular groundwater demand and recommended category for groundwater.

5.3 Wetlands

The Status Quo report (DWS, 2016b) defined the wetlands within the study area according to the spatial framework of Ecoregions to define wetland resource units. The associated hydrogeomorphic (HGM) unit characteristics for each wetland resource unit were also described. According to the “Classification system for wetlands” (Ollis et al., 2013), whilst the HGM unit is influenced by the source of water and how it moves into, through and out of an Inland System, the hydrological regime describes the behaviour of water within the system and in the underlying soil. This level of assessment is an important consideration for the development of scenarios as the hydrological regime relates to the EWRs for surface flow.

In terms of hydrological regime, rivers may be described as either perennial (flows continually throughout the year) or non-perennial (does not flow continually throughout the year). Wetlands should be classified according to the period of inundation (Level 5A) and saturation (Level 5B), together with inundation depth class (Level 5C) for permanently inundated open water bodies. Although classification in this regard may be relatively straightforward for rivers, the classification of the hydrological regime for wetlands is more complicated due the non-uniformity of wetness across a wetland.

There is also lack of quantitative date for most wetlands according to hydrology. An additional constraint for this study is the lack of baseline data for wetlands in the study area in terms of hydroperiod. The NFEPA dataset classifies wetlands up to the HGM unit (Level 4) scale of classification, whilst the FSP dataset classifies wetlands up to the hydrological regime (Level 5), but does not extend over the entire study area.

The methodology proposed for assessment is therefore as follows:

- For all important wetland systems associated with river systems the associated EWR river node will have qualitative data relating to the wetland systems in the upper catchment. This will be considered a dual “wetland” and “river” node.
- For all important wetland systems not associated with river systems, i.e. groundwater driven systems, will also be considered a “wetland node” and have associated qualitative data relating to the wetland system.

6 Conclusion and Way Forward

The results of setting up the balancing tool and running the ESBC scenario revealed some significant challenges that will need to be addressed during the scenarios evaluation phase. These include:

- Elevated current day flows during the dry season due to the Berg River being used to convey releases for downstream users including both irrigation and urban and industrial.
- Elevated current day flows during the dry season due to return flows from treatment plants.
- Significant differences in the flow requirements for river and estuary nodes.

In these cases the Berg River catchment (including the coastal catchments in G2) is different to other catchments were particularly in that it is significantly impacts by development and manged flows. These issues were noted during the Status Quo Assessment and will be addressed during the scenario analysis.

The initial analysis of the ESBC scenario, as presented in this report, does however achieve its primary objectives which are to establish the balancing tool and identify the fact that there are areas of potential surplus and deficit resulting from a minimum sustainable ecological scenario that need to be considered.

After completing the ESBC scenario, the balancing tool will be used to set up the necessary ecological category (EC) requirements to achieve the specific objectives of the alternative proposed classification scenarios including the Present Ecological Scenario (PES), the Recommended Ecological Category (REC) scenario, as well as the high development and future climate change scenarios. The scenarios analysis will then consider the associated social, economic and environmental impacts of these alternative configuration scenarios in order to assess the overall impact and to agree with stakeholders on the final recommended classification scenario for each resource unit and the individual Integrated Units of Analysis (IUA).

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