






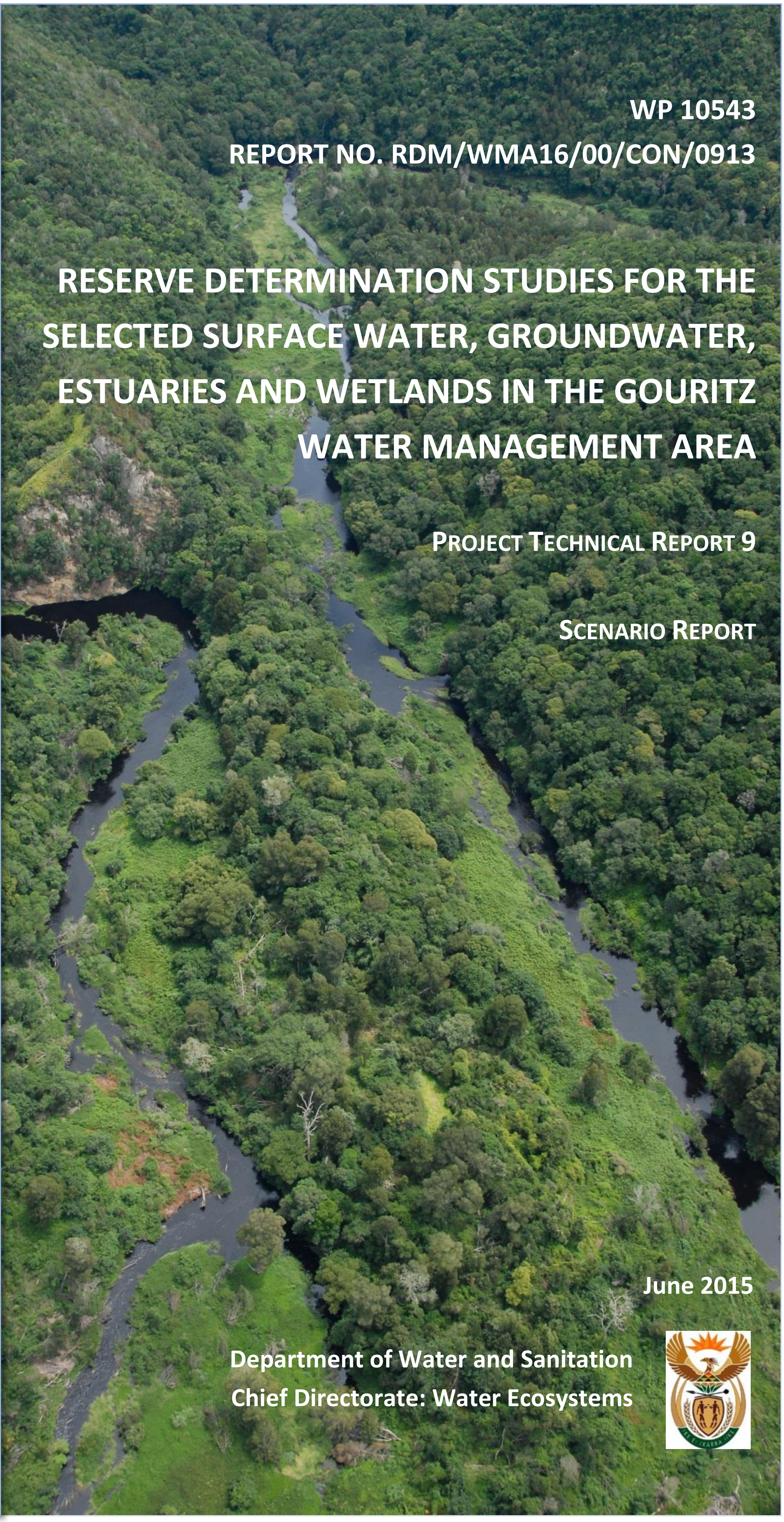

WP 10543

REPORT NO. RDM/WMA16/00/CON/0913

RESERVE DETERMINATION STUDIES FOR THE SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE GOURITZ WATER MANAGEMENT AREA

PROJECT TECHNICAL REPORT 9

SCENARIO REPORT

June 2015

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Chief Directorate: Water Ecosystems

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DOCUMENT INDEX

Reports as part of this project:

INDEX NUMBER	REPORT NUMBER	REPORT TITLE
Report Number 01	RDM/WMA16/00/CON/0113	Inception Report
Report Number 02	RDM/WMA16/00/CON/0213	Desktop EcoClassification Report
Report Number 03, Volume 1	RDM/WMA16/00/CON/0313, Volume 1	Delineation Report, Volume 1 (Groundwater, Estuaries and Wetlands)
Report Number 03, Volume 2	RDM/WMA16/00/CON/0313, Volume 2	Delineation Report, Volume 2 (Rivers)
Report Number 04	RDM/WMA16/02/CON/0413	Groundwater Report
Report Number 05	RDM/WMA16/03/CON/0513	Wetland Report
Report Number 06, Volume 1	RDM/WMA16/04/CON/0613, Volume 1	Estuaries RDM Report – Desktop Assessment
Report Number 06, Volume 2	RDM/WMA16/04/CON/0613, Volume 2	Estuaries RDM Report – Desktop Re-evaluation of the 2008 EWR Study on the Keurbooms Estuary
Report Number 07, Volume 1	RDM/WMA16/04/CON/0713, Volume 1	Estuaries RDM Report – Rapid Assessment, Volume 1 (Klein Brak Estuary)
Report Number 07, Volume 2	RDM/WMA16/04/CON/0713, Volume 2	Estuaries RDM Report – Rapid Assessment, Volume 2 (Wilderness System)
Report Number 08, Volume 1	RDM/WMA16/04/CON/0813, Volume 1	Estuaries RDM Report – Intermediate Assessment, Volume 1 (Duiwenhoks Estuary)
Report Number 08, Volume 2	RDM/WMA16/04/CON/0813, Volume 2	Estuaries RDM Report – Intermediate Assessment, Volume 2 (Gouritz Estuary)
Report Number 08, Volume 3	RDM/WMA16/04/CON/0813, Volume 3	Estuaries RDM Report – Intermediate Assessment, Volume 3 (Goukou Estuary)
Report Number 09	**RDM/WMA16/00/CON/0913**	**Scenario Report**
Report Number 10	RDM/WMA16/01/CON/1013	Rivers RDM Report – Intermediate Assessment
Report Number 11	RDM/WMA16/01/CON/1113	Rivers RDM Report – Rapid Assessment
Report Number 12	RDM/WMA16/00/CON/1213	Monitoring Report
Report Number 13	RDM/WMA16/00/CON/1313	Main Report
Report Number 14	RDM/WMA16/00/CON/1413	Study Closure Report

Bold indicates this report.

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Final Report	November 2015

EXECUTIVE SUMMARY

INTRODUCTION

The objective of this task is to describe and document the results of operational scenarios or water resource developments that may be imposed on the study area. The overarching aim of the scenario evaluation process is to find the appropriate balance between the level of environmental protection and the use of the water to sustain socio-economic activities.

YIELD MODELLING AND SCENARIO DEVELOPMENT

The aim of this report is to describe the natural, present and possible future operational flow scenarios that were developed for the Gouritz Water Management Area (WMA) for selected rivers and estuaries. Limitation of the hydrology and subsequent scenarios provided to ecologists are discussed, primarily in terms of scarcity of flow gauges across the region, the reliability of flow data sets, and the scale of the WR2005 data used as base for inputs into the water resource models used in the study. Updated hydrology was incorporated where possible and iterative modelling undertaken to decrease the present day (PD) streamflow at nodes where irrigation areas were reinstated after the 2004 floods.

The Water Resources Yield Model (WRYM), Water Resources Yield Model – Modelling Framework (WRYM-MF) and Water Resources Modelling Platform (WReMP) were used for the study. Two schematic diagrams for the WRYM system for the Gouritz River and the coastal rivers (Duiwenhoks and Goukou rivers) were developed based on the WR2005 hydrology. A WRYM system network was obtained from AURECON for the Keurbooms River. The WReMP model was used for the Wilderness and Klein Brak catchments because these catchments had already been analysed as part of a Water Research Commission (WRC) study (K5/2187).

ESTUARY SCENARIOS

Results of scenarios for Intermediate level estuary studies are presented in this document, i.e. the Goukou, Gouritz and Duiwenhoks estuaries, as well as in the Estuary Reports for the study.

RIVER SCENARIOS

Wadrif Dam was the only development with sufficient technical data to support a riverine ecological consequences assessment. However, the main impact area is the Keurbooms Estuary, with its requirements overriding those of the Keurbooms and Bitou rivers.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

Ca	Circa
CD: WE	Chief Directorate: Water Ecosystems
CITES	Convention on International Trade in Endangered Species
CMA	Catchment Management Agency
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Fisheries and Forestry
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphate
DWA	Department of Water Affairs (Name change from DWAF applicable after April 2009)
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation (Name change from DWA applicable after May 2014)
EFZ	Estuary Functional Zone
EHI	Estuarine Health Index
EI-ES	Ecological Importance and Ecological Sensitivity
EWR	Ecological Water Requirements
MAR	Mean Annual Runoff
MAR	Mean Annual Runoff
MPA	Marine Protected Area
MSL	Mean Sea Level
NBA 2011	National Biodiversity Assessment 2011
nMAR	Natural Mean Annual Runoff
NMMU	Nelson Mandela Metropolitan University
NTU	Nephelometric Turbidity Units
NWA	National Water Act
ORDS	Outeniqua Reserve Determination Study
PD	Present day
PES	Present Ecological State (or Status)
pMAR	Present day Mean Annual Runoff
PMC	Project Management Committee
ppt	Parts per thousand
RBIG	Regional Bulk Infrastructure Grant
REI	River Estuarine Interface
Sc	Scenario
WMA	Water Management Area
WR2005	Water Resources of South Africa, 2005
WR2012	Water Resources of South Africa, 2012
WRC	Water Research Commission
WRC	Water Research Commission
WReMP	Water Resources Modelling Platform
WRSM2000	Water Resources Simulation Model 2000
WRYM	Water Resources Yield Model
WRYM-MF	Water Resources Yield Model - Modelling Framework

1 INTRODUCTION

1.1 BACKGROUND

The National Water Act (Act No. 36 of 1998) (NWA), Section 3 requires that the Reserve be determined for water resources, i.e. the quantity, quality and reliability of water needed to sustain both human use and aquatic ecosystems, so as to meet the requirements for economic development without seriously impacting on the long-term integrity of ecosystems. The Reserve is one of a range of measures aimed at the ecological protection of water resources and the provision of basic human needs (i.e. in areas where people are not supplied directly from a formal water service delivery system and thus directly dependent on the resource according to Schedule 1 of the NWA). The Chief Directorate: Water Ecosystem (CD: WE) within the Department of Water and Sanitation (DWS) is tasked with the responsibility of ensuring that the Reserve is considered before water allocation and licensing can proceed.

The requirement for detailed Reserve determination studies in the Gouritz Water Management Area (WMA) became apparent for the following reasons:

- Various licence applications in the area.
- Gaps that have been identified as part of the Outeniqua Reserve Determination Study (ORDS) completed in 2010.
- The conservation status of various priority water resources in the catchment and existing and proposed impacts on them.
- Increasing development pressures and secondary impacts related from the aforementioned and the subsequent impact on the availability of water.

For management and improved governance reasons, South Africa's 19 WMAs have been consolidated into nine (9) WMAs. The Gouritz WMA (previously WMA 16) now forms part of the previous Breede WMA (WMA 8) which now is known as the Breede-Gouritz WMA. It will be governed by the Breede-Gouritz Catchment Management Agency (CMA).

1.2 STUDY AREA OVERVIEW

Although it is acknowledged that the Breede and Gouritz WMA have been consolidated, the focus of this study is the Gouritz River and its associated catchments. Therefore the study area has been described in terms of the original WMA; the Gouritz WMA – WMA 16.

The Gouritz WMA (WMA16) is situated on the south coast of the Western Cape, largely falling within the Western Cape Province, and with a surface area of approximately 53 000 km^2. It consists of primary drainage region J (approximately 90 quaternary catchments), and part of primary drainage regions K (K1 to K7) and H (H8 to H9). The WMA therefore consists of approximately 100 -105 quaternary catchments. It consists of the large dry inland area that is comprised of the Karoo and Little Karoo, and the smaller humid strip of land along the coastal belt. The main rivers are the Gouritz and its major tributaries, the Buffels, Touws, Groot, Gamka, Olifants and Kammanassie rivers, with smaller coastal rivers draining the coastal belt. All the inland rivers drain via the Gouritz into the Indian Ocean. The mean annual precipitation varies from as high as 865 mm in the coastal areas, which experience all year round rainfall, to as little as 160 mm in the drier areas inland to the north, which experience late summer rainfall.

According to DWAF (2005) regarding setting up a CMA for the WMA, the area consists of five sub-areas, i.e. the (1) Groot River (secondary catchment J1), (2) the Gamka River (secondary catchment J2), (3) the Olifants River (secondary catchment J3), (4) the Western Coastal rivers (secondary catchments H8, H9 and J4) and (5) the Eastern Coastal rivers (Secondary Catchments K1, K2, K3, K4, K5, K6 and K7).

The Gouritz River is controlled by several dams in its tributaries, including Kammanassie, Stompdrift, Koos Raubenheimer, Leeu-Gamka, Gamkapoort and Floriskraal dams. Several dams have been constructed on the coastal rivers, the largest of which being the Wolwedans Dam. About 41% of the total surface runoff from the WMA comes from the catchment of the Gouritz River, which covers the bulk of the land in the WMA. A further 46% of the flows originate from the Coastal sub-area, while the remaining 13% is contributed by the rivers west of the Gouritz River (DWAF, 2005).

Forestry and agriculture are the two primary activities in the WMA. Most of the afforestation on the coastal belt, primarily in the Plettenberg Bay / Knysna area (K1 to K7) is indigenous forestry. Most irrigation (as at 2005) is opportunistic and lucerne is predominantly grown. Grapes and apples are also grown in the Langkloof area and there is significant ostrich farming near Oudtshoorn.

The coastal belt boasts extensive eco-tourism, with the WMA also having several areas that are ecologically sensitive and important. These include the upper river reaches of the Dwyka, Leeuw and Gamka Rivers in the interior; and the Keurbooms, Knysna and South Cape Coastal River Systems, along the coast. Many of the wetland and estuary systems in the area have not been studied in detail as yet. A map of the study area is provided below (**Figure 1.1**).

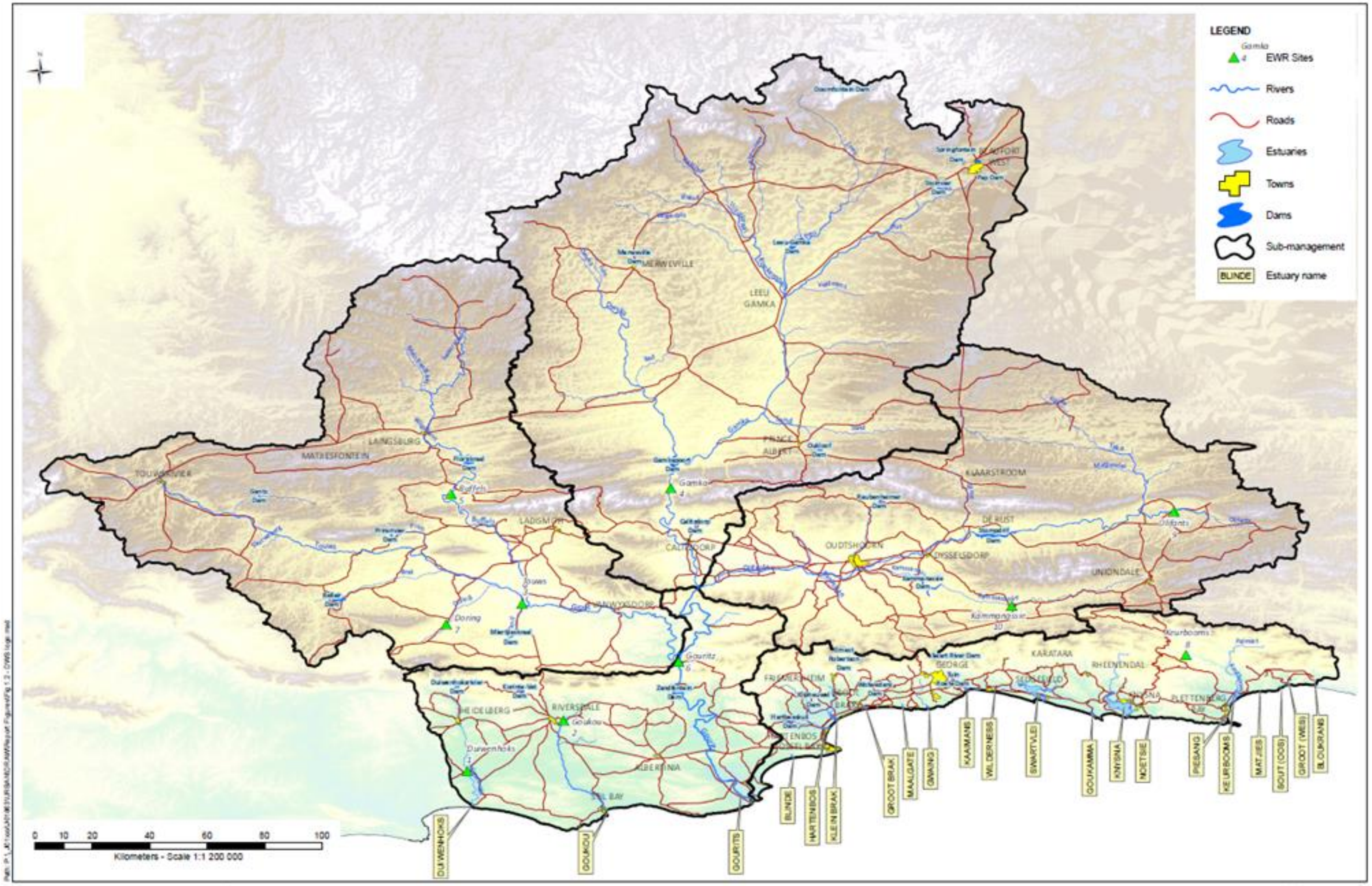


Figure 1.1 Study area

1.3 OBJECTIVES AND APPROACH

The objective of this task is to describe and document the results of operational scenarios or water resource developments that may be imposed on the study area. The overarching aim of the scenario evaluation process is to find the appropriate balance between the level of environmental protection and the use of the water to sustain socio-economic activities. Once the preferred scenario has been selected, the Reserve Ecological Category for managing the resource into the future is defined by the level of environmental protection embedded in that scenario.

The following are important requirements for operational scenarios to be evaluated during a Reserve study:

- Estuaries: The specialist team requires a range of scenarios to test the sensitivity of ecological categories. Hypothetical scenarios may therefore be included.
- Note that the estuarine team REACTS to defined operational scenarios (a top down approach), whereas the river team SETS Ecological Water Requirements (EWRs) and assesses whether scenarios impact on these requirements (a bottom up approach).
- The scenario step in the Reserve process is primarily to test sensitivities and to provide some information for planning prior to Classification. The focus should therefore be on highly likely scenarios as Classification will assess other planning recommendations.
- Scenario assessments are an important part of the Water Resource Classification process.
- The operational scenario step does not evaluate impacts of small developments such as single licenses.
- Operational scenarios are not a wish or shopping list for possible "pie-in-the-sky" developments.
- Operational scenarios cannot evaluate future developments if sufficient technical data are not available. Note the following list of requirements for dam developments, for example:
  - Location and catchment area of the dam;
  - Detailed information such as area / capacity / height relationship and Full supply area, dead storage;
  - Expected abstractions from the dam (including details such as volumes and anticipated users); and
  - Expected dam operations information.
- High resolution scenario evaluations require EWR sites in the river and selected estuary with reasonable confidence level information (e.g. suitable water level and measured hydrological data).

Due to the difficulties experienced with accessing information regarding water resource developments in the study area, a Scenario Workshop was proposed to gather information regarding potential operational scenarios to be assessed by the ecologists. The meeting was attended by a number of representatives of municipalities in the study area, the project team and the DWS, and was held at the AECOM offices in Cape Town on 24 August 2014.

The following approach was proposed during the Scenario Workshop of 24 August 2014:

- Identify the relevant systems in which scenarios will be selected.
- Identify the variables to be considered in the scenario.

- Design a matrix showing the range of scenarios each consisting of some or all of the variables which are in place.

Note that information was not available at the workshop or subsequent to the workshop to properly follow the approach above. When detailed information was sought for the scenarios identified on 24 August 2014, little was available. The only scenarios for which detailed information was available were those outlined in Aurecon's Preliminary Design Report (Eden District Municipality, 2015) for the regional integration of the bulk water supply systems of the Knysna and Bitou municipalities, which focuses on the Wadrif Dam.

Little other information regarding estuary scenarios, e.g. the building of a proposed dam on the Goukou River, could be located. As the estuary team have to evaluate scenarios to assess the sensitivity of their ecological categories, some assumptions were made. The position of the proposed Duiwenhoks dam wall was obtained from Mr John Roberts, but not that of the dam on the Goukou River. A likely position was assumed and information sent to Ms Estelle van Niekerk (AECOM) for modelling and production of the scenarios. The information was inadequate and many assumptions were made to model the impact of the developments and abstractions. This approach was followed where information were not available, and signed off by the Project Management Committee (PMC) at the meeting of December 2014. No follow-up was considered as approval had been given by the PMC. Information regarding proposed dams other than Wadrif is outlined in **Section 7** of this document.

1.4 OUTLINE OF THIS REPORT

The report outline is as follows:

- **Section1** provides general background to the study.
- **Section 2** outlines the approach taken to yield modelling and scenario development. Note that the focus of the scenario component was on estuaries, as little information was available for river scenarios.
- **Sections 3, 4** and **5** provide the results of the scenario analyses for the **Intermediate Reserve studies** on the Gouritz, Goukou and Duiwenhoks estuaries, respectively. Note that this information also appears in the Estuary Reports for the study.
- **Section 6** presents information regarding river scenarios, particularly the Wadrif Dam on the Keurbooms system.
- **Section 7** lists other potential scenarios evaluated.
- **Section 8** presents a brief conclusion.
- References are listed in **Section 9**.
- **Appendix A** shows the systems diagrams for the Gouritz, Goukou, Duiwenhoks and Keurbooms systems.
- **Appendix B** lists notes from the Scenario Meeting held on 26 August 2014.
- **Appendix C** list the comments received from various reviewers.

2 YIELD MODELLING AND SCENARIO DEVELOPMENT

(This section is authored by Estelle van Niekerk, with contributions by Stephen Mallory.)

2.1 SCENARIO SELECTION

The natural, present and possible future operational flow scenarios that were developed for the Gouritz WMA for selected rivers and estuaries are described below. The Water Resources Yield Model (WRYM) also referred to as the WRYM Modelling Framework (WRYM-MF), was used to simulate stream flow at the required locations to represent the various levels of development.

2.2 ASSUMPTIONS AND LIMITATIONS

The main limitations of the hydrology and subsequent scenarios provided to the ecologists can be summarised as follows:

- The Gouritz WMA covers a wide area with very few flow gauging stations.
- The reliability of these flow data sets are generally low to very low.
- A large portion of the Gouritz WMA is situated in the arid Karoo with prolonged times of no flow, interrupted by sporadic floods.
- The Surface Water Resources of South Africa 2005 Study (WR2005) (Middleton and Bailey, 2008; 2011) hydrological information and flow datasets were selected as base for input into the water resources models used in this study.
- The scale of the WR2005 data were not always detailed enough for the required modelling. Although some updates of the hydrology for specific rivers were done, the detail was difficult to incorporate into the WR2005 model (Middleton and Bailey, 2008; 2011). Where possible, the updated hydrology related to new studies was adopted (where flows other than the WR2005 flows were adopted, this is indicated in the appropriate sections).
- In response to flow measured during river surveys, the simulated flows were adjusted, usually by increasing the present day (PD) (2004) and changing the locations of the abstraction points.
- The estuary specialists also requested a reduction of flows at certain estuaries since their experience of the estuaries were different from the WR2005 simulated flows.
- During the 2004 floods, many irrigation areas were destroyed. Unfortunately the WR2005 base year is the year 2004 (Middleton and Bailey, 2008; 2011). Currently many of these irrigation areas were reinstated. This required some iterative modelling to decrease the PD streamflow at many nodes.
- The position and impact of the proposed developments in relation to the existing EWR points are generally such that the impact of the proposed developments could not be described by the impact of the downstream EWR.

2.3 HYDRO-METEOROLOGICAL AND OTHER RELEVANT DATA FROM RELEVANT PREVIOUS STUDIES

2.3.1 Water Research Commission (WRC): Water Resources of South Africa study (WR2005)

The surface water resources of South Africa and related data were assessed and methods developed, primarily for use in surface water resource simulations, during the WRC study: Water Resources of South Africa, 2005 (WR2005 – Middleton and Bailey, 2008; 2011). This study generated information at quaternary level for the whole of South Africa, Lesotho and Swaziland. This information cover dams, evaporation, geology, land cover, rainfall, recorded and simulated runoff, rivers, sediment yield, soils, settlement locations and vegetation types. The WR2005 time series data stretches from 1920 to 2004, i.e. 85 year record.

2.3.2 WRC: Water Resources of South Africa, 2012 study (WR2012)

The WRC study: Water Resources of South Africa, 2012 (WR2012) is an update of its predecessor, the WR2005. The WR2015 hydro-meteorological time series data stretches from 1920 to 2009 (WRC, 2015).

2.3.3 DWS study: Outeniqua Coast Water Situation study

Long term (hydrological years 1920 to 2003) flow sequences for natural and PD (2005) conditions were simulated for each of the quaternary catchments in the Outeniqua Coast Water Situation Study. This study covered quaternary catchments H90A to K60B as well as K60G. Results were captured in Report 8 of the report series (DWA, 2007).

2.3.4 WRYM set-up and hydro-meteorological data for the Keurbooms River to model the Bitou's supply system

The hydro-meteorological data and WRYM set-ups for the Keurbooms River were supplied by AURECON and covers the hydrological years 1930 to 2010. (F. Denys, *Pers. Comm*., August 20, 2014).

2.3.5 WRC: Desktop assessment of temperate estuaries in South Africa

This WRC project: Hydrological Analysis of South Africa's Estuaries (Mallory, 2014) produced natural and PD flow time series for all the temperate estuaries in South Africa. The water resources model setups and results of the study were used and expanded on for the Wilderness and Klein Brak catchments.

2.4 MODELS

Two models were used to simulate the scenarios as follows:

- Water Resources Yield Model – Modelling Framework (WRYM-MF).
- Water Resources Modelling Platform (WReMP) (Mallory *et al.*, 2011).

These models are described in more detail below:

2.4.1 WRYM and WRYM-MF

The scenario analysis of the Gouritz WMA was undertaken using Version 3.2.8 of the WRYM-MF, developed by the DWS which incorporates the WRYM module. The WRYM was developed by the DWS for the purpose of modelling complex water resource systems and is used together with other simulation models, pre- processors and utilities for the purpose of planning and operating South Africa's water resources. The WRYM uses a sophisticated network solver in order to analyse complex multi-reservoir water resource systems for a variety of operating policies and is designed for the purpose of assessing a system's long- and short-term yields. Analyses are undertaken based on a monthly time-step and for constant development levels, i.e. the system configuration and water use characteristics remain unchanged over the simulation period. The major strength of the model lies in the fact that it allows for the configuration of most water resource system networks using basic building blocks. A system network and the relationships between its elements are therefore defined by means of input data, rather than by fixed algorithms embedded in the source code of the model. The WRYM-MF was used to simulate stream flow at the required locations to represent the various levels of development, i.e. natural, PD and expected future developments. Monthly flow data were simulated at the defined EWR site of interest to be analysed by the ecologists.

Two schematic diagrams for the WRYM system for the Gouritz River and the coastal rivers (Duiwenhoks and Goukou rivers) were developed based on the WR2005 hydrology. A WRYM system network was obtained from Aurecon for the Keurbooms River (F. Denys, *Pers. Comm*., August 20, 2014). These three system diagrams are attached in **Appendix A**.

2.4.2 WReMP

The WReMP model (Mallory *et al.*, 2011) was used for the Wilderness and Klein Brak catchments because these catchments had already been analysed as part of the WRC study K5/2187 (Mallory, 2014). WReMP is similar to WRYM in that it is also a monthly time step model using nodes and channels to represent a catchment or system of catchments. The 'network solver' of WReMP, however, strives to model systems as they are actually operated in practice rather than use a penalty structure (DWAF, 1998). The end result in terms of modelled flows produced by WReMP is very similar to that of WRYM.

2.5 EVALUATION OF STREAM FLOW GAUGES

Observed streamflow data provide a critical input to water resources studies and are used in the process of calibrating the Water Resources Simulation Model 2000 (WRSM2000) rainfall-runoff model. It is used as a basis for generating natural streamflow data time-series. The simulated data are used as a direct input to the water resource system analyses using the WRYM-MF.

The modelled natural and PD streamflow at the EWR sites rely to a great extent on the observed historical streamflow and land-use characteristics to establish the confidence in the simulated data.

Although the selection of EWR sites, in general take into consideration the availability of daily observed streamflow from a close-by flow gauging station, there is unfortunately not always a streamflow gauge close to the point of interest to get an indication of the historical daily flow variation.

No streamflow gauges were available at the selected EWR sites in the Doring, Olifants and Kammanassie rivers for use in the EWR determinations and subsequent analyses. The river EWR sites with the characteristics of the streamflow gauges are shown in **Table 2.1**.

Table 2.1 Characteristics of the streamflow gauges associated with the EWR sites

EWR site	River	Quat[1]	Gauge	Period	Comments on gauge		
					DWS	WR2012	Field observations
H8DUIW-EWR1	Duiwen-hoks	H80E	H8H001	1967 to 2014	Flood section only	Used	It is a poor gauge. Especially the period after the January 2014 floods. It was completely silted and filled with debris.
H9GOUK-EWR2	Goukou	H90C	H9H005	1969 to 2014	Not available	Not used	H9H005 upstream of site.
J1TOUW-EWR3	Touws	J12M	J1H018	1982	Good up to Discharge Table limit	Used	The flow gauge J1H018 is upstream of the EWR site. The gauge is only good for measuring low flows.
J2GAMK-EWR4	Gamka	J25A	J2H016	1964 to date	Siltation problems. Accurate for low but not high flows	Not used	J2H016 measures river releases from Gamkapoort Dam. The spill from the dam can be used to estimate high flow.
JIBUFF-EWR5	Buffels	J11H	J1H028	1964 to date	Not available	Not used	Gauge downstream of Floriskraal Dam. J1H028 measures the river releases from the dam.
J4GOUR-EWR6	Gouritz	J40B	J4H002	1990 to date	Not good for low flows. Good for high flows	Used	J4H002 is only a rated section with many gaps. Large discrepancies between the actual data measured by the Study Team and the gauge.
K6KEUR-EWR8	Keur-booms	K60C	K6H001 and K6H019	K6H001: 1961 to date. K6H019: 1988 to date	K6H001: Rea-sonable but not for high flows. K6H019: Good up to Discharge Table limit	K6H001-Used	No reliable gauge present. K6H001 is far upstream and K6H019 far downstream from the EWR site. The gauge station is downstream of the confluence with a large tributary.

1 Quaternary catchment

2.6 RIVER ASSESSMENTS

2.6.1 RAPID Level Reserve Determinations

A total of ten EWR sites were selected in the study area of which five EWR sites were assessed on a Rapid level of Reserve determination:

- H8DUIW-EWR1.
- H9GOUK-EWR2.
- J1DORI-EWR7.
- J3OLIF-EWR9.
- J3KAMM-EWR10.
- The detail required for a Rapid level is significantly smaller than that required for an Intermediate Reserve determination and hence the observed flows are not used for a Rapid determination.

Table 2.2 shows the hydrological characteristics, including the natural Mean Annual Runoff (nMAR) and PD Mean Annual Runoff (pMAR) at the Rapid sites.

Table 2.2 Characteristics of the hydrology at the Rapid level EWR sites

EWR site	River	Quat	Flow gauge	nMAR (million m^3)	pMAR (million m^3)	Hydrology used	WRYM system	WRYM channel number[1]
H8DUIW-EWR1	Duiwenhoks	H80E	H8H001 and H8R001	83.67	79.80	WR2012 (WRC, 2015)	Coastal	7
H9GOUK-EWR2	Goukou	H90C	H9H005	54.09	46.04	WR2012 (WRC, 2015)	Coastal	9
J1DORI-EWR7	Doring	J12L	None	4.52	0.86	WR2012 (WRC, 2015)	Gouritz	361
J3OLIF-EWR9	Olifants	J31D	None	13.76	12.63	WR2012 (WRC, 2015)	Gouritz	353
J3KAMM-EWR10	Kammanassie	J34C	None	20.57	19.63	WR2012 (WRC, 2015)	Gouritz	141

1 Channel number on the WRYM schematic

Note that the Olifants site required a different approach from a Rapid or Intermediate methodology due to the conditions at the EWR site. It was originally planned to be assessed at an Intermediate level, but as Intermediate Reserve methodology could not be followed due to flow conditions at the site, the assessment was conducted using methods more similar to Rapid Reserve methodology.

The WRYM-MF was used to simulate stream flow at the rapid EWR sites for the natural and present development for the Rapid Reserve determinations with the MARs shown in **Table 2.2**, as follows:

Duiwenhoks: H8DUIW-EWR1
Natural streamflow: The natural quaternary data based on the WR2005 (Middleton and Bailey, 2008; 2011) was scaled to obtain representative natural flow at this site.

Present streamflow: The WR2005 (Middleton and Bailey, 2008; 2011) simulated data with the 2004 development level was used as input into the WRYM. The impact of the current use on the streamflow is small with a reduction of less than 2% from the natural streamflow. The streamflow from catchment upstream of the EWR site is largely natural and the present streamflow has decreased by only 5%.

Goukou River: H9GOUK-EWR2
Natural streamflow: The natural quaternary data from the WR2005 study (Middleton and Bailey, 2008; 2011) were scaled to obtain representative natural flow at the EWR site.

Present streamflow: Quaternary WR2005 (Middleton and Bailey, 2008; 2011) streamflow data were used for modelling. Modifications were done to the WR2005 set-up by moving the large irrigation abstraction upstream of the EWR site with access to water from H90A, to a point downstream of the EWR. As a result, PD development levels reduced the natural streamflow by 15%.

Doring River: J1DORI-EWR7
Natural streamflow: The natural quaternary data are based on the WR2005 study (Middleton and Bailey, 2008; 2011) and were scaled to obtain representative natural flow at the EWR site. The nMAR is very small at only 4.5 million m^3/a (see **Table 2.2**) and a monthly model cannot simulate the variation in these flows accurately.

Present streamflow: Flow data were based on the WR2005 (Middleton and Bailey, 2008; 2011) hydrological data. There is an 80% reduction in MAR from natural. The WR2005 (Middleton and Bailey, 2008; 2011) set-up was refined but there was not enough information available to improve the confidence in the modelled results. Only 19% of the natural streamflow are available under PD conditions.

Olifants River: J3OLIF-EWR9
Natural streamflow: The natural quaternary data were from the WR2005 study (Middleton and Bailey, 2008; 2011) and were scaled to obtain representative natural flow at the EWR site. The catchment area is small with uncertainties regarding the historical agriculture abstractions and groundwater-surface water interaction, therefore the confidence in the data is low.

Present streamflow: The PD flow data were based on the WR2005 (Middleton and Bailey, 2008; 2011) hydrological data. More detailed modelling is necessary to model the surface/groundwater. Abstraction is mostly from groundwater but was assumed to be modelled as from surface water to compensate for the groundwater-surface water interaction. The PD runoff is currently 92% of the natural streamflow.

Kammanassie River: J3KAMM-EWR10

Natural streamflow: The natural quaternary data were based on the WR2005 study (Middleton and Bailey, 2008; 2011) and were scaled to obtain representative natural flow at the EWR site.

Present streamflow: Flow data were based on the WR2005 (Middleton and Bailey, 2008; 2011) hydrological data. There is a small reduction (less than 5%) in the pMAR from natural. There was low confidence in information on water use and dams upstream of the EWR site.

2.6.2 INTERMEDIATE Level Reserve Determination

Meetings with water managers, who attended the Scenario workshop in August 2014, and DWS representatives were held to identify the impact of any proposed water schemes in the WMA. Streamflow data at the points of interest were provided. Only natural and PD scenarios were developed for the scenario analyses since the locations of the EWRs relative to new developments proved to be insignificant in relation to the locations and size of these proposed developments (see **Section 7** for more detail).

Table 2.3 shows hydrological characteristics at the Intermediate sites.

Table 2.3 Characteristics of the hydrology at the Intermediate level EWR sites

EWR site	River	Quat	Flow gauge	Simulation nMAR (million m^3/a)	PMAR (million m^3/a)	Hydrology used	WRYM system	WRYM channel number
J1TOUW-EWR3	Touws	J12M	J1H018	45.02	22.26	WR2012 (WRC, 2015)	Gouritz	351
J2GAMK-EWR4	Gamka	J25A	J2H016	85.54	61.69	WR2012 (WRC, 2015)	Gouritz	349
J1BUFF-EWR5	Buffels	J11H	J1H028	29.31	10.65	WR2012 (WRC, 2015)	Gouritz	352
J4GOUR-EWR6	Gouritz	J40B	J4H002	543.52	310.35	WR2012 (WRC, 2015)	Gouritz	347
K6KEUR-EWR8	Keurbooms	K60C	K6H001 and K6H019	49.81	30.45	Denys, 2014	Keurbooms	74

The WRYM-MF was used to simulate stream flow at the EWR sites for the natural and present development for the Intermediate reserve determinations as follows:

Touws River: J1TOUW-EWR3

Measured streamflow: The flow gauge J1H018 is situated upstream of the EWR site. Observations started in 1982 and the station is currently still operational. The gauge is only good for measuring low flows.

Natural streamflow: The quaternary data from WR2005 (Middleton and Bailey, 2008; 2011) were scaled to obtain natural flow at the EWR site. There are large uncertainties regarding the historical agriculture abstractions and sub-surface flow, which means that the natural flows may be under-estimated.

Present streamflow: PD irrigation abstractions from the WR2005 (Middleton and Bailey, 2008; 2011) database were included in the WRYM to provide present (2004) flow at the EWR site. There is a great deal of uncertainty about the extent of current irrigation upstream of the EWR site particularly given that the 1998 irrigated areas are larger than those in 2004. Where there were large discrepancies between the 2004 and 1998 irrigated areas, the higher 1998 areas were used to simulate irrigation demands. The PD streamflow is approximately half of the nMAR.

Gamka River: J2GAMK-EWR4

Measured streamflow: The flow gauge J2H016 measures releases and spill from Gamkapoort Dam. Observations started in 1964 and continue to date.

Natural streamflow: The WR2005 (Middleton and Bailey, 2008; 2011) natural quaternary data were scaled to obtain natural flow at the EWR site. The catchment area is large with uncertainties regarding the historical agriculture abstractions, which means that the natural flows may be under-estimated; therefore the confidence in the data is low.

Present streamflow: Irrigation abstractions were subtracted from the WR2005 data (Middleton and Bailey, 2008; 2011) to provide PD flow at the EWR site. The PD streamflow is approximately 30% lower than the natural streamflow and 72% of the natural streamflow remains under the PD development conditions.

Buffels River: J1BUFF-EWR5

Measured streamflow: The flow gauge J1H028 is downstream of Floriskraal Dam and measures releases from the Floriskraal Dam.

Natural streamflow: The WR2005 natural quaternary data were scaled to obtain natural flow at the EWR site. The catchment area is large with uncertainties regarding the historical agriculture abstractions, which means that the natural flows may be under-estimated.

Present streamflow: Irrigation abstractions were subtracted from the WR2005 data (Middleton and Bailey, 2008; 2011) to provide PD flow at the EWR site. There is low confidence in information on water use upstream of the EWR site and gauge J1H028 cannot be used to assess this. PD land-use has decreased the PD streamflow to less than 40% of the natural flow.

Gouritz River: J4GOUR-EWR6

Measured streamflow: The flow gauge J4H002 is only a flood section and only good for high flows. Gauge data starts from 1964 to date.

Natural streamflow: The WR2005 (Middleton and Bailey, 2008; 2011) natural quaternary data were scaled to obtain natural flow at the EWR site. There is a very large upstream catchment with uncertainties in the upstream land-use and river losses. Relative good calibrations were achieved.

Present streamflow: Irrigation abstractions were subtracted from the WR2005 (Middleton and Bailey, 2008; 2011) data to provide PD flows at the EWR site. There is a great deal of uncertainty about the extent of current irrigation upstream of the EWR site which comprises the entire Gouritz catchment, particularly given that the 1998 irrigated areas are larger than those in 2004. Where there were large discrepancies between the 2004 and 1998 irrigated areas, the higher 1998 areas were used to simulate irrigation demands. Slightly more than half (57%) of the natural streamflow are currently available at the EWR site.

Keurbooms River: K6KEUR-EWR8
Measured streamflow: Flow gauge K6H001 is far upstream and flow gauge K6H019 far downstream from the EWR site.

Natural streamflow: The natural quaternary data were obtained via Email from Aurecon (F. Denys, *Pers. Comm*., August 20, 2014) and were scaled to obtain representative natural flow at the EWR site.

Present streamflow: There is a reduction in present of nearly 40% in MAR from natural. The PD WRYM set-up for the Bitou was obtained from Aurecon (F. Denys, *Pers. Comm*., August 20, 2014) as the Aurecon data were compiled as part of a detailed study and are thus of a higher confidence than WR2005 data (Middleton and Bailey, 2008; 2011). However, no afforestation or alien invasive plants were included in this set-up, which could have resulted in higher than PD base flows.

2.7 ESTUARY ASSESSMENTS

Selected scenarios as requested by the estuarine team were simulated at the following estuaries:

- Gouritz: Intermediate study.
- Duiwenhoks: Intermediate study.
- Goukou: Intermediate study.
- Wilderness system: Rapid study.
- Klein Brak: Rapid study.

2.7.1 Gouritz Estuary

Four scenarios, in addition to the natural and PD streamflow for the Gouritz Estuary, were simulated and provided in **Table 2.4**.

Table 2.4 Gouritz Estuary flow scenarios

Scenario (Sc)	Description	MAR (million m^3)
Reference	Natural flow before development.	623.52
Present	2004-development level.	377.23
Sc 1	Restore about 50% of baseflow (spreadsheet manipulation).	504.48
Sc 2	Restore about 25% of baseflow (spreadsheet manipulation).	440.85
Sc 3	Reduce pMAR by 15% (present WRYM with dummy dam and abstraction upstream of estuary.	296.6
Sc 4	Reduce pMAR by about 25% (present WRYM with large dam and large abstraction upstream of estuary).	225.8

2.7.2 Duiwenhoks Estuary

Four scenarios, in addition to the natural and PD streamflow for the Duiwenhoks Estuary, were simulated and presented in **Table 2.5**.

Table 2.5 Duiwenhoks Estuary flow scenarios

Scenario	Description	MAR (million m^3)
Reference	Natural.	89.29
Present	PD.	72.91
Sc 1	Returning 50% of natural base flows (↓ afforestation/water use).	85.43
Sc 2	With low flow EWR.	73.01
Sc 3	Dam with 1.5 million m^3 capacity, abstracting 9.5 million m^3/annum.	63.63
Sc 4	Worst case dam development.	49.93

2.7.3 Goukou Estuary

Four scenarios, in addition to the natural and PD streamflow for the Goukou Estuary, were simulated as indicted in **Table 2.6**.

Table 2.6 Goukou Estuary flow scenarios

Scenario	Description	MAR (million m^3)
Reference	Natural flow before development.	115.95
Present	PD (2004) development.	91.73
Sc 1	Restore about 50% of baseflow (Present WRYM with no afforestation and decreased abstractions).	101.7
Sc 2	Reduce pMAR by about 10% (present WRYM with two dummy dams with abstractions).	82.57
Sc 3	Reduce pMAR by about 15% (Scenario 2 with increased abstraction).	73.41
Sc 4	Reduce pMAR by about 30% (Scenario 3 with increased abstraction).	55.64

2.7.4 Klein Brak Estuary

Scenarios to illustrate the present, natural and the reduction of 40%, 50% and 60% in the natural streamflow were provided. The flow was reduced by introducing a hypothetical dam on the Moordkuil River. Details of these scenario are as follows:

- Scenario 1: A dam of 10 million m^3 on the Moordkuil River and an abstraction of 12.5 million m^3/a from the dam.
- Scenario 2: Increase the dam to 20 million m^3 and an abstraction of 20 million m^3/a. Add a run-of-river abstraction of 3 million m^3/a from K10D.
- Scenario 3: Increase the dam to 20 million m^3 and an abstraction of 13.5 million m^3/a together with a run-of-river abstraction of 3 million m^3/a from K10D.

The results of these analyses are summarised below in **Table 2.7**.

Table 2.7 Klein Brak flow scenarios

Scenario	Description	MAR (million m^3)
Reference	Natural flow before development.	50.7
Present	PD development.	37.7
Sc 1	Reduce pMAR by about 60%.	30.1
Sc 2	Reduce pMAR by about 40%.	20.2
Sc 3	Reduce pMAR by about 50%.	25.2

2.7.5 Touws Estuary

Scenarios to illustrate the present, natural and the reduction of 10%, 20%, 30%, 40% and 60% in the natural streamflow were presented to the estuary specialists. The flow was reduced by introducing a hypothetical dam near the inflow to the estuary from which water is abstracted.

The results of these analyses are summarised below:

Scenario	Description	MAR (million m^3)
Reference	Natural flow before development.	29.7
Present	PD development.	25.2
Sc 1	Reduce Present MAR by about 10%.	26.2
Sc 2	Reduce Present MAR by about 20%.	23.2
Sc 3	Reduce Present MAR by about 30%.	20.6
Sc 4	Reduce Present MAR by about 40%.	17.0
Sc 5	Reduce Present MAR by about 60%.	11.6

3 SCENARIO RESULTS: GOURITZ ESTUARY

(This section is extracted from the Gouritz estuary report for the study, as authored by the estuary team and compiled by Dr Susan Taljaard – DWS, 2015a.)

3.1 INTRODUCTION

The Gouritz Estuary is a medium/large (245 ha open water area), permanently open system, entering the sea through a shallow dynamic mouth that shifts according to tidal and freshwater flood regimes. Geographically the estuary lies in the warm temperate Southern Cape region approximately 33 km to the south-west of Mossel Bay and enters the Indian Ocean between Bull Point and Kanonpunt. The coastal town of Gouritsmond lies immediately to the west of the mouth and the resorts of Kanon, Fransmanshoek and Vleesbaai lie to the east.

The geographical boundaries of the estuary are defined as follows:

Downstream boundary:	Estuary mouth: 34°20'37.31"S; 21°53'7.21"E
Upstream boundary:	34° 9'27.91"S; 21°44'36.78"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

3.1.1 Present Ecological State

The Estuarine Health Index (EHI) score for the Gouritz Estuary is 61, thus a Present Ecological State (PES) of Category C/D (see **Table 3.1**).

Table 3.1 Gouritz Estuary: PES

Variable	Weight	Score
Hydrology	25	39
Hydrodynamics and mouth condition	25	92
Water quality	25	80
Physical habitat alteration	25	44
Habitat health score		**64**
Microalgae	20	71
Macrophytes	20	30
Invertebrates	20	55
Fish	20	60
Birds	20	75
Biotic health score		**58**
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		**61**
PRESENT ECOLOGICAL STATUS (PES)		**C/D**
OVERALL CONFIDENCE		**Medium**

3.1.2 Ecological importance

The Gouritz Estuary forms part of the core set of priority estuaries (i.e. a desired protected area) identified in the National Estuary Biodiversity Plan in need of protection to meet biodiversity targets under the Biodiversity Act and National Estuarine Management Protocol (Integrated Coastal Management Act). In order to meet these requirements the Gouritz Estuary needs partial protection (e.g. include a no-take fishing zone and 50% of riverine area left untransformed). The system is also important as a nursery for exploited marine-living fish (e.g. collapsed stock: dusky cob, white steenbras), as well as for catchment flows to the marine environment (e.g. sediment and detritus) and coastal connectivity, e.g. way point for fish.

3.2 DESCRIPTION AND CONSEQUENCES OF SCENARIOS

The future scenarios presented in **Table 2.4** were assessed for the Gouritz Estuary. The occurrences of the flow distributions (mean monthly flows in m^3/s) under the future scenarios of the Gouritz Estuary, derived from a 85-year simulated data set are provided in **Tables 3.2** to **3.5** and in **Figures 3.1** to **3.4**. The full sets 85-year series of simulated monthly runoff data for the future Scenarios are provided in **Tables 3.6** to **3.9**.

Table 3.2 Gouritz Estuary: Summary of the monthly flow (in m³/s) distribution under flow Sc 1

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	96.1	303.3	148.6	192.2	272.2	185.9	180.7	83.3	152.1	96.7	134.1	98.9
99	92.1	132.7	130.7	119.9	113.8	139.5	152.2	83.3	120.1	74.6	127.3	84.9
90	40.2	62.4	43.5	25.0	52.7	52.9	51.0	52.9	31.5	23.6	32.7	38.0
80	23.7	27.1	22.3	12.5	13.8	22.3	33.1	22.4	16.1	15.7	15.9	21.4
70	15.1	18.0	12.7	7.7	6.9	14.3	18.7	15.6	11.2	11.3	12.2	10.4
60	8.9	9.6	6.9	4.3	3.6	9.6	13.7	11.9	8.7	7.9	9.8	7.7
50	6.7	5.5	3.9	2.1	2.7	7.8	7.0	8.3	7.1	6.8	7.8	6.6
40	4.5	4.8	3.0	1.6	2.0	4.8	4.5	5.7	5.5	5.2	6.4	5.1
30	3.7	2.9	2.1	1.4	1.2	2.7	3.5	4.4	4.0	4.1	5.0	4.2
20	3.2	2.0	1.5	0.9	1.0	1.7	2.4	2.3	2.7	3.2	3.7	3.5
10	2.4	1.4	1.1	0.7	0.8	1.0	1.3	1.7	1.9	2.2	2.8	2.6
1	1.3	0.9	0.5	0.2	0.4	0.5	0.4	1.0	0.8	1.3	1.9	1.7
0.1	0.9	0.8	0.3	0.2	0.3	0.4	0.2	0.9	0.7	0.9	1.8	1.5

Table 3.3 Gouritz Estuary: Summary of the monthly flow (in m³/s) distribution under flow Sc 2

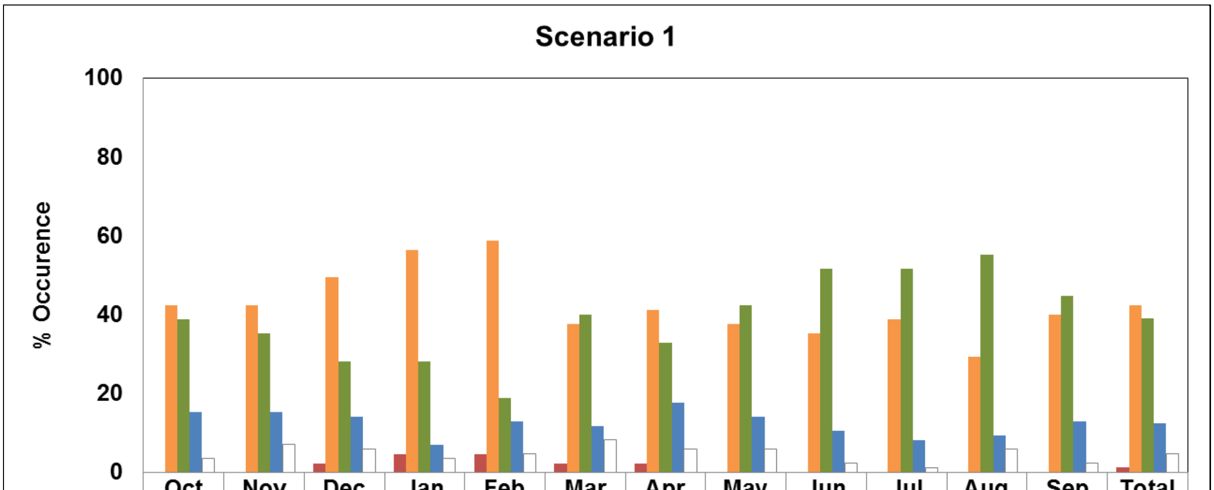
%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	95.3	303.3	148.6	192.2	271.4	185.9	180.7	82.9	152.1	83.9	134.1	98.2
99	83.9	132.7	130.7	119.9	105.8	139.5	152.2	79.2	120.1	70.2	127.3	77.8
90	34.7	56.3	35.8	19.5	41.5	46.1	45.8	46.8	28.6	20.7	30.4	34.9
80	21.0	22.2	17.2	7.8	10.1	18.4	28.8	20.7	13.8	13.4	14.6	18.6
70	12.9	13.6	9.0	5.6	4.5	10.0	15.5	13.0	9.8	9.9	11.2	8.6
60	7.1	6.5	4.5	2.4	2.8	6.7	11.1	10.8	7.7	6.8	8.3	6.1
50	5.6	4.0	2.8	1.1	1.7	4.7	5.0	7.4	6.1	5.8	7.0	4.8
40	2.9	2.9	1.6	0.8	1.2	3.0	3.4	5.2	4.7	4.6	5.2	4.0
30	2.5	1.9	1.1	0.7	0.7	1.7	2.1	3.6	3.5	3.3	4.1	3.2
20	2.1	1.1	0.8	0.4	0.5	1.0	1.6	2.2	2.1	2.7	3.2	2.6
10	1.6	0.8	0.5	0.4	0.4	0.5	0.7	1.5	1.5	1.8	2.2	1.8
1	0.7	0.5	0.2	0.1	0.2	0.2	0.2	0.9	0.5	1.0	1.4	1.3
0.1	0.5	0.5	0.2	0.1	0.1	0.2	0.1	0.9	0.4	0.6	1.2	1.0

Table 3.4 Gouritz Estuary: Summary of the monthly flow (in m^3/s) distribution under flow Sc 3

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	76.5	238.5	114.3	157.8	209.1	144.1	143.4	71.4	117.2	58.5	105.6	81.9
99	62.1	107.1	101.4	95.5	77.5	116.8	124.0	62.3	92.7	52.1	105.4	58.8
90	25.1	40.2	22.2	11.7	22.8	33.5	32.1	33.1	19.5	14.5	20.3	25.9
80	14.2	14.5	10.2	3.1	4.1	10.8	20.3	14.9	9.8	10.1	10.6	12.2
70	7.7	6.9	3.6	0.9	0.6	4.9	9.9	8.4	6.9	7.3	7.9	5.2
60	4.0	3.0	0.7	0.1	0.2	3.0	7.3	7.0	5.0	4.7	5.8	3.3
50	2.8	1.0	0.2	0.0	0.0	1.1	2.2	4.2	3.9	3.8	4.7	2.8
40	0.9	0.5	0.1	0.0	0.0	0.4	1.4	3.2	3.0	3.2	3.6	1.8
30	0.6	0.3	0.0	0.0	0.0	0.1	0.6	1.4	2.3	2.0	2.5	1.4
20	0.5	0.2	0.0	0.0	0.0	0.0	0.2	0.9	1.3	1.6	1.9	1.0
10	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.6	1.0	1.2	0.5
1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.2
0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.2

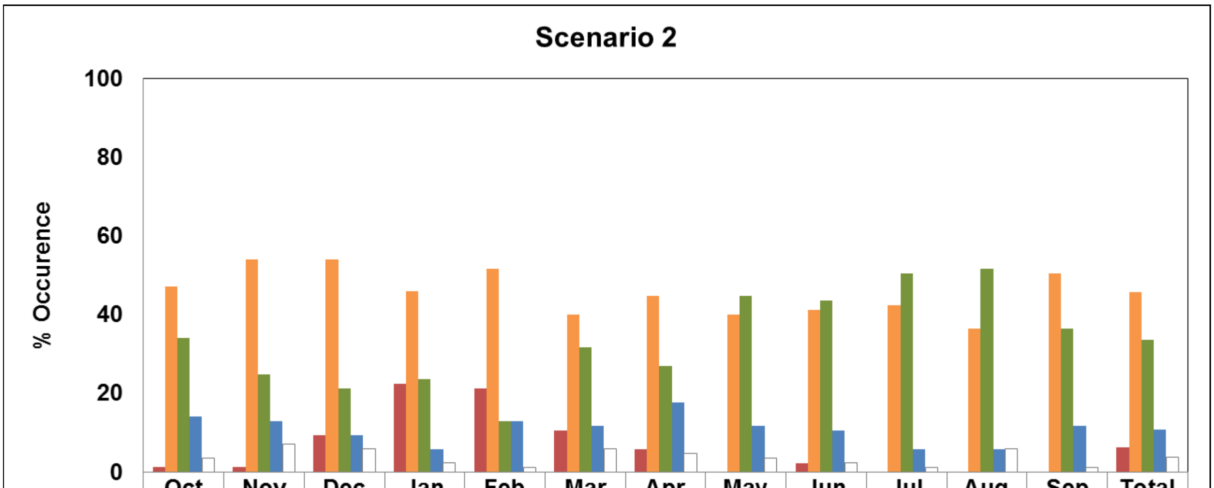
Table 3.5 Gouritz Estuary: Summary of the monthly flow (in m^3/s) distribution under flow Sc 4

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	57.5	174.6	81.9	116.5	150.1	103.3	107.3	54.2	83.9	43.6	84.8	65.7
99	49.4	78.5	73.7	70.8	57.0	83.9	96.5	47.4	66.4	38.3	78.2	43.9
90	19.9	30.4	16.7	8.6	16.7	25.2	24.1	24.7	14.7	11.1	14.9	20.7
80	10.9	11.8	7.9	2.6	3.3	8.7	15.7	11.5	7.9	7.6	8.1	9.3
70	6.1	5.3	2.8	0.8	0.7	3.7	7.5	6.7	5.1	5.7	6.2	4.0
60	3.5	2.5	0.7	0.2	0.2	2.5	5.6	5.1	3.9	3.7	4.5	2.7
50	2.3	1.0	0.3	0.0	0.0	1.1	1.8	3.2	3.2	3.1	3.6	2.3
40	0.9	0.5	0.1	0.0	0.0	0.4	1.1	2.6	2.3	2.4	3.0	1.5
30	0.6	0.3	0.0	0.0	0.0	0.1	0.6	1.3	1.9	1.7	2.0	1.2
20	0.5	0.2	0.0	0.0	0.0	0.0	0.3	0.8	1.1	1.3	1.5	0.9
10	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.6	0.9	1.0	0.6
1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.6	0.3
0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.3



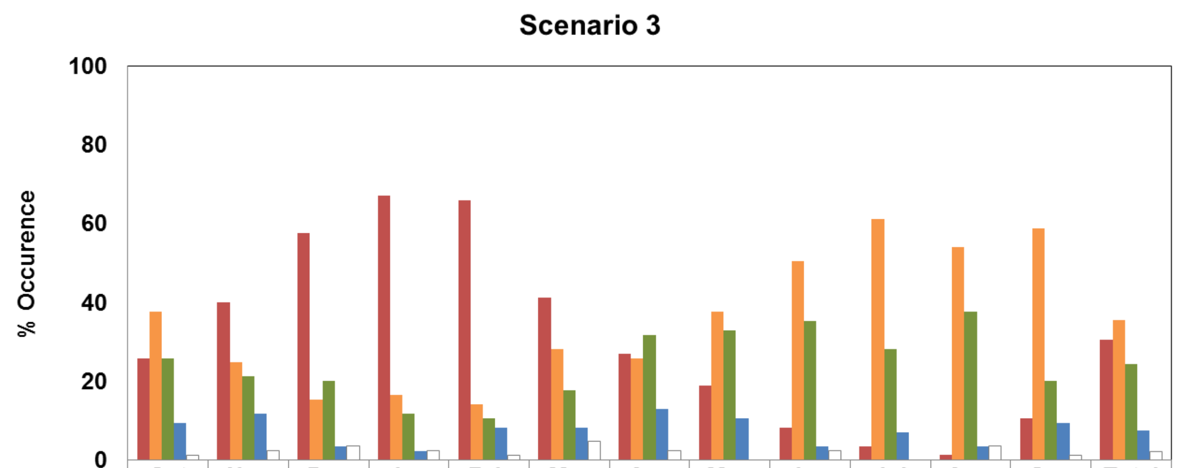
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	2	5	5	2	2	0	0	0	0	0	1
State 2	42	42	49	56	59	38	41	38	35	39	29	40	42
State 3	39	35	28	28	19	40	33	42	52	52	55	45	39
State 4	15	15	14	7	13	12	18	14	11	8	9	13	12
State 5	4	7	6	4	5	8	6	6	2	1	6	2	5

Figure 3.1 Gouritz Estuary: Occurrence of the various abiotic states under flow Sc 1



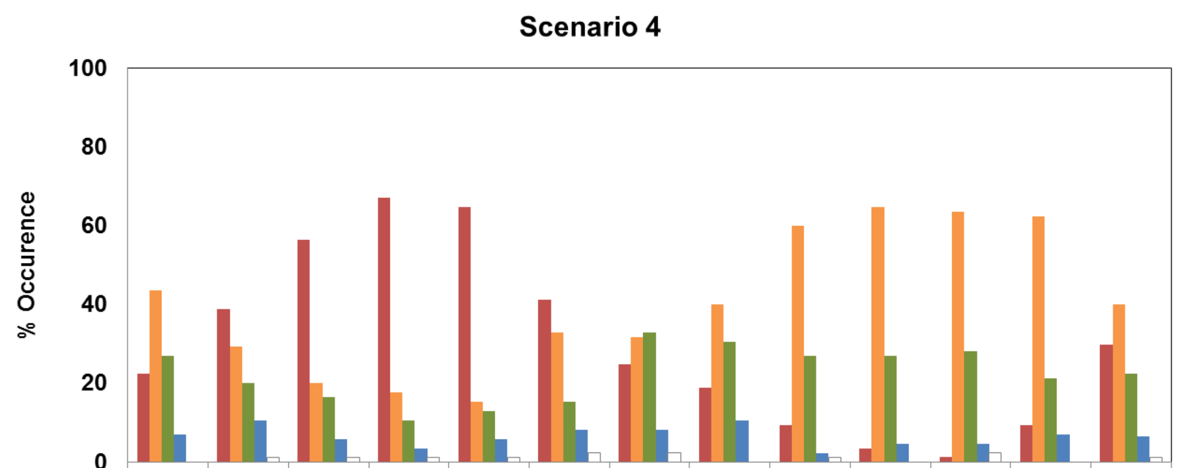
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	1	1	9	22	21	11	6	0	2	0	0	0	6
State 2	47	54	54	46	52	40	45	40	41	42	36	51	46
State 3	34	25	21	24	13	32	27	45	44	51	52	36	34
State 4	14	13	9	6	13	12	18	12	11	6	6	12	11
State 5	4	7	6	2	1	6	5	4	2	1	6	1	4

Figure 3.2 Gouritz Estuary: Occurrence of the various abiotic states under flow Sc 2



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	26	40	58	67	66	41	27	19	8	4	1	11	31
State 2	38	25	15	16	14	28	26	38	51	61	54	59	35
State 3	26	21	20	12	11	18	32	33	35	28	38	20	24
State 4	9	12	4	2	8	8	13	11	4	7	4	9	8
State 5	1	2	4	2	1	5	2	0	2	0	4	1	2

Figure 3.3 Gouritz Estuary: Occurrence of the various abiotic states under flow Sc 3



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	22	39	56	67	65	41	25	19	9	4	1	9	30
State 2	44	29	20	18	15	33	32	40	60	65	64	62	40
State 3	27	20	16	11	13	15	33	31	27	27	28	21	22
State 4	7	11	6	4	6	8	8	11	2	5	5	7	7
State 5	0	1	1	1	1	2	2	0	1	0	2	0	1

Figure 3.4 Gouritz Estuary: Occurrence of the various abiotic states under flow Sc 4

Table 3.6 Gouritz Estuary: Simulated monthly flows (in m³/s) for flow Sc 1

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	20.6	13.1	25.9	10.6	289.9	191.1	64.7	15.7	113.3	46.0	15.1	9.8
1921	5.6	16.7	150.6	83.2	11.9	38.9	15.5	11.9	8.7	8.7	8.1	5.8
1922	3.6	42.8	12.8	1.4	1.9	1.7	35.1	21.6	9.7	6.0	4.2	2.7
1923	10.2	33.5	9.3	2.4	2.6	1.2	2.7	1.9	2.3	1.9	7.7	8.0
1924	3.0	2.8	3.1	1.5	7.1	5.9	2.8	2.3	155.7	60.6	7.8	63.1
1925	30.4	5.1	2.9	1.4	0.8	0.6	0.7	4.6	3.1	4.3	3.3	3.0
1926	49.0	25.6	3.5	0.5	0.5	0.4	7.5	6.9	2.9	1.5	5.8	3.0
1927	0.9	0.9	2.5	1.3	0.5	80.8	32.5	1.6	2.9	1.7	2.3	3.6
1928	1.8	65.2	25.0	1.5	1.2	13.0	6.9	5.1	4.0	51.9	23.6	9.0
1929	3.6	1.4	7.7	5.1	63.3	21.1	4.1	5.6	3.6	2.5	5.6	6.0
1930	3.3	1.6	0.6	1.8	1.0	10.2	30.7	10.1	2.3	14.0	9.6	5.6
1931	14.5	5.6	101.7	62.1	16.9	3.3	1.3	12.8	9.7	7.4	5.4	100.5
1932	40.9	4.8	1.3	0.7	0.8	9.0	4.4	5.0	4.3	3.3	40.9	15.9
1933	2.2	8.0	5.0	7.7	4.1	17.9	7.0	2.0	1.0	5.8	4.7	4.6
1934	84.1	96.4	19.0	0.9	1.0	1.3	25.3	77.7	43.2	15.8	14.1	10.5
1935	4.4	5.0	2.3	1.1	0.9	4.2	2.5	4.8	2.5	7.0	5.3	9.2
1936	4.5	24.8	47.7	12.3	2.7	7.0	2.7	1.0	1.3	3.5	2.2	2.9
1937	3.0	5.5	43.3	17.3	1.3	4.5	9.9	4.9	2.7	2.9	2.8	7.6
1938	7.0	18.3	6.3	1.0	30.1	20.8	7.8	2.9	1.4	4.8	70.7	27.9
1939	4.0	1.8	1.1	2.2	78.2	54.4	15.4	4.8	3.6	3.2	2.8	4.7
1940	2.8	34.8	9.8	5.3	2.4	0.5	69.1	26.6	11.6	6.9	6.3	5.3
1941	14.8	5.3	2.2	1.9	0.8	1.5	1.8	7.6	8.6	4.2	2.3	1.5
1942	37.3	11.5	4.3	5.3	2.5	1.2	0.8	1.1	0.7	0.9	3.9	39.6
1943	14.2	96.6	43.7	2.5	0.8	2.1	2.1	45.9	22.9	13.2	15.2	31.8
1944	11.3	2.4	1.0	0.7	0.6	8.2	3.6	74.0	55.8	18.5	11.6	5.7
1945	24.2	8.3	1.1	0.8	1.1	50.7	20.1	2.7	1.8	2.2	2.5	4.2
1946	3.4	1.4	0.5	0.3	0.3	41.2	14.8	8.3	4.9	22.5	10.1	4.0
1947	2.2	2.3	1.0	14.6	10.8	16.6	13.1	4.5	2.2	2.8	2.2	3.1
1948	37.3	12.3	2.7	1.4	2.4	0.8	1.6	16.3	7.1	2.1	1.8	1.8
1949	1.4	94.8	26.9	0.8	1.0	8.9	4.5	1.7	0.8	11.4	6.8	21.3
1950	22.2	77.7	26.1	104.6	45.0	2.8	1.5	2.3	5.8	25.5	15.7	11.1
1951	4.5	1.3	0.6	0.5	37.5	12.8	1.0	1.3	1.9	4.1	15.6	22.5
1952	7.5	26.0	8.5	0.8	64.3	19.4	9.4	4.4	12.7	48.9	26.5	10.0
1953	39.3	23.6	29.8	8.2	1.1	77.5	60.9	75.0	36.3	12.3	109.8	44.4
1954	5.6	11.7	3.8	1.6	64.2	18.6	3.0	3.9	5.5	6.8	7.7	4.5
1955	3.3	18.3	6.0	10.0	9.4	56.0	20.6	12.9	6.7	5.5	4.2	3.7
1956	9.0	5.5	8.6	5.1	22.8	8.9	2.1	10.4	15.0	8.3	7.8	17.4
1957	8.8	2.1	2.2	1.1	0.5	2.2	4.0	57.6	23.0	3.2	11.6	5.9
1958	3.7	1.6	2.0	5.0	25.3	10.6	37.6	26.1	7.5	18.7	19.3	9.1
1959	36.9	12.4	1.5	1.7	0.9	5.5	3.7	8.1	5.9	4.6	3.4	3.9
1960	2.6	2.9	3.3	2.0	1.8	129.7	87.7	16.2	8.7	15.7	13.2	7.9
1961	5.4	3.0	1.1	13.1	6.2	4.3	4.4	2.8	12.5	5.2	125.8	51.4
1962	14.7	22.2	5.8	35.2	13.1	14.7	21.8	18.5	11.2	10.3	8.9	3.7
1963	6.0	4.8	40.8	13.3	2.4	1.9	1.2	1.1	23.9	9.9	13.8	81.9
1964	28.7	17.0	5.5	0.9	1.7	17.2	15.9	11.4	5.1	7.2	4.9	2.3
1965	30.1	31.1	9.0	2.7	1.1	0.7	5.1	11.9	6.0	2.2	9.9	9.5
1966	3.1	0.8	0.5	0.3	6.1	9.8	146.2	83.3	41.8	19.8	12.3	7.2
1967	3.6	3.4	1.5	0.9	0.8	2.6	2.3	7.7	36.2	15.8	10.8	7.3
1968	5.2	5.6	1.8	0.7	10.8	8.7	4.7	1.9	8.3	5.1	3.1	2.3
1969	2.3	1.1	0.3	0.2	2.9	0.9	0.2	1.2	1.3	1.7	17.5	7.2
1970	4.0	1.5	8.1	3.5	3.6	6.6	41.4	21.3	8.2	99.2	75.7	23.9
1971	4.2	5.2	2.1	4.1	6.3	7.8	5.3	6.2	5.8	4.2	5.8	5.3
1972	2.2	1.1	1.1	0.5	1.4	13.1	6.7	2.7	3.6	11.0	7.0	4.2
1973	4.4	3.8	2.5	27.6	78.4	30.2	5.0	14.5	8.7	3.0	43.2	17.4
1974	3.3	5.2	1.9	1.6	0.9	9.5	4.5	10.8	12.8	12.5	11.8	22.2
1975	8.2	2.2	3.1	14.6	57.9	50.3	23.7	28.3	22.5	10.9	6.5	4.1
1976	22.8	22.5	5.2	1.0	73.4	27.1	14.4	71.1	29.8	7.4	10.1	7.5
1977	4.1	3.6	3.8	4.0	1.6	0.9	2.8	2.3	5.4	3.7	5.1	3.5
1978	6.7	3.6	3.4	1.5	5.1	1.7	0.4	16.4	11.4	30.0	27.2	11.5
1979	4.3	1.7	1.2	1.5	1.2	1.7	1.4	1.3	2.6	2.1	5.0	11.0
1980	17.9	74.3	20.2	200.3	80.3	82.7	78.1	83.3	34.5	13.7	134.9	53.6
1981	23.6	7.4	3.9	2.1	1.4	2.1	183.9	81.2	26.4	15.8	7.4	7.1
1982	8.6	5.3	1.6	0.9	1.1	0.9	1.1	18.3	20.2	69.9	27.2	21.9
1983	13.1	7.6	2.3	0.8	0.6	13.9	6.0	9.1	4.2	6.0	3.7	2.3
1984	2.4	1.4	1.6	22.2	31.5	8.3	16.2	8.3	11.3	20.1	9.9	3.7
1985	41.5	21.9	82.3	42.9	3.4	2.7	4.0	2.0	9.8	6.6	86.2	35.5
1986	41.8	16.6	1.9	0.7	1.0	0.8	42.6	15.3	5.0	3.9	3.7	62.4
1987	19.1	1.6	1.5	0.6	3.4	7.4	20.9	8.6	5.6	3.9	5.8	5.4
1988	3.1	1.5	20.3	9.4	2.1	11.9	94.3	31.0	4.5	4.0	3.8	3.0
1989	45.8	82.2	20.4	1.2	5.9	4.5	41.5	17.7	10.3	6.1	3.6	2.5
1990	2.4	1.3	0.8	7.0	4.0	1.0	0.6	0.9	6.8	7.2	3.2	2.5
1991	96.6	38.5	3.6	2.1	3.5	7.5	3.5	2.5	13.7	24.3	16.4	7.3
1992	57.3	32.5	5.6	1.5	7.5	2.9	50.7	25.6	8.1	8.8	7.1	61.5
1993	22.4	3.7	12.4	4.4	2.2	9.2	16.7	6.9	6.2	14.1	15.8	7.5
1994	7.7	2.6	19.1	7.4	3.6	27.3	13.1	29.6	14.3	4.7	8.0	4.6
1995	3.7	56.6	79.7	26.5	3.6	2.5	1.3	1.7	2.3	4.4	4.9	3.0
1996	91.2	322.3	127.0	10.2	1.8	34.9	19.2	26.8	21.8	14.2	9.0	4.4
1997	8.4	4.5	1.2	14.6	7.1	14.5	8.8	5.8	3.5	3.0	9.7	4.6
1998	3.2	7.9	21.7	12.0	3.2	2.4	2.4	1.6	0.9	1.4	3.2	3.4
1999	4.0	2.2	53.0	33.1	34.5	129.1	44.9	2.8	2.3	2.7	1.9	2.3
2000	1.5	58.4	18.0	1.4	1.0	3.7	13.2	5.8	1.6	7.7	8.3	6.6
2001	15.1	65.2	16.1	1.6	2.0	1.7	3.1	14.0	9.8	10.0	29.0	28.6
2002	8.5	1.8	35.9	10.5	0.9	102.3	51.1	77.9	32.6	7.1	7.9	4.6
2003	6.7	2.8	1.1	1.7	13.1	5.0	40.1	14.3	7.9	5.8	35.1	13.9
2004	20.1	6.7	55.2	22.7	2.8	5.5	15.8	12.2	8.0	3.7	2.7	1.9

Table 3.7 Gouritz Estuary: Simulated monthly flows (in m^3/s) for flow Sc 2

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	15.2	9.2	21.3	7.1	289.9	191.1	61.8	13.9	113.3	45.2	14.0	6.8
1921	3.1	13.8	150.6	75.0	8.8	34.2	12.4	10.8	7.1	7.3	7.0	4.3
1922	2.1	38.2	8.9	0.7	0.9	0.9	31.7	19.8	8.5	5.1	3.4	1.9
1923	8.9	28.0	6.3	1.2	1.4	0.6	1.9	1.7	1.9	1.5	6.9	5.1
1924	1.6	1.7	1.5	0.8	4.4	3.6	1.8	2.2	155.7	59.3	7.1	52.5
1925	25.9	2.9	1.5	0.7	0.4	0.3	0.4	3.5	2.8	3.9	2.8	2.4
1926	44.7	20.8	1.8	0.3	0.2	0.2	5.8	5.7	2.1	1.1	5.0	2.1
1927	0.5	0.6	1.8	0.7	0.2	60.3	28.0	1.2	1.9	1.2	2.0	3.0
1928	1.0	62.7	23.6	0.9	0.6	9.4	5.0	4.7	3.5	45.9	20.6	7.2
1929	2.1	0.7	4.8	2.8	49.1	16.1	3.2	5.4	3.1	1.9	4.5	4.4
1930	2.0	0.9	0.3	0.9	0.5	7.3	27.9	8.9	2.0	12.8	8.3	4.4
1931	12.9	4.5	101.7	53.1	13.2	2.1	0.7	11.3	8.6	6.5	4.4	100.5
1932	35.6	2.7	0.7	0.4	0.5	6.9	3.4	4.9	3.8	2.7	36.2	12.7
1933	1.2	6.2	3.0	6.0	3.0	14.2	4.8	1.5	0.6	5.4	4.1	4.0
1934	77.6	86.6	13.3	0.4	0.5	0.7	22.7	68.0	40.3	15.0	13.0	8.9
1935	2.7	3.4	1.4	0.6	0.5	2.1	1.3	4.5	1.8	6.4	4.3	8.1
1936	2.9	21.2	39.0	7.7	1.4	5.6	1.9	0.9	1.0	2.9	1.6	2.4
1937	2.1	3.7	27.1	14.1	0.7	3.0	8.5	4.4	2.4	2.5	2.5	6.9
1938	5.6	14.2	4.3	0.5	22.1	18.0	6.9	2.4	1.0	4.4	61.0	22.9
1939	2.6	1.0	0.5	1.3	67.9	49.4	13.7	4.5	3.1	2.7	1.9	3.9
1940	1.9	30.8	7.7	2.8	1.2	0.2	62.7	23.9	10.6	6.1	5.2	4.4
1941	12.3	3.6	1.2	1.0	0.4	1.0	1.2	7.0	6.8	3.4	1.8	1.0
1942	29.7	6.8	2.9	4.2	1.9	0.6	0.5	1.0	0.4	0.6	3.3	36.7
1943	11.7	96.6	35.9	1.2	0.4	1.0	1.6	37.4	20.8	12.5	14.3	28.9
1944	8.5	1.3	0.5	0.3	0.3	4.1	1.8	63.0	51.2	16.8	10.9	4.1
1945	21.7	6.3	0.6	0.4	0.6	45.2	17.1	2.1	1.4	1.9	2.1	3.2
1946	2.2	0.7	0.2	0.1	0.1	35.1	12.2	7.7	4.2	20.0	8.0	3.0
1947	1.2	1.5	0.5	12.7	7.4	11.1	10.1	3.6	1.8	2.5	1.8	2.5
1948	33.2	9.8	1.4	0.7	2.1	0.4	1.1	15.4	6.1	1.7	1.5	1.4
1949	0.8	80.1	19.1	0.4	0.5	6.5	3.5	1.5	0.5	8.2	5.2	18.5
1950	19.5	77.7	19.6	104.6	37.3	1.8	0.9	2.2	4.7	22.5	14.7	9.7
1951	3.2	0.7	0.3	0.3	26.5	9.8	0.6	1.2	1.6	3.0	11.5	19.5
1952	5.6	18.3	4.8	0.4	53.8	15.4	6.9	3.5	11.0	45.9	24.1	7.9
1953	31.9	19.1	25.2	5.9	0.6	71.4	57.2	75.0	33.2	11.1	109.8	39.6
1954	3.5	8.7	2.0	0.8	52.7	11.9	2.0	3.6	4.7	6.0	6.4	3.3
1955	2.1	12.9	3.0	6.0	5.5	46.8	17.5	12.3	5.6	4.8	3.7	2.9
1956	6.7	3.2	5.8	3.2	18.0	5.8	1.5	9.0	13.2	7.3	7.1	15.3
1957	7.1	1.2	1.1	0.5	0.2	2.0	3.3	53.1	21.1	2.5	10.8	4.8
1958	2.6	0.9	1.0	2.8	21.4	8.6	33.2	22.9	6.1	17.7	16.4	7.1
1959	33.3	9.3	0.8	1.1	0.5	3.0	2.5	7.5	5.1	4.0	2.7	3.3
1960	1.7	2.1	2.2	1.3	1.4	129.7	87.7	14.2	7.8	14.3	12.1	6.0
1961	4.0	1.9	0.6	8.1	3.8	3.1	3.8	2.6	9.3	4.2	125.8	45.7
1962	12.9	19.3	4.1	27.7	9.3	10.0	18.7	17.0	10.2	9.6	7.4	2.2
1963	4.8	3.0	35.6	10.2	1.4	1.1	0.7	1.0	20.4	8.1	12.4	73.5
1964	24.0	13.0	3.5	0.4	1.3	12.3	13.1	10.7	4.5	6.5	4.1	1.6
1965	25.6	26.4	6.3	1.4	0.6	0.4	4.3	11.7	5.4	1.8	9.5	8.6
1966	2.2	0.4	0.3	0.1	4.9	7.4	146.2	83.3	38.7	18.7	11.3	5.7
1967	2.1	2.3	0.7	0.4	0.4	1.3	1.6	6.8	29.5	12.8	10.2	5.7
1968	3.4	4.2	1.0	0.3	5.6	5.2	3.2	1.6	7.9	4.7	2.7	1.7
1969	1.4	0.6	0.2	0.1	2.4	0.4	0.1	1.1	1.0	1.4	13.2	4.8
1970	3.0	0.8	4.6	1.7	3.0	3.9	37.8	20.1	7.7	85.4	75.7	19.4
1971	2.5	4.0	1.2	2.2	4.3	4.2	3.7	5.5	5.0	3.4	5.2	4.3
1972	1.3	0.6	0.5	0.3	0.7	6.5	3.9	2.4	3.3	8.5	6.3	3.5
1973	2.4	2.6	1.7	20.2	70.3	25.3	3.3	11.7	6.9	2.0	35.6	13.6
1974	2.1	3.4	0.9	0.8	0.5	4.7	2.7	8.9	10.9	11.4	10.9	21.1
1975	6.5	1.4	1.6	9.8	44.2	43.5	21.2	25.9	20.8	10.0	5.5	3.0
1976	19.8	17.6	3.1	0.5	60.4	21.2	12.6	62.8	27.1	6.5	9.2	5.8
1977	2.7	2.7	2.5	2.1	0.8	0.5	2.0	2.1	5.1	3.2	3.9	2.6
1978	5.8	2.9	1.9	0.7	3.5	0.9	0.2	11.0	9.9	24.9	23.6	9.6
1979	2.9	0.9	0.8	0.8	0.6	0.9	0.9	1.3	2.3	1.6	4.2	8.5
1980	11.6	64.0	14.5	200.3	70.8	82.7	74.9	78.4	32.2	12.9	134.9	48.8
1981	20.8	4.2	2.8	1.1	0.7	1.1	183.9	77.8	25.7	15.2	6.2	5.9
1982	6.1	2.9	0.8	0.4	0.7	0.4	0.7	14.6	16.6	67.3	25.4	19.5
1983	10.6	5.5	1.3	0.4	0.3	7.8	3.7	7.6	3.5	5.8	3.2	1.7
1984	1.6	0.9	1.0	15.2	23.8	5.2	13.6	7.4	10.3	18.7	8.5	2.7
1985	39.1	18.9	82.3	36.2	2.1	1.7	2.6	1.5	7.9	5.7	86.2	32.3
1986	36.8	11.8	1.0	0.4	0.5	0.4	38.0	13.1	4.3	3.2	3.1	55.4
1987	14.0	0.8	1.1	0.3	1.7	3.8	15.8	7.2	5.0	3.3	5.1	4.1
1988	1.8	0.8	13.8	6.5	1.1	9.6	83.8	28.3	4.1	3.5	3.2	2.1
1989	42.7	75.4	16.7	0.6	4.0	3.0	33.0	15.2	9.6	5.3	2.9	1.8
1990	1.8	0.8	0.4	3.9	2.9	0.6	0.4	0.9	4.9	5.8	2.4	1.6
1991	96.6	30.4	2.1	1.0	2.6	5.4	2.6	2.5	11.8	21.2	14.6	5.6
1992	52.6	27.6	4.4	0.7	4.7	1.5	44.6	23.2	7.2	7.3	6.1	54.2
1993	17.8	2.1	9.0	2.6	1.1	5.7	14.3	6.0	4.8	12.5	14.8	6.3
1994	5.9	1.4	16.7	5.6	2.7	20.1	10.4	25.9	12.4	3.8	7.0	3.2
1995	2.4	51.8	79.7	19.6	2.1	1.3	0.7	1.6	1.5	3.3	3.5	1.9
1996	81.4	322.3	127.0	5.4	0.9	30.5	17.3	24.1	18.5	13.1	8.1	3.2
1997	7.2	3.6	0.6	9.3	4.5	11.3	7.4	5.4	3.0	2.6	8.3	3.2
1998	2.0	5.5	15.6	6.6	1.7	1.2	1.7	1.5	0.7	1.2	2.5	2.6
1999	2.8	1.1	42.4	26.9	28.0	129.1	41.2	2.3	1.7	1.9	1.2	1.8
2000	0.9	49.2	12.2	0.7	0.5	2.6	9.8	5.0	1.2	5.5	6.9	5.4
2001	12.7	59.4	10.9	0.8	1.4	0.9	1.6	12.6	9.0	8.9	24.7	24.4
2002	5.9	1.0	27.2	6.1	0.5	102.3	46.6	74.9	31.3	6.5	7.3	3.4
2003	5.4	1.8	0.6	0.9	7.3	2.7	34.0	11.7	6.9	5.1	33.7	11.7
2004	17.4	4.9	50.7	19.2	2.0	3.3	13.6	10.9	7.0	2.8	2.1	1.3

Table 3.8 Gouritz Estuary: Simulated monthly flows (in m^3/s) for flow Sc 3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	7.4	3.8	12.9	2.4	223.7	147.1	45.4	9.3	87.5	34.3	10.0	3.0
1921	0.3	8.0	115.7	51.6	3.2	23.7	7.4	7.1	4.5	4.9	4.7	1.7
1922	0.2	26.3	3.5	0.0	0.0	0.0	22.3	14.0	6.0	3.5	2.0	0.5
1923	5.9	17.6	1.8	0.0	0.0	0.0	0.2	0.4	1.2	0.8	4.7	1.3
1924	0.1	0.2	0.0	0.0	0.0	0.7	0.4	0.8	119.9	44.6	4.7	31.8
1925	16.8	0.2	0.0	0.0	0.0	0.0	0.0	1.0	1.9	2.9	2.0	1.1
1926	32.6	11.9	0.1	0.0	0.0	0.0	2.2	2.9	1.0	0.5	3.3	0.5
1927	0.1	0.1	0.0	0.0	0.0	38.4	18.0	0.1	0.6	0.3	1.2	1.6
1928	0.3	53.7	18.9	0.2	0.0	3.6	2.1	2.6	2.3	31.3	13.8	4.2
1929	0.4	0.0	0.1	0.1	32.9	10.6	1.6	3.4	2.1	1.0	2.4	1.8
1930	0.4	0.1	0.0	0.0	0.0	3.0	20.3	5.6	1.3	10.3	6.0	2.2
1931	9.4	2.3	79.5	34.6	7.1	0.6	0.1	7.0	6.0	4.4	2.7	84.5
1932	26.3	0.5	0.0	0.0	0.0	3.6	1.4	3.5	2.6	1.6	24.8	7.0
1933	0.3	3.5	0.6	3.2	0.6	8.1	1.6	0.1	0.1	4.1	3.0	2.3
1934	59.1	61.2	5.3	0.0	0.0	0.0	14.5	45.4	30.0	11.3	9.3	5.2
1935	0.5	0.8	0.2	0.0	0.0	0.0	0.0	2.5	0.8	4.6	2.4	4.9
1936	0.5	14.0	22.5	2.1	0.0	3.2	0.7	0.1	0.5	1.9	0.6	1.1
1937	0.7	0.6	20.3	8.0	0.0	0.7	5.5	2.4	1.6	1.5	1.6	4.2
1938	2.9	7.0	1.0	0.0	13.9	13.0	5.1	0.9	0.4	3.4	41.5	14.3
1939	0.8	0.2	0.0	0.0	46.1	34.7	9.6	3.0	2.3	1.8	0.6	1.9
1940	0.5	20.0	3.1	0.0	0.0	0.0	46.0	16.5	7.6	4.2	3.6	2.8
1941	7.9	1.0	0.1	0.0	0.0	0.2	0.2	4.1	3.9	1.9	0.9	0.3
1942	16.4	0.8	0.4	2.6	0.5	0.0	0.1	0.1	0.1	0.1	1.9	26.8
1943	7.5	79.3	21.6	0.0	0.0	0.0	0.3	22.2	15.1	9.2	10.5	20.4
1944	4.3	0.3	0.0	0.0	0.0	0.0	0.0	40.4	37.5	12.0	7.9	1.8
1945	14.5	2.7	0.0	0.0	0.0	32.4	11.2	0.4	0.7	1.2	1.2	1.3
1946	0.5	0.0	0.0	0.0	0.0	23.4	7.9	4.8	2.8	14.3	4.7	1.2
1947	0.2	0.1	0.0	8.4	2.2	3.9	7.1	1.7	1.1	1.8	0.9	1.4
1948	24.6	5.7	0.0	0.0	0.0	0.0	0.1	11.7	4.2	1.1	0.8	0.4
1949	0.1	58.3	11.2	0.0	0.0	2.5	1.8	0.3	0.1	3.8	2.7	12.6
1950	13.4	60.7	10.0	82.4	22.1	0.4	0.2	1.0	2.8	15.6	10.8	6.5
1951	1.4	0.1	0.0	0.0	14.2	5.0	0.1	0.2	1.0	1.5	5.9	13.2
1952	2.8	7.7	0.4	0.0	32.0	8.5	3.2	1.4	8.2	34.9	17.3	4.3
1953	20.8	11.1	15.5	2.3	0.0	50.3	41.2	60.4	24.3	7.9	88.0	27.6
1954	0.9	4.2	0.2	0.0	29.7	3.7	0.5	1.7	3.0	4.1	4.0	1.4
1955	0.4	5.2	0.0	1.1	0.0	34.2	11.2	9.0	3.8	3.6	2.6	1.5
1956	3.2	0.5	1.8	0.6	8.4	1.9	0.6	5.3	9.5	5.3	5.3	11.0
1957	4.2	0.3	0.0	0.0	0.0	0.7	1.8	41.4	16.4	1.5	8.4	2.8
1958	0.9	0.1	0.0	0.2	11.4	5.3	23.1	15.2	3.8	13.8	10.9	3.9
1959	23.6	4.5	0.1	0.2	0.0	0.2	0.9	4.7	3.5	2.7	1.6	1.9
1960	0.3	0.6	0.1	0.3	0.2	111.0	67.6	9.6	5.4	10.1	8.7	3.0
1961	1.9	0.3	0.0	2.1	0.2	1.6	2.6	1.4	4.7	2.4	105.7	33.1
1962	9.5	12.7	1.3	16.7	3.4	4.5	12.9	11.6	7.1	7.1	4.5	0.4
1963	2.3	0.3	22.7	5.1	0.0	0.1	0.1	0.1	14.0	5.2	8.6	53.9
1964	15.3	6.3	0.5	0.0	0.0	5.5	8.6	7.6	3.2	4.8	2.5	0.3
1965	16.5	16.8	2.1	0.1	0.0	0.0	2.2	8.4	3.8	1.0	7.8	6.1
1966	0.9	0.1	0.0	0.0	0.7	3.8	120.0	72.4	28.0	13.9	8.1	2.9
1967	0.5	0.2	0.0	0.0	0.0	0.0	0.2	3.8	18.4	7.9	7.5	2.8
1968	0.8	1.5	0.0	0.0	0.8	3.3	1.1	0.3	6.1	3.4	1.8	0.6
1969	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.5	0.8	6.9	2.5
1970	1.1	0.1	0.0	0.0	0.8	0.9	27.8	14.8	5.9	59.2	60.5	12.0
1971	0.5	1.8	0.2	0.0	0.8	0.3	1.7	3.1	3.5	2.1	3.7	2.4
1972	0.5	0.2	0.0	0.0	0.0	0.0	1.0	1.0	2.4	4.8	4.2	1.7
1973	0.5	0.6	0.3	13.0	47.7	15.7	1.1	7.2	4.1	0.7	21.6	7.1
1974	0.5	0.5	0.0	0.0	0.0	0.0	1.3	4.8	7.3	8.3	7.9	16.4
1975	3.8	0.4	0.0	3.9	23.2	28.2	14.4	18.2	15.3	7.4	3.5	1.2
1976	14.1	10.1	0.3	0.0	36.5	11.7	8.3	43.7	19.6	4.5	6.4	3.0
1977	0.9	0.8	0.3	0.0	0.0	0.0	0.4	0.9	4.1	2.3	2.1	0.9
1978	3.5	1.0	0.1	0.0	0.5	0.1	0.0	3.2	6.4	16.1	16.0	5.8
1979	1.0	0.2	0.2	0.1	0.0	0.0	0.1	0.2	1.5	0.8	2.6	4.2
1980	3.5	41.1	5.6	164.8	49.6	64.2	59.0	58.2	23.4	9.6	105.3	34.4
1981	13.8	0.4	0.5	0.0	0.0	0.1	145.6	58.4	19.5	11.4	3.9	3.5
1982	2.9	0.2	0.0	0.0	0.0	0.0	0.2	8.4	10.9	50.7	18.5	13.3
1983	6.1	2.0	0.1	0.0	0.0	1.3	0.9	4.2	2.2	4.8	2.3	0.5
1984	0.5	0.2	0.1	6.6	11.4	2.0	9.7	4.7	7.6	14.1	5.6	0.9
1985	28.9	11.8	69.0	22.5	0.1	0.4	0.6	0.1	4.5	3.6	73.8	24.5
1986	25.5	5.6	0.1	0.0	0.0	0.0	25.9	8.0	2.9	1.9	2.0	39.3
1987	6.9	0.1	0.2	0.0	0.0	0.1	8.5	4.5	3.4	2.0	3.3	2.0
1988	0.3	0.1	5.5	2.4	0.0	5.4	57.2	19.8	3.0	2.4	1.9	0.6
1989	32.9	55.1	9.7	0.0	0.2	0.9	20.6	10.1	7.5	3.6	1.7	0.5
1990	0.6	0.2	0.0	0.1	0.5	0.1	0.1	0.1	2.2	3.3	1.1	0.2
1991	78.1	17.6	0.1	0.0	0.2	2.6	1.2	1.2	7.8	14.6	10.4	2.9
1992	38.1	18.8	2.2	0.0	0.4	0.1	30.1	15.9	5.0	4.4	4.0	39.0
1993	10.9	0.3	3.7	0.3	0.0	1.9	9.9	3.3	2.7	9.0	11.5	4.0
1994	2.8	0.1	11.8	3.1	0.5	10.1	6.9	19.3	9.0	2.3	4.9	1.0
1995	0.7	38.7	65.0	9.7	0.0	0.1	0.1	0.1	0.5	1.7	1.5	0.2
1996	56.4	253.2	98.6	0.1	0.0	19.9	11.9	16.8	11.9	9.6	5.7	1.3
1997	4.4	1.7	0.1	3.3	0.7	7.9	5.3	3.7	2.1	1.9	6.2	1.4
1998	0.4	1.8	7.8	0.6	0.0	0.1	0.4	0.4	0.2	0.6	1.2	1.1
1999	1.0	0.1	25.0	16.1	16.4	100.4	29.1	0.9	1.1	1.1	0.3	0.7
2000	0.2	29.9	3.8	0.0	0.0	1.1	7.2	3.3	0.7	2.5	4.4	3.2
2001	7.8	41.9	3.6	0.0	0.0	0.0	0.0	8.0	6.4	6.2	18.0	16.3
2002	2.4	0.2	14.0	1.0	0.0	80.3	33.4	57.6	23.9	4.6	5.3	1.3
2003	3.0	0.3	0.0	0.1	0.0	0.2	23.3	7.0	4.7	3.4	24.9	6.8
2004	11.6	2.0	38.9	13.4	0.2	0.7	9.6	8.0	5.0	1.5	1.1	0.3

Table 3.9 Gouritz Estuary: Simulated monthly flows (in m^3/s) for flow Sc 4

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	5.5	2.9	9.5	1.9	160.5	105.4	32.6	6.8	62.7	24.7	7.3	2.4
1921	0.4	5.9	82.9	37.5	2.7	17.6	5.7	5.2	3.3	3.7	3.6	1.4
1922	0.3	19.0	2.7	0.0	0.0	0.0	16.7	10.8	4.8	2.9	1.7	0.5
1923	4.6	13.1	1.6	0.0	0.0	0.0	0.4	0.4	0.9	0.7	3.6	1.1
1924	0.1	0.2	0.0	0.0	0.0	0.6	0.4	0.6	85.8	32.1	3.5	23.1
1925	12.3	0.2	0.0	0.0	0.0	0.0	0.0	0.9	1.4	2.3	1.7	1.1
1926	25.6	9.5	0.1	0.0	0.0	0.0	1.7	2.2	0.9	0.5	2.5	0.6
1927	0.1	0.1	0.1	0.0	0.0	28.2	13.1	0.1	0.5	0.3	1.0	1.3
1928	0.3	47.5	16.8	0.2	0.0	2.8	1.6	2.0	1.9	23.0	10.5	3.4
1929	0.4	0.0	0.3	0.2	26.5	8.7	1.4	2.7	1.7	0.9	1.9	1.5
1930	0.4	0.1	0.0	0.0	0.0	2.5	15.8	4.6	1.1	8.3	4.9	1.9
1931	8.0	2.3	58.0	25.2	5.6	0.7	0.1	5.1	4.4	3.4	2.2	68.1
1932	21.7	0.5	0.0	0.0	0.0	2.7	1.2	3.0	2.2	1.4	18.6	5.5
1933	0.3	3.1	0.6	2.6	0.6	6.2	1.4	0.2	0.1	3.2	2.5	2.0
1934	47.6	46.7	4.2	0.0	0.0	0.0	10.6	33.1	22.0	8.5	7.0	4.1
1935	0.6	0.8	0.2	0.0	0.0	0.0	0.0	1.9	0.7	3.4	2.0	3.7
1936	0.6	11.6	16.9	1.7	0.0	2.7	0.7	0.1	0.4	1.5	0.7	0.9
1937	0.7	0.6	14.8	5.9	0.0	0.8	4.3	2.0	1.3	1.2	1.3	3.1
1938	2.3	5.3	0.9	0.0	10.7	10.7	4.4	0.9	0.4	2.7	30.9	11.0
1939	0.9	0.2	0.0	0.0	35.5	25.7	7.6	2.7	2.0	1.5	0.6	1.5
1940	0.5	14.9	2.5	0.1	0.0	0.0	33.7	12.2	5.8	3.3	3.0	2.5
1941	6.1	1.0	0.1	0.0	0.0	0.2	0.2	3.2	3.0	1.5	0.8	0.3
1942	11.9	0.8	0.5	2.4	0.6	0.0	0.1	0.1	0.1	0.2	1.4	20.5
1943	6.2	58.2	15.9	0.0	0.0	0.0	0.5	16.3	11.1	6.9	7.8	15.3
1944	3.6	0.3	0.0	0.0	0.0	0.0	0.0	30.2	28.0	9.2	6.0	1.6
1945	10.8	2.2	0.0	0.0	0.0	25.5	9.0	0.5	0.6	1.0	1.0	1.0
1946	0.5	0.0	0.0	0.0	0.0	18.9	6.6	3.7	2.3	11.1	4.0	1.1
1947	0.2	0.1	0.0	6.9	1.9	2.9	5.3	1.4	1.0	1.4	0.8	1.2
1948	20.6	5.4	0.0	0.0	0.2	0.0	0.2	9.6	3.7	1.0	0.7	0.5
1949	0.1	45.3	9.3	0.0	0.0	2.0	1.4	0.3	0.1	2.9	2.2	9.2
1950	10.1	44.4	7.6	61.1	16.7	0.4	0.3	0.8	2.2	11.8	8.3	5.4
1951	1.4	0.1	0.0	0.0	10.2	3.7	0.1	0.3	0.8	1.2	4.5	10.4
1952	2.5	6.0	0.4	0.0	23.2	6.2	2.4	1.1	6.0	25.9	13.2	3.6
1953	15.3	8.2	11.2	1.8	0.0	36.2	29.7	45.9	18.7	6.1	67.3	21.5
1954	0.9	3.3	0.2	0.0	22.1	2.9	0.5	1.4	2.3	3.1	3.1	1.3
1955	0.5	3.9	0.0	0.9	0.0	24.8	8.2	7.1	3.2	3.0	2.3	1.4
1956	2.5	0.5	1.5	0.6	6.1	1.5	0.6	4.0	7.7	4.5	4.3	8.6
1957	3.6	0.3	0.0	0.0	0.0	0.8	1.5	34.6	13.9	1.4	7.0	2.6
1958	0.9	0.1	0.0	0.2	8.6	4.3	17.8	11.7	3.1	11.0	8.7	3.3
1959	18.4	3.9	0.1	0.3	0.0	0.3	0.8	3.6	2.7	2.3	1.4	1.6
1960	0.4	0.6	0.2	0.4	0.2	79.8	48.5	7.2	4.1	7.4	6.5	2.4
1961	1.6	0.3	0.0	1.6	0.3	1.4	2.2	1.3	3.6	1.8	85.5	27.5
1962	8.2	10.1	1.3	12.2	2.5	3.5	9.4	8.5	5.2	5.5	3.6	0.4
1963	1.8	0.4	16.6	3.9	0.0	0.2	0.1	0.1	11.0	4.3	6.4	39.3
1964	11.3	4.8	0.5	0.0	0.0	4.0	6.5	6.0	2.7	3.7	2.0	0.4
1965	12.6	12.8	1.9	0.1	0.0	0.0	1.8	6.4	3.0	0.9	6.5	5.1
1966	1.0	0.1	0.0	0.0	0.6	2.9	94.2	55.0	20.7	10.5	6.2	2.4
1967	0.5	0.3	0.0	0.0	0.0	0.0	0.3	2.8	14.0	6.2	5.7	2.3
1968	0.8	1.3	0.0	0.0	0.7	2.5	0.9	0.3	4.8	2.8	1.5	0.6
1969	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.7	5.4	2.2
1970	1.0	0.1	0.0	0.0	1.0	1.0	21.0	11.5	4.8	44.2	45.6	9.6
1971	0.6	1.6	0.2	0.0	0.8	0.4	1.5	2.5	2.8	1.8	3.1	2.2
1972	0.5	0.2	0.0	0.0	0.0	0.0	0.7	0.8	1.9	3.7	3.2	1.4
1973	0.5	0.6	0.3	9.5	34.2	11.4	1.0	5.5	3.2	0.6	15.6	5.3
1974	0.6	0.5	0.0	0.0	0.0	0.0	1.0	3.5	5.4	6.3	6.2	13.4
1975	3.6	0.4	0.0	3.1	16.7	20.3	10.4	13.2	11.5	5.8	2.9	1.2
1976	11.1	7.9	0.3	0.0	27.1	8.7	6.1	33.1	15.0	3.6	4.9	2.5
1977	0.9	0.9	0.4	0.0	0.0	0.0	0.6	0.8	3.3	2.0	1.8	0.9
1978	2.7	0.9	0.1	0.0	0.7	0.1	0.0	2.6	4.7	12.4	12.4	4.7
1979	1.1	0.2	0.2	0.1	0.0	0.0	0.1	0.2	1.3	0.8	2.0	3.2
1980	2.7	30.3	4.4	121.5	37.2	46.7	46.6	43.6	17.4	7.2	76.9	25.6
1981	10.2	0.4	0.6	0.0	0.0	0.1	108.5	43.4	14.2	8.5	3.1	2.9
1982	2.4	0.2	0.0	0.0	0.0	0.0	0.2	7.2	8.8	37.2	14.0	10.3
1983	4.9	1.8	0.1	0.0	0.0	1.1	0.8	3.1	1.7	4.0	2.1	0.5
1984	0.6	0.2	0.1	5.7	9.4	1.8	7.4	3.6	5.7	10.9	4.6	0.9
1985	22.1	9.1	49.6	16.3	0.1	0.4	0.5	0.2	3.3	2.7	61.4	20.9
1986	18.9	4.4	0.1	0.0	0.0	0.0	20.1	6.4	2.3	1.6	1.6	28.7
1987	5.3	0.1	0.2	0.0	0.0	0.1	6.6	3.4	2.6	1.6	2.6	1.6
1988	0.3	0.1	4.4	1.9	0.0	4.2	41.5	14.5	2.3	1.9	1.6	0.6
1989	26.8	41.0	7.3	0.0	0.4	0.8	15.7	7.8	6.0	3.1	1.5	0.6
1990	0.6	0.2	0.0	0.3	0.7	0.1	0.1	0.1	1.6	2.5	0.9	0.3
1991	58.4	13.6	0.1	0.0	0.4	2.1	1.1	1.1	5.9	11.2	8.1	2.6
1992	29.1	15.5	2.2	0.0	0.4	0.1	22.6	12.0	3.9	3.4	3.1	29.5
1993	8.6	0.3	3.1	0.4	0.0	1.5	7.2	2.5	2.1	6.8	9.3	3.6
1994	2.3	0.1	10.3	2.9	0.5	7.4	5.2	14.2	6.7	1.9	3.7	0.9
1995	0.7	31.7	48.5	7.3	0.0	0.1	0.1	0.3	0.4	1.3	1.2	0.3
1996	42.0	185.3	72.0	0.3	0.0	14.4	8.6	12.4	8.8	7.2	4.5	1.3
1997	3.5	1.5	0.1	2.6	0.7	6.4	4.5	3.1	1.9	1.6	4.7	1.2
1998	0.5	1.7	5.8	0.6	0.0	0.1	0.6	0.4	0.3	0.5	1.0	0.9
1999	0.9	0.1	18.1	12.0	12.0	72.8	21.3	0.8	0.9	0.9	0.3	0.6
2000	0.2	21.6	2.9	0.0	0.0	1.1	5.6	2.6	0.7	1.9	3.5	2.6
2001	6.0	30.4	2.8	0.0	0.0	0.0	0.0	6.3	4.9	4.8	13.9	12.5
2002	2.2	0.2	10.2	0.9	0.0	60.0	25.0	43.7	18.4	3.7	4.1	1.3
2003	2.5	0.3	0.0	0.1	0.0	0.4	17.2	5.4	3.5	2.6	18.0	5.1
2004	9.3	1.9	31.8	11.1	0.2	0.7	7.4	6.0	3.8	1.3	1.0	0.3

3.3 HYDROLOGY

Tables 3.10 and **3.11** provide a summary of the changes in low flows and flood regime that have occurred under the different scenarios.

Table 3.10 Gouritz Estuary: Summary of the change in low flow conditions under a range of flow scenarios

Percentile	Monthly flow (m^3/s)					
	Natural	Present	Sc 1	Sc 2	Sc 3	Sc 4
30%	4.3	1.1	3.1	2.1	0.5	0.5
20%	3.0	0.4	2.2	1.4	0.1	0.2
10%	1.9	0.0	1.3	0.7	0.0	0.0
% Similarity in low flows		**13.1**	**70.1**	**44.0**	**5.2**	**5.8**

Table 3.11 Gouritz Estuary: Summary of the ten highest simulated monthly volumes under Reference Condition, Present State and a range of flow scenarios

Date	Monthly volume (million m^3 /month)					
	Natural	Present	Sc 1	Sc 2	Sc 3	Sc 4
Aug 1986	1007.13	835.40	835.40	835.40	656.17	480.37
Nov 1928	862.90	707.47	707.47	707.47	546.02	391.68
Apr 1967	684.49	536.43	536.43	536.43	441.28	325.51
Sep 1932	684.23	476.59	476.59	476.59	377.30	281.22
Dec 2005	562.81	511.82	511.82	511.82	394.08	282.32
Apr 1982	553.03	347.33	347.33	347.33	297.28	213.67
Aug 1967	507.18	378.99	378.99	378.99	310.92	244.13
Mar 2003	485.26	403.54	403.54	403.54	310.87	222.45
Oct 1934	481.93	403.24	403.24	403.24	309.92	221.92
Nov 1996	443.29	337.02	337.02	337.02	282.98	229.10
Apr 1981	414.44	340.03	340.03	340.03	264.19	192.83
Oct 1991	402.46	345.73	345.73	345.73	268.84	195.11
May 1958	400.54	273.96	273.96	273.96	215.17	160.72
Nov 1936	391.68	361.28	361.28	361.28	282.04	205.85
Jan 1981	390.13	272.28	272.28	272.28	212.92	155.29
Apr 1993	381.72	258.62	258.62	258.62	209.10	156.54
Oct 2004	379.71	250.35	250.35	250.35	205.47	150.82
Feb 1930	365.95	220.36	220.36	220.36	184.72	132.89
Dec 1929	359.82	280.08	280.08	280.08	220.59	163.69
Mar 2000	336.34	294.05	294.05	294.05	235.60	180.13
% Similarity in floods		**77.09**	**77.09**	**77.09**	**77.09**	**45.29**

A summary of the EHI hydrology score are provided in **Table 3.12**.

Table 3.12 Gouritz Estuary: EHI scores for hydrology under different scenarios

Variable	Weight	Scenario					
		Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. % Similarity in low flows	60	13	70	44	5	6	Medium
b. % Similarity in flood volumes	40	77	77	77	61	45	Medium
Hydrology weighted mean (a,b)		**39**	**73**	**57**	**27**	**22**	**Medium**

3.4 PHYSICAL HABITATS

The relevant change in sediment dynamics and geomorphology drivers is that further progressive reductions in large floods occur under Sc 3 and Sc 4 (about 16 and 32% respectively compared to present). The Present State and both Sc 1 and Sc 2 receive similar large floods than to Reference Condition, thus sediment dynamics is reflected as being similar to Present. A summary of the expected changes in the physical habitat of the Gouritz Estuary under each of the future scenarios are provided in **Table 3.13**.

Table 3.13 Gouritz Estuary: Summary of physical habitat changes under different scenarios

Parameter	Scenario
Supratidal area and sediments	The only potential new changes are related to changes in flood regime. Changes to low flows have virtually no impact on sediment dynamics and morphology within the estuary. Thus, Sc 1 and Sc 2 are not different from the Present State. Sc 3 and Sc 4 have additional 16 and 32% (negative) change effect respectively on flood regime which will translate into direct associated effects on sediment dynamics and morphology in the estuary. Under Sc 3 and Sc 4 there will be progressively less large floods which flush out sediments from the estuary and deposit new sediments on the floodplain. Longer retention of riverine sediment deposits, enabling more consolidation and more enduring plant growth, all contribution to slightly less dynamic estuarine geomorphology.
Intertidal areas and sediments	Same as for supratidal. Also progressively more ingress of marine sediments under Sc 3 and Sc 4.
Subtidal area and sediments	Same as for intertidal.
Estuary bathymetry (relates to water volume)	Under Sc 3 and Sc 4 there would be progressively less flushing of sediments due to further floods reduction, thus reduced water volume. Sc 3 and Sc 4 would also progressively allow slightly larger marine waters and sediment ingress, thus slightly reduced water volume. Overall all these effects considered significant, altering progressively the score from present.

The physical habitat health scores for the present and future scenarios are provided in **Table 3.14**.

Table 3.14 Gouritz Estuary: Physical habitat health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Supratidal area and sediments	44	44	44	44	44	Low
b. Intertidal areas and sediments	62	62	62	46	30	Low
c. Subtidal area and sediments	62	62	62	46	30	Low
d. Estuary bathymetry/water volume	87	87	87	79	71	Low
Physical habitat score minimum (a to d)	**44**	**44**	**44**	**44**	**30**	**Low**

3.5 HYDRODYNAMICS AND MOUTH CONDITION

Based on available literature, a number of characteristic 'states' can be identified for the Gouritz Estuary, related to tidal exchange, salinity distribution and water quality. These are primarily determined by river inflow patterns. The different states are listed in **Table 3.15**. A summary of the expected changes in the hydrodynamic and mouth conditions of the Gouritz Estuary under each of the future scenarios are provided in **Table 3.16.**

Table 3.15 Gouritz Estuary: Summary of the abiotic states that can occur

Abiotic state	Flow range (m^3/s)	Description
State 1	> 0.5	Marine dominated, no River Estuarine Interface (REI).
State 2	0.5 – 5.0	Full salinity gradient.
State 3	5.0 – 25.0	Partial salinity gradient.
State 4	25.0 – 75.0	Intermittent pulses.
State 5	> 75.0	Freshwater dominated

Table 3.16 Gouritz Estuary: Summary of the changes in the hydrodynamics under the various scenarios

<table>
<tr><th>Parameter</th><th>Future scenarios</th></tr>
<tr><td>Mouth condition</td><td>No change in mouth to state under Sc 1 and Sc 2, but there is a high likelihood of mouth closure under Sc 3 and Sc 4.</td></tr>
<tr><td>Inundation</td><td>Sc 1: Similar to present.
Sc 2: Similar to present.
Sc 3: Intertidal areas will be inundated between 5 and 10% of the time during closed periods.
Sc 4: Intertidal areas will be inundated between 10 and 20% of the time during closed periods.</td></tr>
<tr><td>Tidal range</td><td>Shift in tidal amplitude under the future scenarios are driven by change in State 1, 2 and 4.
<table><tr><th>Reference</th><th>Present</th><th>1</th><th>2</th><th>3</th><th>4</th></tr><tr><td>1.91</td><td>1.8</td><td>1.89</td><td>1.85</td><td>1.61</td><td>1.42</td></tr></table></td></tr>
<tr><td>Dominant circulation process</td><td>Under the Reference Condition the tide was the dominant circulation process (State 1 and 2) for about 35% of the time. This has increased to</td></tr>
</table>

<table>
<tr><th>Parameter</th><th>Future scenarios</th></tr>
<tr><td></td><td>about 60% of the time under the Present State.

Under Sc 1 to 4 will remain the dominant mixing process and occur for 44%, 52%, 66%, and 70% respectively.</td></tr>
<tr><td>Water column structure</td><td>From Reference Condition to Present State there has been some loss of stratification in all zones.

Sc 1: The system becomes more stratified than at present, especially in Zone B.
Sc 2: Very similar to present, with slightly more stratification in Zone B.
Sc 3: The system becomes more homogenous than at present.
Sc 4: The system becomes very homogenous.

<table>
<tr><th rowspan="2">Zone</th><th colspan="6">ΔS</th></tr>
<tr><th>Reference</th><th>Present</th><th>Sc 1</th><th>Sc 2</th><th>Sc 3</th><th>Sc 4</th></tr>
<tr><td>A</td><td>8</td><td>5</td><td>7</td><td>6</td><td>4</td><td>4</td></tr>
<tr><td>B</td><td>10</td><td>7</td><td>9</td><td>8</td><td>6</td><td>5</td></tr>
<tr><td>C</td><td>7</td><td>5</td><td>7</td><td>6</td><td>5</td><td>5</td></tr>
<tr><td>D</td><td></td><td>2</td><td>3</td><td>2</td><td>2</td><td>2</td></tr>
</table>
</td></tr>
<tr><td>Retention</td><td>The high retention states (1 and 2) have increased from 35% under the Reference Condition to about 60% under the Present State.

Under Sc 1 to 4 high retention states (1 and 2) have increased from 35% under Reference to 44%, 52%, 66% and 70%, respectively.</td></tr>
</table>

The hydrodynamics and mouth condition health scores for the present and future scenarios of the Gouritz Estuary are provided in **Table 3.17**.

Table 3.17 Gouritz Estuary: Hydrodynamics and mouth condition health scores for present and future scenarios

Variable	Scenario					Confidence
	Present	Sc 1	Sc 2	Sc 3	Sc 4	
a. % similarity in abiotic states and mouth condition	99	100	99	90	80	Medium
b. % similarity in the water column structure	83	95	90	78	75	Medium
c. % similarity in water retention time						
d. % similarity in tidal amplitude and symmetry)	97	99	98	91	85	Low
Hydrodynamics and mouth weighted mean (a to d)	**92**	**98**	**97**	**90**	**83**	**Medium**

3.6 WATER QUALITY

Table 3.18 provides a summary the occurrence of various abiotic states under reference, present and each of the future scenarios for the Gouritz Estuary.

Table 3.18 Gouritz Estuary: Summary of the occurrence of the abiotic states under the Reference Condition, Present State and Sc 1 to 4

Abiotic state	Natural	Present	Scenario			
			Sc 1	Sc 2	Sc 3	Sc 4
State 1: Marine dominated, limited REI	0	21	1	6	31	30
State 2: Full salinity gradient	34	39	42	46	35	40
State 3: Partial salinity gradient	44	28	39	34	24	22
State 4: Intermittent pulse	15	9	12	11	8	7
State 5: Freshwater dominated	6	3	5	4	2	1

Table 3.19 provides a summary of the expected average changes in various water quality parameters in different zones under present and future scenarios, while **Table 3.20** summarises the cause of such changes.

Table 3.19 Gouritz Estuary: Estimated changes in water quality in different zones under different scenarios

Zone	Volume weighting	Estimated salinity concentration based on distribution of abiotic states					
		Reference	Present	Sc 1	Sc 2	Sc 3	Sc 4
Zone A (surface)	0.075	26	30	28	28	31	31
Zone A (bottom)	0.075	34	34	34	34	34	35
Zone B (surface)	0.20	21	26	23	25	27	28
Zone B (bottom)	0.20	29	31	30	30	32	32
Zone C (surface)	0.075	12	18	13	15	20	21
Zone C (bottom)	0.075	18	22	19	21	23	24
Zone D	0.30	2	7	3	4	8	8
Zone	**Volume weighting**	**Estimated Dissolved Inorganic Nitrogen (DIN) concentration (µg/L) based on distribution of abiotic states**					
		Reference	**Present**	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
Zone A (surface)	0.075	70	89	85	88	90	90
Zone A (bottom)	0.075	70	85	79	83	86	87
Zone B (surface)	0.2	53	59	63	62	57	55
Zone B (bottom)	0.2	53	55	57	57	53	52
Zone C (surface)	0.075	53	64	69	68	61	59
Zone C (bottom)	0.075	53	64	69	68	61	59
Zone D	0.3	53	64	69	68	61	59
Zone	**Volume weighting**	**Estimated Dissolved Inorganic Phosphate (DIP) concentration (µg/L) based on distribution of abiotic states**					
		Reference	**Present**	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
Zone A (surface)	0.075	11	15	17	16	14	13
Zone A (bottom)	0.075	11	12	13	13	11	11
Zone B (surface)	0.2	11	15	17	16	14	13
Zone B (bottom)	0.2	11	12	13	13	11	11
Zone C (surface)	0.075	11	19	23	22	18	16

Zone C (bottom)	0.075	11	17	19	18	15	14
Zone D	0.3	11	23	28	26	21	20
Zone	**Volume weighting**	**Estimated turbidity (Nephelometric Turbidity Units - NTU) based on distribution of abiotic states**					
		Reference	**Present**	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
Zone A (surface)	0.075	53	33	45	40	27	21
Zone A (bottom)	0.075	34	22	30	26	18	14
Zone B (surface)	0.2	83	59	74	68	53	47
Zone B (bottom)	0.2	57	37	49	44	32	26
Zone C (surface)	0.075	98	68	86	79	61	54
Zone C (bottom)	0.075	27	22	24	24	22	21
Zone D	0.3	87	55	73	66	48	40
Zone	**Volume weighting**	**Estimated Dissolved Oxygen (mg/L) based on distribution of abiotic states**					
		Reference	**Present**	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
Zone A (surface)	0.075	8	8	8	8	8	8
Zone A (bottom)	0.075	8	8	8	8	8	8
Zone B (surface)	0.2	6	6	6	6	6	6
Zone B (bottom)	0.2	6	6	6	6	6	6
Zone C (surface)	0.075	6	6	6	6	6	6
Zone C (bottom)	0.075	5	5	5	5	5	5
Zone D	0.3	7	7	7	7	6	6

Table 3.20 Gouritz Estuary: Summary of water quality changes under different scenarios

Parameter	Summary of changes
Changes salinity gradient	⇧ Due to the increase in low flows.
Inorganic nutrients (DIN and DIP) in estuary	⇧ Due to the catchment activities, especially DIP. Slight improvement (from Present) in Sc 3 and Sc 4 relates to reduction in high flows (introducing higher DIP).
Turbidity in estuary	⇩ Due to reduction in high flows. Improvement in Sc 1 and Sc 2 (from Present) relates to increase in high flow periods (compared with Present), while higher modification in Sc 3 and Sc 4 relates to reduction in high flows (introducing higher turbidity).
Dissolved oxygen in estuary	No marked change.
Toxic substances in estuary	⇧ Due to agriculture.

The EHI scores for water quality are presented in **Table 3.21**.

Table 3.21 Gouritz Estuary: Water quality health scores for present and future scenarios

Variable	Weight	Scenario					
		Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
1 Similarity in salinity	40	81	95	89	77	76	Medium
2 General water quality min (a to d).	60	80	81	82	74	66	
a. DIN/DIP concentrations		85	81	82	88	90	Low/Medium

Variable	Weight	Scenario					
		Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
b. Turbidity		80	93	88	74	66	Medium
c. Dissolved oxygen		98	99	99	97	97	Medium
d. Toxic substances		85	85	85	85	85	Low
Water quality score weighted mean (1,2)		**80**	**87**	**85**	**75**	**70**	**Medium**

3.7 MICROALGAE

A summary of the expected changes under various scenarios for the microalgae component in the Gouritz Estuary is provided in **Table 3.22**.

Table 3.22 Gouritz Estuary: Summary of change in microalgae under different scenarios

Scenario	Summary of changes
1	50% of the flow is restored to the estuary (MAR = 81%), flood volumes are similar to present (23% lost). Changes to low flows have virtually no impact on sediment dynamics and morphology within the estuary. **Phytoplankton:** The 19% decrease in river flow from reference is likely to shift the system to have a higher proportion of low flows and a decrease in floods. Elevated turbidity, particularly at high flows, limit phytoplankton growth, whereas the increased residence time and elevated nutrients are likely to result a 14% increase in phytoplankton biomass from reference (half of the change from present). With regards to community composition the reduced river flow (19%) and elevated nutrients (15%) favour a decrease in the diatoms:flagellates ratio, and an increase in dinoflagellates, blue-greens and chlorophytes (17% change). **Benthic microalgae:** The largest factors affecting benthic microalgae are related to catchment flow reductions (incl. floods), sediment input (lower coarse sediment) and elevated nutrients. Reduction in flood volumes is similar to present so assuming that change in benthic microalgae from present is negligible.
2	25% of the flow is restored to the estuary (MAR = 71%), flood volumes are similar to present (23% lost). Changes to low flows have virtually no impact on sediment dynamics and morphology within the estuary. **Phytoplankton:** The 29% decrease in river flow from reference is likely to shift the system to have a higher proportion of low flows and a decrease in floods. Elevated turbidity, particularly at high flows, limit phytoplankton growth, whereas the increased residence time and elevated nutrients are likely to result in a 22% increase in phytoplankton biomass from reference (three quarters of the change from present). With regards to community composition the reduced river flow (29%) and elevated nutrients (15%) favour a decrease in the diatoms:flagellates ratio, and an increase in dinoflagellates, blue-greens and chlorophytes (22% change). **Benthic microalgae:** The largest factors affecting benthic microalgae are related to catchment flow reductions (incl. floods), sediment input (lower coarse sediment) and elevated nutrients. Reduction in flood volumes is similar to present so assuming that change in benthic microalgae from present is negligible.
3	Construction of a dam reduces MAR by further 15% (MAR = 48%), flood volumes have decreased (39% lost). Longer retention of riverine sediment deposits, enabling more consolidation and more enduring plant growth. **Phytoplankton:** The 52% decrease in river flow from reference is likely to shift the system to have a higher proportion of low flows and a decrease in floods. Elevated turbidity, particularly at high flows, limit phytoplankton growth, whereas the increased residence time and elevated nutrients are likely to result a 38% increase in phytoplankton biomass from reference (based on a linear regression through present, and Scenarios 1 and 2). With regards to community composition the reduced river flow (52%) and elevated nutrients (15%) favour a decrease in

Scenario	Summary of changes
	the diatoms:flagellates ratio, and an increase in dinoflagellates, blue-greens and chlorophytes (34% change). **Benthic microalgae:** The largest factors affecting benthic microalgae are related to catchment flow reductions (incl. floods), sediment input (lower coarse sediment) and elevated nutrients. Reduction in flood volumes (39%) is likely to affect the deposition and consolidation of fine sediments and organic material; expect a 39%*0.55 change in community (21% change).
4	Construction of a dam reduces MAR by further 25% (MAR = 36%), flood volumes have decreased (55% lost). Longer retention of riverine sediment deposits, enabling more consolidation and more enduring plant growth. **Phytoplankton:** The 64% decrease in river flow from reference is likely to shift the system to have a higher proportion of low flows and a decrease in floods. Elevated turbidity, particularly at high flows, limit phytoplankton growth, whereas the increased residence time and elevated nutrients are likely to result a 47% increase in phytoplankton biomass from reference (based on a linear regression through present, and Scenarios 1 and 2). With regards to community composition the reduced river flow (64%) and elevated nutrients (15%) favour a decrease in the diatoms:flagellates ratio, and an increase in dinoflagellates, blue-greens and chlorophytes (47% change). **Benthic microalgae:** The largest factors affecting benthic microalgae are related to catchment flow reductions (incl. floods), sediment input (lower coarse sediment) and elevated nutrients. Reduction in flood volumes (39%) is likely to affect the deposition and consolidation of fine sediments and organic material; expect a 55%*0.55 change in community (30% change).

The EHI scores for microalgale under the various scenarios are presented in **Table 3.23**.

Table 3.23 Gouritz Estuary: Microalgae health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
Phytoplankton						
a. Species richness	95	95	95	95	95	Low
b Abundance	71	85	78	62	53	Medium
c. Community composition	72	83	78	66	53	Medium
Benthic microalgae						
a. Species richness	95	95	95	95	95	Medium
b Abundance	77	77	77	61	45	Medium
c. Community composition	87	87	87	79	70	Medium
Microalgae score min (a to c)	**71**	**77**	**77**	**61**	**45**	**Medium**

3.8 MACROPHYTES

A summary of the expected changes under various scenarios for the macrophyte component in the Gouritz Estuary is provided in **Table 3.24**.

Table 3.24 Gouritz Estuary: Summary of change in macrophytes under different scenarios

Scenario	Summary of changes
1	In this scenario approximately 50% of the base flow would be restored. The lower salinity conditions in the middle / upper reaches of the estuary will restore some reeds to this area. There is no change in floods and so no improvement of salinity conditions is expected in the supratidal / floodplain salt marsh areas. Most of the macrophyte habitat has been lost due to agriculture in the Estuary Functional Zone (EFZ) and therefore there is little improvement in the macrophyte score for this scenario.
2	In this scenario approximately 25% of the base flow would be restored. The lower salinity conditions in the middle / upper reaches of the estuary will restore some reeds to this area. Other conditions are similar to that described for Scenario 1.
3	Reduce PMAR by about 15% with large dam. This scenario will reduce flooding and flushing of supratidal marsh / floodplain areas due to 16% reduction in floods. Salinity will increase causing die-back of plants and bare areas. The status of the reeds in the upper reaches of the estuary (Zone D) will remain similar to present as average salinity will increase from 7 to 8 parts per thousand (ppt).
4	Reduce pMAR by about 25% with large dam with a 32% reduction in floods. Further reduction in maximum flood heights expected, therefore supratidal / floodplain areas less inundated. Salinity will increase causing die-back of plants and bare areas. There will be some die-back of reeds and sedges in the upper reaches of the estuary as salinity at the end of summer would be 14 ppt in Zone D compared to 3 ppt for Reference Conditions. Some of this loss would be compensated for by an increase in reed area due to reduced flooding and removal of reeds.

The EHI scores for macrophytes under the various scenarios are presented in **Table 3.25**.

Table 3.25 Gouritz Estuary: Macrophyte health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	60	65	63	50	55	Medium
b. Abundance	41	45	43	38	35	Medium
c. Community composition	30	33	31	27	24	Medium
Macrophyte score min (a to c)	**30**	**33**	**31**	**27**	**24**	**Medium**

3.9 INVERTEBRATES

A summary of the expected changes under various scenarios for the invertebrate component in the Gouritz Estuary is provided in **Table 3.26**, while the health scores for the present and future scenarios are provided in **Table 3.27**.

Table 3.26 Gouritz Estuary: Gouritz Estuary: Summary of change in invertebrates under different scenarios

Scenario	Summary of changes
1	Under this scenario, the increase in baseflow (Circa (ca) 50%) leads to a decrease in marine dominance and the restoration of the REI for most of the year compared to present. Thus, the full salinity gradient persists for a greater proportion of the time (42%) compared to present (39%), but also for longer when compared to the natural the natural state (34%). Invertebrate response will be positive and average biomass will increase significantly and attain levels similar to the natural state or even higher. This is because variability and population fluctuations will be marginally less when compared to natural because of States 3 - 5 which now occur less frequently under Sc 1 (reduced flushing effects and population recovery levels will begin form a higher base level). The oligohaline community will also be well represented and is similar to natural under Sc 1. Stronger zonation of populations will also occur under this scenario when compared to present.
2	Under this scenario, State 2 persists for longer (46%) compared to Sc 1 (42%) as well as under natural conditions (34%). States 3 - 5 also occur less frequently compared to State 1 and the natural condition. Thus, invertebrate population fluctuations will be less variable and average biomass will exceed levels under natural, present and Sc 1 because of more constant average biomass levels over time (less frequent flushing, etc.). Salinity along the length of the estuary is very similar to natural and the oligohaline community will be well represent and similar to natural. Strong zonation of populations will also occur under this scenario and will be similar to Sc 1.
3 and 4	Sc 3 and Sc 4 follow a reverse trajectory described under Sc 1 and Sc 2. The reduction in MAR (15 and 25% respectively) compared to present, now results in State 1 persisting for much longer in Sc 3 (31% of the time) and Sc 4 (30% of the time) compared to present (21% of the time). A second major influence of Sc 3 and Sc 4 is the reduction in floods (by 16 and 32% respectively). There is a stronger ingress of marine sediment and mouth closure is possible under these scenarios. Under Sc 4, freshwater pulses occur only occasionally. Overall, there will be a strong downward shift in invertebrate biomass (average) compared to present, with less variability over time. Mouth closure by contrast, will lead to high variability in the abundance of intertidal organisms (particularly the mudprawn *Upogebia africana*). At times of mouth closure, mudprawn recruitment ceases. The presence of the oligohaline community will be more occasional and zonation of communities along the estuary will weaken further compared to present, particularly under Sc 4.

Table 3.27 Gouritz Estuary: Invertebrates health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
Zooplankton						
a. Species richness	100	100	100	100	100	Low/Medium
b. Abundance	60	95	90	50	45	Low/Medium
c. Community composition	55	95	90	50	45	Low/Medium
Hyperbenthos						
a. Species richness	100	100	100	100	100	Low/Medium
b. Abundance	60	95	90	50	45	Low/Medium
c. Community composition	55	95	90	50	45	Low/Medium
Benthos						
a. Species richness	100	100	100	100	100	Low/Medium

Variable	Scenario					
	Present	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**	**Confidence**
b. Abundance	55	95	90	45	40	Low/Medium
c. Community composition	55	95	90	45	40	Low/Medium
Invertebrate score min (a to c)	**55**	**95**	**90**	**45**	**40**	**Low/Medium**

3.10 FISH

A summary of the expected changes under various scenarios for the fish component in the Gouritz Estuary is provided in **Table 3.28**, while the health scores for the present and future scenarios are provided in **Table 3.29**.

Table 3.28 Gouritz Estuary: Summary of change in fish under different scenarios

Scenario	Summary of changes
1	Slight ⇧ turbidity ⇧ 0+ cob, ⇧ recruitment cues, ⇩marine dominance ⇧ REI species, e.g. *Gilchristella aestuaria*, *Myxus capensis*. Marine migrants associated with lower reaches of the estuary. Estuary resident Ia species ⇧ upper reaches. Slight ⇧connectivity and recruitment with marine environment and other estuaries in region for estuary dependent and associated marine species. ⇧ Invertebrate biomass ⇧ zoo and benthic invertivores.
2	⇧ State 2, fish distributed along salinity preferences, ⇧ recruitment at a maximum. ⇧ phytoplankton and zooplankton production ⇧ food for juvenile and larval fish, benthic algal biomass no change. Re-established REI ⇧ *Myxus* spp. etc., ⇧ invertebrate burrowers ⇧ *Pomadasys commersonnii*, ⇩ macrophytes (depauperate naturally?) ⇩ pipefish
3 and 4	Loss of the REI for a large part of the year and REI species functionally extinct. *G. aestuaria* (Ia) distributed throughout the system but ⇩⇩densities and biomass. ⇩⇩ recruitment estuary-dependent and associated marine species, ⇩⇩ benthic invertebrates ⇩ benthic feeders, e.g. *P. commersonnii*, ⇩ turbidity ⇩ 0+ cob, . Marine vagrants throughout estuary and marine opportunists *Liza. richardsonii* dominant. ⇩ *Upogebia* ⇩ burrow symbionts, e.g. *Caffrogobius* spp.

Table 3.29 Gouritz Estuary: Fish health scores for present and future scenarios

Variable	Scenario					
	Present	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**	**Confidence**
a. Species richness	80	90	90	60	60	High
b. Abundance	60	90	90	40	35	High
c. Community composition	60	90	90	45	35	High
Fish score min (a to c)	**60**	**90**	**90**	**40**	**35**	**High**

3.11 BIRDS

A summary of the expected changes under various scenarios for the bird component in the Gouritz Estuary is provided in **Table 3.30**, while the health scores for the present and future scenarios are provided in **Table 3.31**. As for the Reference Condition, the changes in relevant food and habitat drivers were used to estimate the degree of change in different bird groups, and the resultant estimated changes in numbers of each group were used to estimate change in overall numbers and in species composition. Community composition changes were scored using a similarity index.

Table 3.30 Gouritz Estuary: Summary of change in birds under different scenarios

Scenario	Summary of changes
1	50% of baseflow restored. Estuary moves towards natural. Freshwater penetrates lower into the system. Reeds and sedges increase in upper system. Inverts and fish increase. Positive for all bird groups.
2	25% baseflow restored. As above but changes more slight.
3	Reduce MAR by 15%. Salinity increases. Reduced reeds, sedges. Reduced invertebrate populations, reduced fish. Populations of all groups reduced from present.
4	Further reduction in flows. Reduced reeds, sedges. Much reduced invert populations, reduced fish. Greater impact than Sc 4.

Table 3.31 Gouritz Estuary: Bird health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	95	95	95	90	90	Medium
b. Abundance	75	82	79	69	59	Medium
c. Community composition	86	90	88	82	74	Medium
Bird scores min (a to c)	**75**	**82**	**79**	**69**	**59**	**Medium**

3.12 ECOLOGICAL CATEGORIES ASSOCIATED WITH SCENARIOS

The individual health scores for the various abiotic and biotic components are used to determine the ecological status or ecological category for the Gouritz Estuary under each of the future scenarios (**Table 3.32**), again using the EHI.

Table 3.32 Gouritz Estuary: EHI score and corresponding Ecological Categories under present and future scenarios

Variable	Weight	Scenario					
		Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
Hydrology	25	39	73	57	27	22	Medium
Hydrodynamics and mouth condition	25	92	98	97	90	83	Medium
Water quality	25	80	87	85	75	70	Medium
Physical habitat alteration	25	44	44	44	44	30	Low
Habitat health score	**50**	**64**	**75**	**71**	**59**	**51**	
Microalgae	20	71	77	77	61	45	Medium
Macrophytes	20	30	33	31	27	24	Medium
Invertebrates	20	55	95	90	45	40	Low/Medium
Fish	20	60	90	90	40	35	High

Variable	Weight	Scenario					
		Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
Birds	20	75	82	79	69	59	Medium
Biotic health score	**50**	**58**	**73**	**73**	**48**	**41**	
ESTUARY HEALTH SCORE		**61**	**75**	**72**	**54**	**46**	**Medium**
ECOLOGICAL CATEGORY		**C/D**	**B/C**	**B/C**	**D**	**D**	**Medium**

3.13 RECOMMENDED ECOLOGICAL FLOW SCENARIO

In the case of the Gouritz Estuary a **Category B** was proposed as the REC. Applying this guideline, none of the potential flow scenarios evaluated as part of the GRDS were able to reverse modification in the ecological state to a Category B. This is mainly as a result of significant non-flow related impacts also contributing to the present ecological status in the estuary. However, Sc 2 could restore the estuary to a Category B/C (just below a Category B). Sc 2 assumes a 25% base flow return to the estuary, e.g. through removal of alien invasive plants, as well as reducing run-off river abstraction during the low flow season. Restoring some base flow addresses the key flow-related factor contributing to the changes in ecological health in this estuary, namely the re-establishment of the REI zone. Considering the significant contribution of non-flow related factors the present health in the Gouritz Estuary, as well as the reversibility of some of these impacts, Sc 2 was identified as the recommended flow scenario from an ecological perspective. Important is that the Gouritz Estuary is very sensitive to base flows less than 0.5 m^3/s as it rapidly loses the REI zone under these type of flow conditions. This effectively requires a capping flow of 0.5 m^3/s during low flow periods in order to maintain the REC.

However, in order to improve from a Category B, additional intervention in terms of non-flow related impacts will be essential.

4 SCENARIO RESULTS: GOUKOU ESTUARY

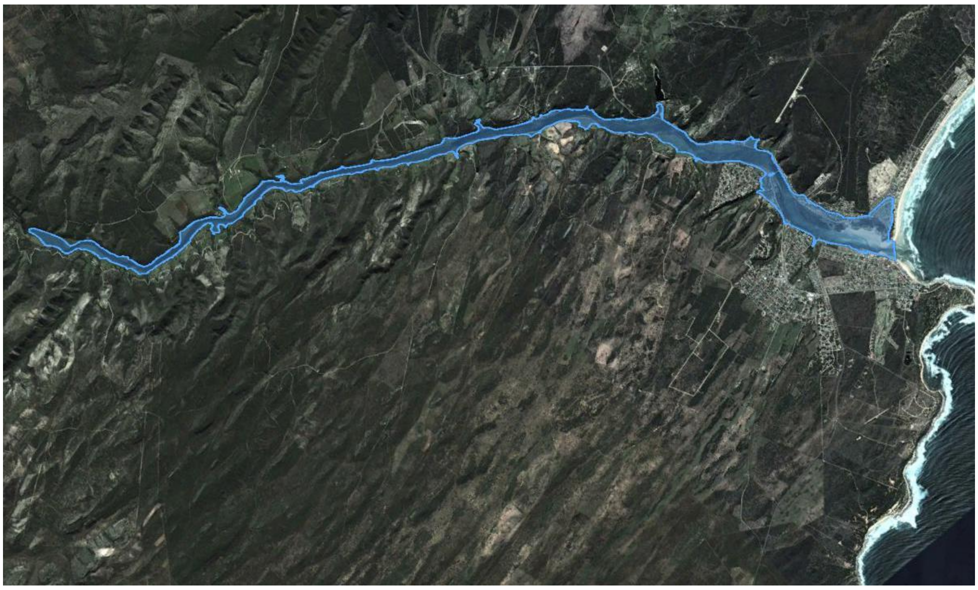
(This section is extracted from the Goukou estuary report for the study, as authored by the estuary team and compiled by Dr Susan Taljaard – DWS, 2015b.)

4.1 INTRODUCTION

The Goukou Estuary is located on the Indian Ocean seaboard, about 300 km east of Cape Town. The estuary covers approximately 250 ha, is 19 km in length, and is embedded in a deep valley.

The geographical boundaries of the estuary are defined as follows:

Downstream boundary:	Estuary mouth: 34°22'43.36"S; 21°25'22.19"E
Upstream boundary:	34°17'32.20"S; 21°18'29.03"E
Lateral boundaries:	5 m contour above MSL along each bank



4.1.1 Present Ecological State

The EHI score for the Goukou Estuary is 69, thus a PES of Category C **(Table 4.1).**

Table 4.1 Goukou Estuary: PES

Variable	Weight	Score
Hydrology	25	54
Hydrodynamics and mouth condition	25	95
Water quality	25	75
Physical habitat alteration	25	65
Habitat health score		**72**
Microalgae	20	57

Variable	Weight	Score
Macrophytes	20	68
Invertebrates	20	60
Fish	20	75
Birds	20	73
Biotic health score		**67**
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		**69**
PRESENT ECOLOGICAL STATUS (PES)		**C**
OVERALL CONFIDENCE		**Medium**

4.1.2 Ecological importance

The Goukou estuary is rated as a 'Highly Important' system. The system is part of the Stilbaai Marine Protected Area (MPA). The National Biodiversity Assessment 2011 (NBA 2011) (Van Niekerk and Turpie, 2012) identified the estuary as an important nursery area for red data species and exploited fish stocks. Further, this estuary is very important conduit for eels which is Convention on International Trade in Endangered Species (CITES) listed species.

4.2 DESCRIPTION AND CONSEQUENCES OF SCENARIOS

The future scenarios presented in **Table 2.6** were assessed for the Goukou Estuary. The occurrences of the flow distributions (mean monthly flows in m^3/s) under the future Scenarios of the Goukou Estuary, derived from a 85-year simulated data set are provided in **Tables 4.1** to **4.4** and in **Figures 4.1** to **4.4**. The full sets 85-year series of simulated monthly runoff data for the future Scenarios are provided in **Tables 4.5** to **4.8**.

Table 4.2 Goukou Estuary: Summary of the monthly flow (in m^3/s) distribution under Sc 1

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	23.4	30.8	27.2	16.6	16.7	24.2	30.3	17.9	8.1	10.1	34.9	29.1
99	19.5	23.6	16.6	12.3	13.2	16.3	29.0	14.9	7.5	9.8	26.8	15.7
90	11.2	9.3	4.8	3.5	6.4	7.6	8.6	7.4	5.3	5.1	6.6	7.0
80	5.8	7.3	3.4	2.5	3.3	5.7	6.0	5.0	3.5	3.4	5.4	5.2
70	4.4	4.8	2.1	1.3	2.2	3.9	3.8	3.6	2.9	2.6	3.8	4.0
60	3.5	3.4	1.4	0.8	1.0	3.3	3.0	3.0	2.2	2.3	3.5	3.2
50	2.8	2.4	1.0	0.6	0.7	2.4	2.3	2.7	1.9	2.0	2.6	2.8
40	2.1	1.8	0.6	0.4	0.5	1.6	1.8	2.0	1.5	1.8	2.3	2.4
30	1.8	1.2	0.5	0.3	0.4	1.1	1.5	1.1	1.2	1.4	1.6	2.0
20	1.4	0.9	0.4	0.3	0.3	0.4	1.3	0.7	0.8	1.0	1.4	1.5
10	1.1	0.7	0.4	0.3	0.3	0.3	0.7	0.4	0.5	0.8	1.0	1.2
1	0.6	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.6	0.7
0.1	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.6	0.5

Table 4.3 Goukou Estuary: Summary of the monthly flow (in m³/s) distribution under Sc 2

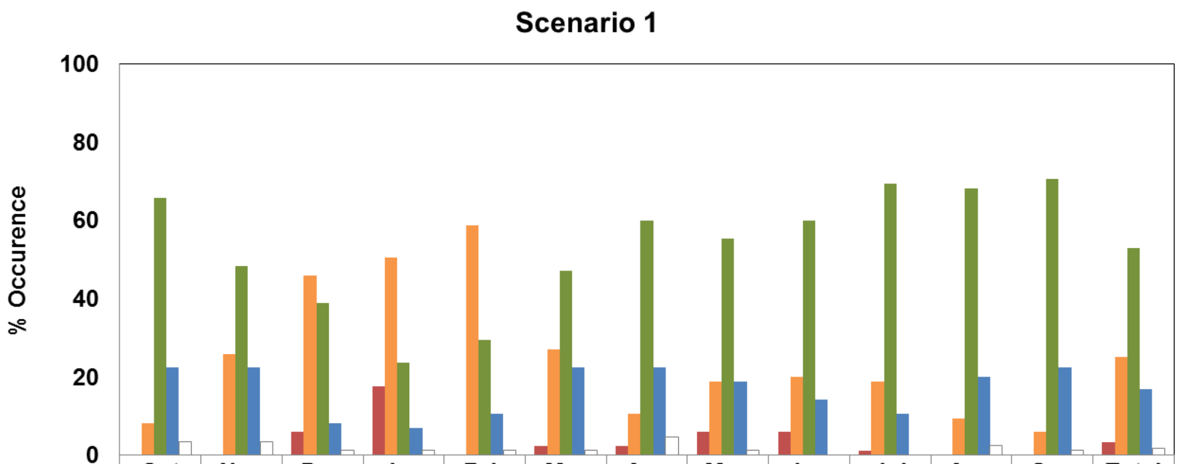
%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	23.1	29.5	27.0	15.7	15.0	22.3	30.0	16.4	7.8	9.9	34.3	28.8
99	17.7	22.2	15.6	11.4	11.7	15.0	28.8	13.7	7.3	9.6	26.6	15.0
90	10.6	8.1	3.8	2.5	4.9	5.9	8.1	7.1	5.0	4.8	6.2	6.7
80	5.6	6.1	2.5	1.5	2.3	4.1	5.4	4.7	3.2	3.1	4.9	4.8
70	3.7	3.7	1.2	0.6	0.9	2.9	3.4	3.1	2.5	2.1	3.5	3.6
60	2.6	2.4	0.7	0.2	0.2	2.0	2.6	2.6	1.9	1.9	2.9	2.7
50	1.8	1.5	0.4	0.1	0.1	1.5	1.6	2.1	1.6	1.6	2.2	2.2
40	1.2	0.8	0.2	0.1	0.1	0.5	1.2	1.4	1.2	1.4	1.9	1.8
30	0.9	0.5	0.2	0.0	0.0	0.1	0.8	0.9	0.8	1.0	1.3	1.5
20	0.6	0.3	0.1	0.0	0.0	0.0	0.5	0.3	0.5	0.7	1.0	0.9
10	0.4	0.2	0.1	0.0	0.0	0.0	0.2	0.1	0.2	0.6	0.6	0.5
1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2
0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1

Table 4.4 Goukou Estuary: Summary of the monthly flow (in m³/s) distribution under Sc 3

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	22.7	29.2	26.7	15.4	13.9	20.8	29.7	16.1	7.5	9.6	32.8	28.5
99	16.4	21.9	15.3	11.1	11.0	14.5	28.5	13.4	7.0	9.4	26.1	14.7
90	10.1	7.8	3.3	2.2	4.5	5.5	7.8	6.8	4.7	4.5	5.9	6.3
80	5.3	5.6	2.0	1.0	1.8	3.8	4.6	4.1	2.9	2.8	4.6	4.6
70	3.4	3.4	0.9	0.3	0.4	2.3	2.9	2.9	2.1	1.8	3.1	3.3
60	2.3	2.1	0.4	0.1	0.1	1.2	2.3	2.3	1.6	1.6	2.5	2.4
50	1.5	1.2	0.3	0.1	0.1	0.8	1.0	1.4	1.2	1.3	1.9	1.9
40	0.9	0.5	0.2	0.1	0.0	0.2	0.6	0.8	0.8	1.1	1.5	1.5
30	0.7	0.3	0.1	0.0	0.0	0.1	0.3	0.4	0.5	0.7	0.9	1.2
20	0.4	0.3	0.1	0.0	0.0	0.0	0.1	0.0	0.2	0.4	0.6	0.6
10	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.3
1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1

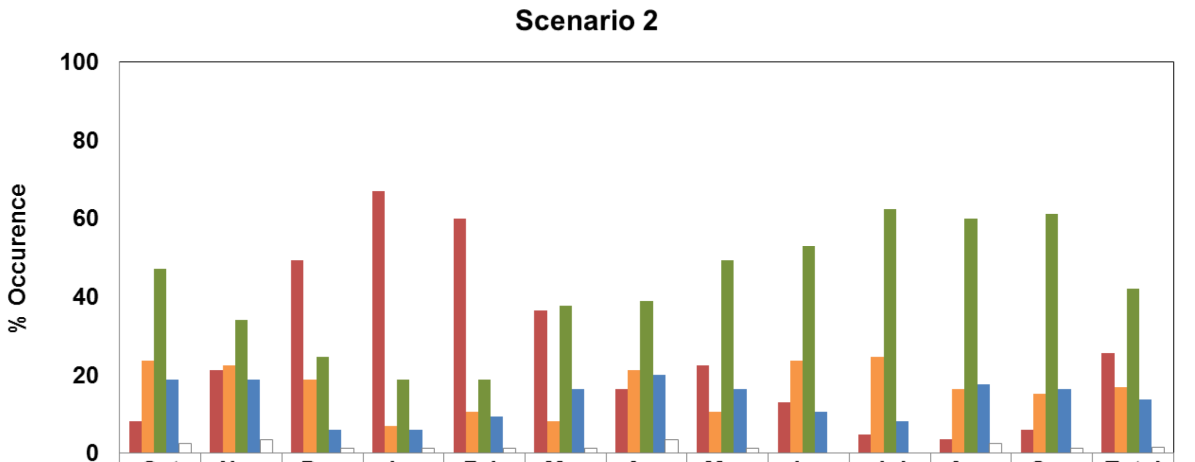
Table 4.5 Goukou Estuary: Summary of the monthly flow (in m^3/s) distribution under Sc 4

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	21.9	27.9	26.0	14.7	11.8	19.3	28.8	15.4	6.8	8.9	31.0	25.5
99	14.8	21.1	14.6	9.9	10.0	13.3	26.3	12.7	6.3	8.6	24.3	13.6
90	9.0	6.9	2.1	1.0	3.2	4.8	6.7	5.7	3.9	3.6	5.2	5.6
80	4.0	4.3	0.9	0.3	0.6	2.3	3.0	2.9	2.1	2.0	3.5	3.6
70	2.5	2.6	0.4	0.1	0.2	1.0	2.0	2.0	1.4	1.1	2.2	2.3
60	1.2	1.1	0.3	0.1	0.1	0.2	1.4	1.5	0.8	0.8	1.4	1.5
50	0.8	0.5	0.2	0.1	0.1	0.2	0.3	0.6	0.4	0.5	0.9	0.8
40	0.7	0.3	0.2	0.1	0.0	0.1	0.2	0.2	0.3	0.4	0.6	0.6
30	0.5	0.3	0.1	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.4	0.3
20	0.3	0.2	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.3	0.3
10	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2
1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1



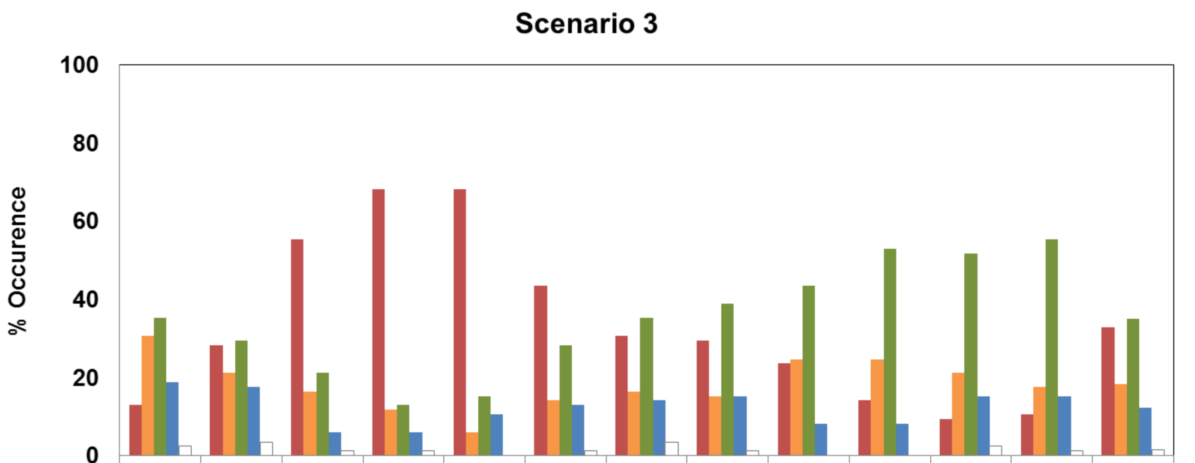
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	6	18	0	2	2	6	6	1	0	0	3
State 2	8	26	46	51	59	27	11	19	20	19	9	6	25
State 3	66	48	39	24	29	47	60	55	60	69	68	71	53
State 4	22	22	8	7	11	22	22	19	14	11	20	22	17
State 5	4	4	1	1	1	1	5	1	0	0	2	1	2

Figure 4.1 Goukou Estuary: Occurrence of the various abiotic states under the Sc 1



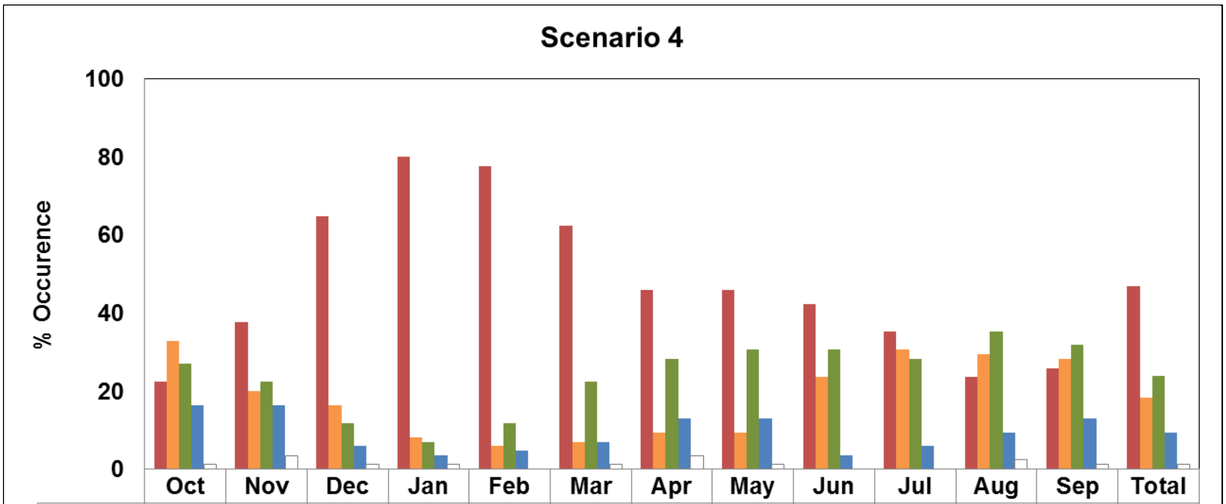
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	8	21	49	67	60	36	16	22	13	5	4	6	26
State 2	24	22	19	7	11	8	21	11	24	25	16	15	17
State 3	47	34	25	19	19	38	39	49	53	62	60	61	42
State 4	19	19	6	6	9	16	20	16	11	8	18	16	14
State 5	2	4	1	1	1	1	4	1	0	0	2	1	2

Figure 4.2 Goukou Estuary: Occurrence of the various abiotic states under the Sc 2



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	13	28	55	68	68	44	31	29	24	14	9	11	33
State 2	31	21	16	12	6	14	16	15	25	25	21	18	18
State 3	35	29	21	13	15	28	35	39	44	53	52	55	35
State 4	19	18	6	6	11	13	14	15	8	8	15	15	12
State 5	2	4	1	1	0	1	4	1	0	0	2	1	1

Figure 4.3 Goukou Estuary: Occurrence of the various abiotic states under the Sc 3



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	22	38	65	80	78	62	46	46	42	35	24	26	47
State 2	33	20	16	8	6	7	9	9	24	31	29	28	18
State 3	27	22	12	7	12	22	28	31	31	28	35	32	24
State 4	16	16	6	4	5	7	13	13	4	6	9	13	9
State 5	1	4	1	1	0	1	4	1	0	0	2	1	1

Figure 4.4 Goukou Estuary: Occurrence of the various abiotic states under the Sc 4

Table 4.6 Goukou Estuary: Simulated monthly flows (in m³/s) for Sc 1

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	1.6	0.9	4.8	0.8	8.1	3.8	7.7	2.9	5.6	3.4	3.6	3.0
1921	1.2	0.5	1.9	7.2	1.9	6.2	2.9	1.1	1.0	2.3	1.6	1.2
1922	1.8	4.2	0.5	0.3	0.3	12.4	6.0	6.2	4.3	2.2	1.4	0.9
1923	3.2	4.4	0.5	0.3	0.4	0.3	0.4	0.3	1.3	0.9	5.7	2.6
1924	0.8	2.1	0.6	0.3	0.3	3.6	1.6	0.3	2.2	1.3	1.0	3.1
1925	3.5	2.0	0.4	0.3	0.3	0.6	1.6	0.5	0.7	2.5	2.4	2.2
1926	7.9	4.8	0.5	0.3	0.5	1.2	1.3	2.1	1.2	0.4	2.5	1.3
1927	0.5	2.1	0.5	0.3	0.3	7.8	2.5	0.4	0.8	0.5	1.8	3.4
1928	1.4	31.6	14.2	0.9	0.7	1.6	1.2	2.4	1.8	6.4	5.3	3.1
1929	1.8	0.6	1.0	0.4	17.1	7.7	2.1	3.8	2.2	1.0	1.9	2.0
1930	4.1	1.2	0.3	0.3	0.3	7.3	10.1	2.8	0.8	4.7	2.9	2.6
1931	8.1	2.4	9.8	2.8	4.8	2.0	0.4	0.3	1.3	1.4	0.9	30.6
1932	11.0	1.6	0.4	0.3	0.4	1.4	0.7	2.9	1.7	0.9	6.5	2.8
1933	0.7	7.7	1.4	3.5	3.5	6.0	1.9	0.3	0.3	3.8	4.1	2.8
1934	23.8	13.6	1.3	0.3	0.4	1.3	1.7	7.1	6.0	2.8	1.4	4.1
1935	2.8	4.8	1.5	0.4	0.5	0.4	0.3	3.2	1.0	2.0	1.1	4.0
1936	3.2	18.0	7.6	1.2	0.3	6.3	2.0	0.3	0.4	1.4	1.2	2.4
1937	0.8	1.8	4.2	1.8	0.3	3.3	3.3	1.1	0.9	1.4	1.1	1.8
1938	3.9	7.5	2.7	0.6	3.8	9.5	3.8	0.9	0.3	2.6	12.4	5.1
1939	2.0	1.4	0.4	0.7	12.4	5.2	3.5	1.7	1.0	0.8	0.7	2.0
1940	1.0	5.6	0.9	1.0	0.4	0.3	7.9	2.8	3.1	2.0	2.2	2.7
1941	5.2	2.6	0.8	2.5	0.5	1.6	1.5	2.3	1.5	0.9	0.8	1.5
1942	2.1	0.7	2.6	9.5	3.2	1.2	1.3	0.6	0.3	0.3	1.2	7.4
1943	3.1	8.3	2.7	0.4	0.3	3.3	1.8	4.7	2.7	2.5	3.0	6.4
1944	5.1	1.0	0.3	0.3	0.3	0.3	0.4	7.0	5.2	2.5	3.6	3.2
1945	6.7	2.0	0.4	0.3	0.4	11.4	3.8	0.3	0.3	1.1	1.4	1.3
1946	1.3	0.8	0.3	0.3	0.7	12.0	5.0	2.8	1.8	4.3	2.3	3.0
1947	3.1	2.9	0.4	2.6	0.5	4.9	5.6	2.0	0.7	1.0	0.8	1.9
1948	13.3	4.4	0.5	0.9	0.4	0.3	1.5	3.0	1.6	0.8	0.6	1.1
1949	0.6	12.1	2.5	0.3	0.3	0.3	1.8	1.8	0.8	1.9	2.2	1.7
1950	5.4	8.7	1.7	11.4	3.6	3.2	1.3	1.6	2.5	6.7	3.5	7.0
1951	2.7	0.7	0.3	0.8	0.8	0.3	1.2	0.5	0.5	0.8	2.5	9.9
1952	4.3	7.3	2.3	0.5	1.3	0.3	2.3	1.0	1.4	7.2	3.7	5.3
1953	5.9	5.0	0.6	0.3	0.3	1.3	6.1	11.4	4.3	2.7	11.7	5.3
1954	1.3	2.2	0.5	2.5	10.5	2.3	0.7	0.4	1.0	1.9	2.6	3.2
1955	2.4	1.7	0.4	0.3	0.3	3.6	1.8	7.9	3.2	2.0	2.5	2.5
1956	5.2	1.4	4.8	0.6	3.1	2.3	1.4	3.5	8.1	4.4	5.1	8.0
1957	4.8	1.0	0.3	0.3	0.3	4.7	2.9	18.2	7.1	1.8	6.4	3.5
1958	2.8	0.9	0.4	3.6	6.8	6.1	10.1	7.0	2.4	9.8	7.7	4.1
1959	8.5	2.5	0.5	0.6	0.5	3.4	2.1	2.9	3.1	2.4	1.4	2.3
1960	1.4	4.0	4.0	3.4	1.2	2.1	1.6	3.0	1.7	2.4	3.4	3.0
1961	4.3	1.8	0.4	0.5	2.5	4.3	3.7	1.3	1.3	1.0	25.1	8.7
1962	8.3	8.0	1.2	1.6	0.4	7.4	3.3	2.7	1.2	2.6	1.4	0.7
1963	2.6	1.8	4.3	2.9	1.5	4.0	1.6	0.5	6.2	2.4	4.1	7.0
1964	4.4	3.3	0.6	0.3	1.6	3.4	2.5	4.6	2.0	1.6	1.9	1.2
1965	12.4	9.6	3.5	2.0	0.3	0.9	1.4	5.4	2.3	0.9	8.5	6.7
1966	1.9	0.6	0.3	0.3	1.0	5.3	30.5	14.3	5.1	4.8	3.9	5.1
1967	2.1	3.1	0.5	0.3	0.3	0.9	2.3	3.6	6.6	2.7	5.8	3.3
1968	1.9	5.4	0.6	0.3	0.4	0.4	1.5	0.5	4.3	2.1	2.3	1.9
1969	1.0	0.4	0.3	0.3	2.4	0.4	0.3	0.3	0.8	0.8	4.4	1.9
1970	2.7	0.6	1.2	0.3	5.9	5.6	8.1	6.3	3.4	10.1	11.3	4.5
1971	2.0	5.8	0.9	0.4	3.2	3.0	3.5	3.3	2.0	2.0	5.5	5.7
1972	1.5	1.9	0.4	0.3	0.3	0.3	1.6	1.1	2.4	2.3	2.8	2.1
1973	1.2	1.5	1.8	4.5	7.2	5.8	1.7	7.7	3.1	1.0	5.8	3.9
1974	1.9	1.7	0.4	0.6	0.3	0.3	0.7	2.2	2.9	3.2	6.6	7.6
1975	2.7	3.5	1.2	0.4	3.6	4.8	3.2	3.4	7.4	5.2	2.8	2.6
1976	11.4	7.7	2.1	0.4	8.4	3.3	3.0	12.4	5.5	2.2	2.4	2.9
1977	2.8	4.8	1.7	0.4	0.3	0.4	3.1	1.1	2.2	2.4	3.6	2.4
1978	3.1	1.3	2.5	0.8	4.0	0.8	0.3	3.6	1.6	7.4	6.4	5.2
1979	4.6	1.2	1.8	2.0	0.6	0.3	1.1	0.3	2.2	1.0	1.5	2.4
1980	3.4	11.7	3.4	17.1	12.0	10.1	19.5	10.1	3.5	3.3	11.2	5.5
1981	1.5	0.9	4.0	0.6	0.9	2.7	28.7	8.9	3.1	3.9	3.6	8.6
1982	4.6	1.0	0.4	0.3	0.7	0.4	1.1	3.8	5.1	5.4	3.1	6.5
1983	3.7	4.9	1.0	0.4	0.5	3.5	1.7	0.5	0.5	2.0	1.5	0.7
1984	2.7	0.7	0.4	8.5	7.1	1.2	4.4	2.0	2.2	7.7	3.7	1.2
1985	12.3	8.3	4.4	0.6	0.6	0.8	1.0	0.7	0.3	0.5	35.8	12.8
1986	5.8	2.7	0.5	0.3	0.4	0.3	10.1	3.1	1.9	1.4	3.7	4.8
1987	1.7	0.6	1.0	0.3	0.3	1.7	6.5	2.2	2.3	1.8	2.7	2.3
1988	2.0	0.8	2.2	1.8	0.5	2.6	8.7	3.0	1.2	1.1	1.8	1.4
1989	13.5	8.9	0.9	0.3	0.9	0.7	12.0	4.9	5.3	2.8	1.3	1.4
1990	1.7	0.7	1.2	2.2	3.2	0.6	0.4	0.8	0.6	0.8	0.8	0.5
1991	18.7	5.1	1.2	0.6	1.5	1.8	1.4	1.0	3.5	4.0	2.4	2.4
1992	12.8	9.5	1.4	0.4	0.4	0.4	16.3	6.9	2.1	1.8	2.1	4.1
1993	1.7	0.7	5.9	1.3	2.3	2.8	2.8	1.4	1.4	1.7	6.3	3.9
1994	3.9	0.8	9.0	2.4	2.9	4.6	5.2	5.3	2.1	1.2	1.4	2.1
1995	1.4	13.0	14.3	3.3	0.4	2.2	1.0	0.4	0.3	1.8	1.2	1.3
1996	7.9	22.1	5.2	0.3	0.5	3.3	2.4	4.1	2.8	4.9	4.7	2.5
1997	1.0	0.9	0.4	0.6	0.8	7.0	6.5	3.5	1.5	1.8	1.4	1.3
1998	0.7	3.4	3.8	2.5	4.9	3.9	2.6	1.3	0.7	1.3	0.9	1.8
1999	3.5	0.7	0.3	5.0	1.6	14.6	4.6	3.3	1.3	0.6	0.6	0.9
2000	1.7	4.0	2.1	0.4	0.3	1.2	6.0	1.9	0.4	0.4	4.2	2.9
2001	1.3	3.1	0.5	0.9	1.0	0.3	1.5	2.3	1.6	1.9	3.9	4.0
2002	1.2	0.7	0.9	0.9	0.3	25.1	8.6	8.1	3.6	1.6	2.8	1.6
2003	4.3	0.9	0.4	0.7	2.2	1.1	6.0	2.3	1.4	1.9	1.1	1.3
2004	16.2	4.3	28.3	10.7	0.8	2.4	7.1	4.4	3.8	2.0	1.6	1.3

Table 4.7 Goukou Estuary: Simulated monthly flows (in m^3/s) for Sc 2

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.9	0.4	3.8	0.3	6.9	2.9	7.5	2.6	5.4	3.1	3.3	2.7
1921	0.4	0.1	0.9	6.0	1.1	6.0	2.1	0.8	0.7	2.1	1.3	0.4
1922	0.9	3.1	0.1	0.0	0.0	0.0	3.8	5.7	4.1	1.9	1.1	0.3
1923	2.0	3.3	0.2	0.0	0.0	0.0	0.0	0.0	0.4	0.6	4.9	1.5
1924	0.2	1.0	0.1	0.0	0.0	2.0	0.8	0.0	1.8	1.0	0.7	2.7
1925	2.4	1.0	0.1	0.0	0.0	0.0	0.8	0.3	0.5	2.1	1.9	1.8
1926	7.5	3.7	0.3	0.0	0.0	0.1	0.6	1.7	0.8	0.2	2.1	0.5
1927	0.1	1.0	0.0	0.0	0.0	5.5	1.6	0.2	0.5	0.3	1.4	3.0
1928	0.5	30.3	13.2	0.4	0.1	0.7	0.8	2.1	1.5	6.1	5.1	2.2
1929	1.0	0.2	0.2	0.1	15.4	6.6	1.3	3.6	1.9	0.7	1.6	1.2
1930	3.8	0.4	0.0	0.0	0.0	5.2	9.8	2.5	0.6	4.4	2.6	2.3
1931	7.8	1.5	9.5	2.0	3.7	1.2	0.1	0.1	0.9	1.0	0.6	30.4
1932	9.9	0.7	0.2	0.0	0.1	0.2	0.2	2.4	1.3	0.6	5.8	1.9
1933	0.3	6.1	0.6	2.6	2.5	5.7	1.2	0.1	0.0	3.1	3.7	1.8
1934	23.7	12.5	0.6	0.1	0.0	0.2	1.4	6.5	5.7	2.5	1.1	3.8
1935	1.8	3.7	0.8	0.1	0.0	0.0	0.0	1.5	0.6	1.6	0.8	3.5
1936	2.1	16.8	6.6	0.5	0.0	4.9	1.2	0.0	0.2	1.0	0.4	1.9
1937	0.1	0.8	3.0	0.9	0.0	2.2	3.0	0.8	0.7	1.2	0.8	1.5
1938	2.9	7.3	1.8	0.1	2.6	9.2	3.0	0.3	0.1	2.1	11.1	4.8
1939	1.1	0.6	0.1	0.1	10.9	4.2	3.2	1.0	0.8	0.6	0.2	1.6
1940	0.2	5.0	0.4	0.2	0.0	0.0	6.0	2.6	2.8	1.8	1.9	2.4
1941	4.9	1.7	0.2	1.5	0.1	0.7	1.2	2.0	1.2	0.6	0.6	1.1
1942	1.2	0.1	1.6	8.3	2.3	0.5	0.6	0.0	0.0	0.0	0.9	6.6
1943	2.2	8.0	1.9	0.1	0.0	2.0	0.9	4.3	2.4	2.2	2.8	6.2
1944	4.0	0.4	0.1	0.0	0.0	0.0	0.0	4.9	4.7	2.1	3.1	2.8
1945	6.5	1.1	0.2	0.0	0.0	9.6	3.0	0.2	0.2	0.9	1.0	0.5
1946	0.5	0.1	0.0	0.0	0.0	9.9	4.7	2.5	1.5	4.1	1.4	2.8
1947	2.1	1.9	0.1	1.5	0.1	3.6	5.3	1.1	0.5	0.7	0.2	1.5
1948	12.1	3.5	0.2	0.2	0.0	0.0	0.5	2.6	0.8	0.6	0.4	0.4
1949	0.1	10.1	1.7	0.1	0.0	0.0	0.6	1.0	0.1	1.5	1.8	1.3
1950	4.8	7.4	0.9	10.5	2.7	2.3	0.6	1.3	2.3	6.4	3.2	6.7
1951	1.8	0.3	0.1	0.0	0.1	0.0	0.4	0.2	0.3	0.6	2.0	8.8
1952	3.3	6.1	1.5	0.1	0.4	0.0	1.2	0.3	1.1	6.8	3.4	5.1
1953	5.6	3.9	0.3	0.0	0.0	0.2	5.4	10.1	4.1	2.5	11.6	4.3
1954	0.8	1.2	0.2	1.4	10.1	1.6	0.2	0.3	0.7	1.5	2.2	2.9
1955	1.5	0.8	0.1	0.0	0.0	2.1	1.3	7.4	2.9	1.7	2.3	1.6
1956	5.0	0.6	3.8	0.1	2.0	1.5	0.7	3.2	7.9	4.1	4.9	7.7
1957	3.8	0.5	0.1	0.0	0.0	3.0	2.4	16.7	6.8	1.1	6.1	2.6
1958	1.9	0.3	0.2	2.2	5.6	5.8	9.9	6.7	2.1	9.6	7.5	3.1
1959	8.3	1.7	0.2	0.2	0.2	1.8	1.7	2.6	2.8	2.1	1.1	2.0
1960	0.6	3.0	3.0	2.5	0.4	1.3	1.3	2.7	1.4	2.2	3.2	2.7
1961	4.0	0.9	0.1	0.1	1.2	3.8	3.4	1.0	1.0	0.7	25.0	7.7
1962	8.0	7.8	0.5	0.9	0.1	5.9	3.1	2.5	0.9	2.3	1.1	0.2
1963	1.5	0.9	3.3	2.0	0.7	3.0	0.9	0.3	5.9	2.1	3.9	6.7
1964	3.4	2.4	0.3	0.0	0.4	2.2	2.2	4.4	1.7	1.3	1.6	0.4
1965	11.3	9.3	2.6	1.2	0.0	0.1	1.0	5.0	2.0	0.6	8.3	6.4
1966	1.0	0.2	0.0	0.0	0.0	3.8	30.1	13.2	4.8	4.6	3.6	4.9
1967	1.2	2.2	0.2	0.0	0.0	0.0	1.2	3.0	6.0	1.8	5.5	3.1
1968	1.0	4.2	0.1	0.0	0.0	0.0	0.2	0.3	3.6	1.6	2.0	1.0
1969	0.2	0.1	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.5	3.8	0.8
1970	1.6	0.1	0.4	0.0	4.0	4.1	7.8	6.0	3.2	9.9	10.2	3.6
1971	1.2	4.6	0.3	0.1	1.9	2.1	3.2	3.0	1.7	1.7	5.3	5.5
1972	0.7	1.0	0.1	0.0	0.0	0.0	0.3	0.8	2.0	1.9	2.3	1.7
1973	0.4	0.6	1.0	3.5	6.0	5.5	0.9	7.5	2.8	0.4	5.4	3.7
1974	1.0	0.8	0.1	0.0	0.0	0.0	0.0	1.4	2.4	2.7	6.3	7.4
1975	1.8	2.5	0.4	0.1	2.3	3.7	3.0	3.2	7.2	5.0	2.5	2.4
1976	11.2	6.5	1.3	0.1	6.8	2.4	2.7	12.3	5.3	2.0	2.2	2.6
1977	1.8	3.7	0.9	0.1	0.0	0.0	1.6	0.8	1.9	2.0	3.1	2.1
1978	2.1	0.4	1.6	0.2	3.0	0.3	0.1	2.2	1.2	7.2	6.1	4.9
1979	3.5	0.5	1.0	1.1	0.1	0.1	0.2	0.1	1.8	0.6	1.2	2.0
1980	2.4	10.5	2.5	16.2	10.7	9.9	19.4	9.9	3.2	3.0	11.0	4.6
1981	0.8	0.5	2.8	0.1	0.1	1.7	28.6	8.0	2.8	3.7	3.3	8.4
1982	3.5	0.4	0.1	0.1	0.1	0.1	0.1	3.1	4.5	4.9	2.2	6.2
1983	2.7	3.8	0.3	0.1	0.1	2.0	0.9	0.3	0.3	1.7	0.7	0.2
1984	1.5	0.1	0.1	6.7	5.9	0.4	4.2	1.2	2.0	7.5	2.8	0.6
1985	11.0	7.0	3.4	0.2	0.1	0.1	0.6	0.0	0.0	0.3	35.1	12.0
1986	5.5	1.8	0.3	0.1	0.0	0.0	7.6	2.6	1.6	1.1	3.5	4.6
1987	0.9	0.2	0.2	0.0	0.0	0.5	5.7	1.9	2.1	1.6	2.4	1.4
1988	1.2	0.3	1.2	1.0	0.1	1.5	8.4	2.1	0.9	0.8	1.5	0.6
1989	12.4	7.6	0.4	0.0	0.0	0.0	10.6	4.6	5.1	1.9	1.0	0.7
1990	0.8	0.1	0.4	1.1	2.1	0.2	0.1	0.0	0.3	0.6	0.1	0.1
1991	16.6	4.2	0.5	0.0	0.5	0.9	0.7	0.7	3.2	3.8	2.2	1.5
1992	11.7	8.2	1.0	0.1	0.1	0.1	13.8	6.6	1.8	1.5	1.8	3.9
1993	0.8	0.2	4.5	0.6	1.4	1.8	2.5	1.1	1.1	1.4	6.0	2.9
1994	2.8	0.3	7.5	1.5	1.9	3.5	4.9	5.0	1.8	1.0	1.1	1.8
1995	0.5	11.9	13.2	2.4	0.1	1.1	0.3	0.0	0.0	1.3	0.4	0.9
1996	7.2	20.7	4.4	0.2	0.1	1.8	1.9	3.8	2.5	4.6	4.4	1.5
1997	0.4	0.3	0.1	0.1	0.1	5.8	6.2	3.2	1.2	1.5	1.2	0.5
1998	0.2	2.1	2.7	1.6	3.7	2.9	2.3	1.0	0.4	1.0	0.7	1.5
1999	3.2	0.1	0.0	3.3	0.7	13.4	3.7	3.1	1.0	0.4	0.4	0.2
2000	0.7	2.6	1.2	0.1	0.0	0.1	5.3	1.6	0.2	0.2	3.7	1.9
2001	0.5	2.0	0.1	0.1	0.2	0.0	0.6	1.8	1.2	1.5	3.5	3.7
2002	0.5	0.2	0.1	0.1	0.0	23.1	8.3	7.9	3.3	1.3	2.5	0.8
2003	4.0	0.3	0.1	0.1	1.0	0.4	5.5	2.0	1.2	1.6	0.8	1.0
2004	14.9	3.4	28.2	9.6	0.3	1.4	6.8	4.1	3.5	1.1	1.3	0.5

Table 4.8 Goukou Estuary: Simulated monthly flows (in m^3/s) for Sc 3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.7	0.4	3.1	0.3	6.2	2.6	7.2	2.3	5.1	2.8	3.1	2.4
1921	0.4	0.1	0.1	5.6	0.8	5.7	1.8	0.5	0.5	1.8	1.1	0.2
1922	0.6	2.8	0.1	0.0	0.0	0.0	2.3	5.4	3.8	1.6	0.8	0.3
1923	1.5	2.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.2	1.2
1924	0.2	0.5	0.1	0.0	0.0	0.8	0.5	0.0	1.3	0.7	0.4	2.4
1925	2.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.6	1.5
1926	7.2	3.4	0.3	0.0	0.0	0.0	0.0	0.6	0.5	0.1	1.7	0.2
1927	0.1	0.3	0.0	0.0	0.0	4.3	1.3	0.0	0.2	0.0	1.1	2.7
1928	0.2	30.0	12.9	0.4	0.1	0.1	0.4	1.8	1.2	5.9	4.8	1.9
1929	0.7	0.2	0.1	0.1	14.2	6.4	1.0	3.3	1.6	0.4	1.4	0.9
1930	3.5	0.2	0.0	0.0	0.0	3.9	9.6	2.3	0.4	4.1	2.3	2.0
1931	7.5	1.2	9.2	1.7	3.4	0.9	0.1	0.0	0.2	0.7	0.3	30.1
1932	9.6	0.5	0.2	0.0	0.1	0.1	0.1	0.8	1.0	0.3	5.5	1.6
1933	0.3	5.5	0.3	2.3	2.2	5.4	0.9	0.1	0.0	2.3	3.4	1.5
1934	23.4	12.2	0.6	0.1	0.0	0.1	0.1	6.2	5.4	2.2	0.9	3.5
1935	1.5	3.4	0.5	0.1	0.0	0.0	0.0	0.1	0.3	1.3	0.5	3.2
1936	1.9	16.5	6.3	0.3	0.0	4.2	0.9	0.0	0.0	0.4	0.1	1.6
1937	0.1	0.2	2.7	0.7	0.0	1.6	2.7	0.5	0.4	0.9	0.5	1.2
1938	2.6	7.0	1.6	0.1	2.1	8.9	2.7	0.3	0.1	1.3	10.8	4.5
1939	0.8	0.3	0.1	0.1	10.0	3.9	2.9	0.7	0.5	0.4	0.2	0.9
1940	0.2	4.5	0.4	0.0	0.0	0.0	4.7	2.3	2.5	1.5	1.6	2.2
1941	4.6	1.4	0.2	1.0	0.1	0.1	0.8	1.7	1.0	0.3	0.3	0.8
1942	0.9	0.1	1.0	8.0	2.0	0.2	0.3	0.0	0.0	0.0	0.0	5.9
1943	1.9	7.7	1.6	0.1	0.0	1.2	0.6	4.0	2.1	1.9	2.5	5.9
1944	3.7	0.4	0.1	0.0	0.0	0.0	0.0	3.1	4.4	1.8	2.8	2.5
1945	6.2	0.8	0.2	0.0	0.0	8.4	2.8	0.2	0.1	0.2	0.6	0.2
1946	0.2	0.1	0.0	0.0	0.0	8.4	4.4	2.2	1.2	3.8	1.1	2.5
1947	1.8	1.6	0.1	0.9	0.1	3.0	5.0	0.8	0.2	0.4	0.2	1.0
1948	11.7	3.2	0.2	0.1	0.0	0.0	0.0	1.4	0.6	0.3	0.2	0.1
1949	0.1	9.3	1.4	0.1	0.0	0.0	0.0	0.1	0.0	1.1	1.4	1.0
1950	4.5	7.1	0.7	10.2	2.4	2.0	0.3	1.0	2.0	6.1	3.0	6.4
1951	1.5	0.3	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.2	0.4	8.5
1952	3.0	5.8	1.2	0.1	0.1	0.0	0.3	0.0	0.8	6.5	3.2	4.8
1953	5.3	3.6	0.3	0.0	0.0	0.1	4.0	9.8	3.8	2.2	11.3	4.0
1954	0.8	0.7	0.2	0.7	9.8	1.3	0.2	0.1	0.1	1.1	1.9	2.6
1955	1.2	0.5	0.1	0.0	0.0	1.0	1.0	7.1	2.6	1.4	2.0	1.3
1956	4.7	0.3	3.5	0.1	1.4	1.2	0.4	2.9	7.6	3.8	4.6	7.4
1957	3.5	0.5	0.1	0.0	0.0	1.6	2.1	16.4	6.5	0.9	5.7	2.3
1958	1.6	0.3	0.2	1.3	5.3	5.6	9.6	6.4	1.8	9.3	7.2	2.9
1959	8.0	1.4	0.2	0.2	0.2	0.7	1.4	2.3	2.6	1.8	0.8	1.8
1960	0.3	2.7	2.7	2.2	0.2	1.0	1.0	2.4	1.1	1.9	2.9	2.4
1961	3.8	0.6	0.1	0.1	0.2	3.5	3.1	0.7	0.7	0.4	24.7	7.4
1962	7.7	7.5	0.5	0.4	0.1	5.3	2.8	2.2	0.6	2.1	0.8	0.2
1963	0.9	0.6	3.0	1.7	0.4	2.7	0.6	0.0	5.6	1.8	3.6	6.5
1964	3.1	2.1	0.3	0.0	0.0	1.4	1.9	4.1	1.4	1.0	1.3	0.3
1965	10.8	9.0	2.3	0.9	0.0	0.0	0.3	4.7	1.7	0.4	8.0	6.2
1966	0.7	0.2	0.0	0.0	0.0	2.3	29.8	12.9	4.5	4.3	3.3	4.6
1967	0.9	1.9	0.2	0.0	0.0	0.0	0.1	2.4	5.7	1.5	5.2	2.8
1968	0.7	3.9	0.1	0.0	0.0	0.0	0.1	0.0	1.9	1.3	1.7	0.7
1969	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.5
1970	1.3	0.1	0.1	0.0	3.1	3.8	7.5	5.7	2.9	9.6	9.9	3.3
1971	1.0	4.3	0.3	0.1	1.0	1.8	3.0	2.7	1.5	1.4	5.0	5.2
1972	0.6	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.9	1.6	2.0	1.4
1973	0.2	0.3	0.6	3.1	5.7	5.2	0.6	7.2	2.5	0.3	4.9	3.4
1974	0.8	0.5	0.1	0.0	0.0	0.0	0.0	0.0	1.7	2.4	6.0	7.1
1975	1.5	2.2	0.2	0.1	1.6	3.4	2.7	2.9	6.9	4.7	2.2	2.1
1976	10.9	6.2	1.0	0.1	6.2	2.1	2.4	12.0	5.0	1.7	1.9	2.3
1977	1.5	3.4	0.6	0.1	0.0	0.0	0.4	0.5	1.6	1.8	2.8	1.8
1978	1.8	0.2	1.3	0.1	2.5	0.3	0.1	1.3	0.9	6.9	5.8	4.6
1979	3.2	0.5	0.4	0.8	0.1	0.1	0.1	0.0	0.5	0.4	0.9	1.7
1980	2.1	10.3	2.2	15.9	10.4	9.6	19.1	9.6	2.9	2.8	10.7	4.3
1981	0.8	0.5	1.9	0.1	0.1	0.8	28.3	7.7	2.5	3.4	3.1	8.1
1982	3.2	0.4	0.1	0.1	0.1	0.1	0.1	1.4	3.9	4.6	2.0	6.0
1983	2.4	3.5	0.3	0.1	0.1	0.9	0.6	0.1	0.2	1.2	0.5	0.2
1984	0.8	0.1	0.1	5.8	5.6	0.2	3.8	0.9	1.7	7.2	2.5	0.6
1985	10.5	6.7	3.1	0.2	0.1	0.1	0.1	0.0	0.0	0.1	33.6	11.7
1986	5.3	1.5	0.3	0.1	0.0	0.0	6.2	2.3	1.3	0.8	3.2	4.3
1987	0.7	0.2	0.1	0.0	0.0	0.0	4.3	1.6	1.8	1.3	2.1	1.1
1988	0.9	0.3	0.6	0.7	0.1	1.0	8.1	1.8	0.6	0.5	1.2	0.3
1989	12.1	7.4	0.4	0.0	0.0	0.0	9.1	4.3	4.8	1.6	0.7	0.5
1990	0.4	0.1	0.1	0.5	1.8	0.2	0.1	0.0	0.1	0.1	0.1	0.1
1991	15.1	3.9	0.2	0.0	0.1	0.5	0.4	0.4	2.9	3.5	1.9	1.3
1992	11.4	7.9	1.0	0.1	0.1	0.1	12.4	6.3	1.5	1.2	1.5	3.6
1993	0.6	0.2	3.9	0.3	1.1	1.6	2.2	0.9	0.8	1.2	5.7	2.6
1994	2.5	0.3	7.0	1.3	1.7	3.2	4.6	4.7	1.5	0.7	0.8	1.5
1995	0.3	11.5	12.9	2.1	0.1	0.5	0.1	0.0	0.0	0.4	0.1	0.6
1996	6.9	20.4	4.1	0.2	0.1	1.0	1.7	3.5	2.3	4.3	4.2	1.3
1997	0.4	0.3	0.1	0.1	0.1	4.1	5.9	2.9	0.9	1.2	0.9	0.3
1998	0.2	1.3	2.4	1.3	3.4	2.6	2.0	0.7	0.2	0.7	0.4	1.2
1999	2.9	0.1	0.0	2.5	0.4	13.1	3.4	2.8	0.7	0.2	0.2	0.1
2000	0.1	2.3	0.9	0.1	0.0	0.0	4.2	1.3	0.2	0.2	2.9	1.6
2001	0.3	1.6	0.1	0.0	0.1	0.0	0.0	0.8	0.9	1.2	3.2	3.4
2002	0.5	0.2	0.1	0.0	0.0	21.5	8.0	7.6	3.0	1.0	2.2	0.5
2003	3.7	0.3	0.1	0.1	0.1	0.1	4.8	1.7	0.9	1.3	0.5	0.7
2004	14.6	3.1	27.9	9.3	0.3	0.8	6.6	3.8	3.2	0.9	1.0	0.3

Table 4.9 Goukou Estuary: Simulated monthly flows (in m^3/s) for Sc 4

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.7	0.4	1.1	0.3	4.8	1.9	6.5	1.6	4.4	2.1	2.4	1.7
1921	0.4	0.1	0.1	2.8	0.3	4.8	1.1	0.2	0.2	0.3	0.3	0.2
1922	0.1	1.1	0.1	0.0	0.0	0.0	1.1	4.7	3.1	0.9	0.4	0.3
1923	0.3	1.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.5	0.5
1924	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.1	0.2
1925	0.9	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.4
1926	5.8	2.7	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2
1927	0.1	0.0	0.0	0.0	0.0	2.7	0.6	0.0	0.0	0.0	0.1	0.4
1928	0.2	28.7	12.2	0.4	0.1	0.1	0.1	0.2	0.3	4.0	4.1	1.2
1929	0.6	0.2	0.1	0.1	12.0	5.7	0.4	2.5	0.9	0.3	0.3	0.3
1930	2.5	0.2	0.0	0.0	0.0	2.3	8.9	1.6	0.4	2.7	1.6	1.3
1931	6.8	1.1	8.0	1.0	2.7	0.2	0.1	0.0	0.1	0.2	0.3	26.8
1932	8.9	0.5	0.2	0.0	0.1	0.1	0.1	0.3	0.4	0.3	2.8	0.9
1933	0.3	4.1	0.3	0.9	1.5	4.7	0.4	0.1	0.0	0.3	2.4	0.8
1934	22.7	11.5	0.6	0.1	0.0	0.1	0.1	3.4	4.7	1.5	0.7	2.3
1935	0.8	2.7	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.8
1936	1.1	15.8	5.6	0.3	0.0	2.2	0.3	0.0	0.0	0.1	0.1	0.2
1937	0.1	0.1	0.1	0.1	0.0	0.2	1.4	0.2	0.2	0.2	0.2	0.2
1938	0.9	6.2	0.9	0.1	0.6	8.2	2.0	0.3	0.1	0.4	8.9	3.8
1939	0.7	0.3	0.1	0.1	7.4	3.2	2.2	0.6	0.5	0.4	0.2	0.2
1940	0.2	1.6	0.4	0.0	0.0	0.0	2.8	1.6	1.8	0.8	0.9	1.5
1941	3.9	0.7	0.2	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3
1942	0.3	0.1	0.3	5.2	1.3	0.2	0.1	0.0	0.0	0.0	0.0	3.1
1943	1.2	7.0	0.9	0.1	0.0	0.1	0.2	2.0	1.4	1.2	1.8	5.2
1944	3.0	0.4	0.1	0.0	0.0	0.0	0.0	2.4	3.7	1.1	2.1	1.8
1945	5.5	0.6	0.2	0.0	0.0	6.7	2.1	0.2	0.1	0.2	0.2	0.2
1946	0.2	0.1	0.0	0.0	0.0	6.8	3.7	1.5	0.5	3.1	0.8	1.5
1947	1.0	0.9	0.1	0.1	0.1	1.0	4.3	0.2	0.2	0.2	0.2	0.3
1948	9.1	2.5	0.2	0.1	0.0	0.0	0.0	0.9	0.6	0.2	0.2	0.1
1949	0.1	6.7	1.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3
1950	2.3	6.4	0.6	8.9	1.7	1.3	0.2	0.2	0.9	5.4	2.3	5.7
1951	1.1	0.3	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.2	0.3	6.1
1952	2.3	5.1	0.6	0.1	0.1	0.0	0.1	0.0	0.1	3.4	2.5	4.1
1953	4.6	2.9	0.3	0.0	0.0	0.1	1.9	9.1	3.1	1.5	10.6	3.3
1954	0.8	0.5	0.2	0.1	6.9	0.6	0.2	0.1	0.1	0.4	0.6	0.7
1955	0.5	0.3	0.1	0.0	0.0	0.3	0.3	5.3	1.9	0.9	1.1	0.8
1956	3.8	0.3	2.1	0.1	0.2	0.3	0.3	1.6	6.9	3.1	3.9	6.7
1957	2.8	0.5	0.1	0.0	0.0	0.4	1.3	15.7	5.8	0.9	4.3	1.8
1958	0.8	0.3	0.2	0.2	3.4	4.9	8.9	5.7	1.2	8.6	6.5	2.2
1959	7.3	1.1	0.2	0.2	0.2	0.2	0.2	0.7	1.9	1.1	0.5	0.7
1960	0.3	1.2	2.0	1.5	0.2	0.2	0.2	1.4	0.6	1.0	2.1	1.7
1961	3.1	0.3	0.1	0.1	0.1	0.7	2.4	0.3	0.3	0.2	22.9	6.7
1962	7.0	6.8	0.5	0.1	0.1	2.8	2.1	1.5	0.2	1.1	0.4	0.2
1963	0.1	0.1	1.1	1.0	0.2	1.6	0.2	0.0	3.9	1.1	2.9	5.8
1964	2.4	1.4	0.3	0.0	0.0	0.1	0.4	2.8	0.7	0.5	0.6	0.3
1965	9.3	8.3	1.6	0.2	0.0	0.0	0.1	2.1	1.0	0.2	6.7	5.5
1966	0.7	0.2	0.0	0.0	0.0	0.6	29.1	12.2	3.8	3.6	2.6	3.9
1967	0.7	0.8	0.2	0.0	0.0	0.0	0.1	0.2	4.9	0.8	4.5	2.1
1968	0.5	2.8	0.1	0.0	0.0	0.0	0.1	0.0	0.3	0.5	1.0	0.3
1969	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.3
1970	0.2	0.1	0.1	0.0	0.6	3.1	6.8	5.0	2.2	8.9	9.2	2.6
1971	1.0	2.9	0.3	0.1	0.1	0.2	1.8	2.0	0.8	0.7	4.3	4.5
1972	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.4	0.7
1973	0.2	0.1	0.1	1.0	5.0	4.5	0.3	6.1	1.8	0.3	3.5	2.7
1974	0.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.1	1.4	5.3	6.4
1975	1.2	1.2	0.2	0.1	0.1	2.0	2.0	2.2	6.2	4.0	1.5	1.4
1976	10.2	5.5	0.6	0.1	4.5	1.4	1.7	11.3	4.3	1.0	1.2	1.6
1977	0.8	2.7	0.2	0.1	0.0	0.0	0.1	0.1	1.4	1.0	0.8	0.7
1978	0.7	0.2	0.1	0.1	0.7	0.3	0.1	0.0	0.1	5.4	5.1	3.9
1979	2.5	0.5	0.4	0.2	0.1	0.1	0.1	0.0	0.1	0.1	0.2	0.3
1980	0.3	9.2	1.5	15.2	9.7	8.9	18.4	8.9	2.2	2.1	10.0	3.6
1981	0.8	0.5	0.3	0.1	0.1	0.2	25.7	7.0	1.8	2.7	2.4	7.4
1982	2.5	0.4	0.1	0.1	0.1	0.1	0.1	1.4	2.1	3.9	1.3	5.2
1983	1.7	2.8	0.3	0.1	0.1	0.1	0.2	0.1	0.2	0.5	0.5	0.2
1984	0.2	0.1	0.1	3.6	4.9	0.2	2.4	0.4	0.8	6.4	1.8	0.6
1985	9.1	6.0	2.4	0.2	0.1	0.1	0.1	0.0	0.0	0.1	31.7	11.0
1986	4.6	0.8	0.3	0.1	0.0	0.0	5.0	1.6	0.6	0.4	2.2	3.5
1987	0.7	0.2	0.1	0.0	0.0	0.0	2.2	0.9	1.1	0.6	1.4	0.5
1988	0.5	0.3	0.3	0.1	0.1	0.2	5.4	1.1	0.3	0.3	0.3	0.3
1989	10.1	6.7	0.4	0.0	0.0	0.0	7.1	3.6	4.1	1.1	0.7	0.5
1990	0.3	0.1	0.1	0.1	0.3	0.2	0.1	0.0	0.1	0.1	0.1	0.1
1991	13.3	3.2	0.2	0.0	0.1	0.2	0.2	0.1	0.4	2.0	1.2	0.9
1992	10.4	7.2	1.0	0.1	0.1	0.1	11.1	5.6	0.8	0.6	0.8	2.9
1993	0.6	0.2	1.8	0.3	0.1	0.4	1.5	0.2	0.3	0.4	4.8	1.9
1994	1.8	0.3	5.6	0.6	1.0	2.5	3.9	4.0	0.8	0.5	0.5	0.4
1995	0.3	9.5	12.2	1.4	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1
1996	3.8	19.7	3.4	0.2	0.1	0.2	0.3	2.2	1.6	3.6	3.5	0.7
1997	0.4	0.3	0.1	0.1	0.1	2.8	5.2	2.2	0.7	0.5	0.4	0.3
1998	0.2	0.2	0.2	0.6	2.7	1.9	1.3	0.1	0.1	0.1	0.1	0.2
1999	1.4	0.1	0.0	0.4	0.2	12.0	2.7	2.1	0.3	0.2	0.2	0.1
2000	0.1	0.2	0.2	0.1	0.0	0.0	1.9	0.6	0.2	0.2	0.9	0.9
2001	0.3	0.3	0.1	0.0	0.1	0.0	0.0	0.2	0.3	0.4	0.9	2.7
2002	0.5	0.2	0.1	0.0	0.0	20.0	7.3	6.9	2.3	0.7	1.1	0.5
2003	2.3	0.3	0.1	0.1	0.1	0.1	2.0	1.0	0.3	0.6	0.4	0.3
2004	13.1	2.4	27.2	8.6	0.3	0.2	5.1	3.1	2.5	0.6	0.4	0.3

4.3 HYDROLOGY

Tables 4.10 and **4.11** provide a summary of the changes in low flows and flood regime that have occurred under the different scenarios. The freshwater reduction to the micro-habitats will remain similar to present state under the future scenarios.

Table 4.10 Goukou Estuary: Summary of the change in low flow conditions under a range of flow scenarios

Percentile	Monthly flow (m^3/s)					
	Natural	Present	Sc 1	Sc 2	Sc 3	Sc 4
30%	1.6	0.8	1.1	0.5	0.2	0.1
20%	1.2	0.3	0.7	0.2	0.1	0.1
10%	0.7	0.1	0.4	0.0	0.0	0.0
% Similarity in low flows		**30.2**	**59.7**	**16.8**	**9.3**	**6.9**

Table 4.11 Goukou Estuary: Summary of the ten highest simulated monthly volumes under Reference Condition, Present State and a range of flow scenarios

Date	Monthly volume (million m^3/month)					
	Natural	Present	Sc 1	Sc 2	Sc 3	Sc 4
Aug 1986	98.98	96.00	96.00	94.12	89.98	84.97
Nov 1928	83.43	78.95	78.95	78.60	77.85	74.36
Apr 1967	81.82	79.00	79.00	77.96	77.21	75.40
Sep 1932	81.82	79.36	79.36	78.69	77.89	69.51
Dec 2005	78.36	75.92	75.92	75.62	74.84	72.97
Apr 1982	77.05	74.49	74.49	74.08	73.33	66.70
Aug 1967	70.02	67.15	67.15	66.89	66.11	61.39
Mar 2003	68.73	64.30	64.30	61.96	57.63	53.52
Oct 1934	66.43	63.73	63.73	63.36	62.58	60.71
Nov 1996	57.26	54.11	54.11	53.65	52.90	51.09
Apr 1981	52.83	50.59	50.59	50.18	49.43	47.62
Oct 1991	50.98	47.40	47.40	44.47	40.41	35.66
May 1958	49.10	46.26	46.26	44.69	43.91	42.04
Nov 1936	46.89	44.01	44.01	43.56	42.81	40.99
Jan 1981	46.09	43.85	43.85	43.31	42.53	40.66
Apr 1993	43.50	39.79	39.79	35.88	32.05	28.85
Oct 2004	43.48	40.45	40.45	39.95	39.18	34.97
Feb 1930	42.54	39.64	39.64	37.56	34.72	29.25
Dec 1929	39.41	36.21	36.21	35.44	34.66	32.79
Mar 2000	39.33	36.44	36.44	35.97	35.19	32.26

Date	Monthly volume (million m^3/month)					
	Natural	Present	Sc 1	Sc 2	Sc 3	Sc 4
% Similarity in floods		94.64	94.64	92.62	89.90	84.00

A summary of the EHI hydrology score for the present and future scenarios are provided in **Table 4.12**.

Table 4.12 Goukou Estuary: Hydrology health scores for present and future scenarios

Variable	Weight	Scenario					
		Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. % Similarity in low flows	55	30	42	17	9	7	Low
b. % Similarity in flood volumes	35	95	95	93	90	84	Medium
c. % Similarity in freshwater input from fountains and seeps	10	40	40	40	40	40	Low
Hydrology weighted mean (a,b)		**54**	**60**	**46**	**40**	**37**	**Low/Medium**

4.4 PHYSICAL HABITATS

The relevant changes in sediment dynamics and geomorphology drivers is that a further progressive reduction in large floods occurs under Sc 2, 3 and 4 (about 2, 5 and 11% respectively compared to present), while both the present and Sc 1 reduce large floods by 5% from Reference Conditions. A summary of the expected changes in the physical habitat of the Goukou Estuary under each of the future scenarios are provided in **Table 4.13**.

Table 4.13 Goukou Estuary: Summary of physical habitat changes under different scenarios

Parameter	Scenario
a. Supratidal area and sediments	The only potential new changes are related to changes in flood regime. Changes to low flows have virtually no impact on sediment dynamics and morphology within the estuary. Thus Sc 1 is not different from the Present State. Sc 2, Sc 3 and Sc 4 have additional 2, 5 and 11% (negative) change effect respectively on flood regime which will translate into direct associated effects on sediment dynamics and morphology in the estuary. Under Sc 2, Sc 3 and Sc 4 there will be progressively less large floods which flush out sediments from the estuary and deposit new sediments on the floodplain. Slightly longer retention of riverine sediment deposits, enabling more consolidation and more enduring plant growth, all contribution to slightly less dynamic estuarine geomorphology.
b. Intertidal areas and sediments	Same as for supratidal. Also progressively slightly more ingress of marine sediments under Sc 2, Sc 3 and Sc 4.
c. Subtidal area and sediments	Same as for intertidal.
d. Estuary bathymetry (relates to water volume)	Under Sc 2, Sc 3 and Sc 4 there would be progressively slightly less flushing of sediments due to further floods reduction, thus slightly reduced water volume. Sc 2, Sc 3 and Sc 4 would also

Parameter	Scenario
	progressively allow slightly larger marine waters and sediment ingress, thus slightly reduced water volume. Overall all these effects considered small, only altering marginally the score from present (proportion of small percentage change on top of only a 15% change).

The physical habitat health scores for the present and future scenarios are provided in **Table 4.14**.

Table 4.14 Goukou Estuary: Physical habitat health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Supratidal area and sediments	65	65	63	60	54	Low (1); Very Low (2-4)
b. Intertidal areas and sediments	65	65	63	60	54	Low (1); Very Low (2-4)
c. Subtidal area and sediments	72	72	70	68	61	Low (1); Very Low (2-4)
d. Estuary bathymetry/water volume	85	85	84	83	80	Low (1); Very Low (2-4)
Physical habitat score min (a to d)	**65**	**65**	**63**	**60**	**54**	**Low (1);** Very Low **(2-4)**

4.5 HYDRODYNAMICS AND MOUTH CONDITION

Based on available literature, a number of characteristic 'states' can be identified for the Goukou Estuary, related to tidal exchange, salinity distribution and water quality. These are primarily determined by river inflow patterns. The different states are listed in **Table 4.15**. A summary of the expected changes in the hydrodynamic and mouth conditions in the Goukou Estuary under each of the future scenarios are provided in **Table 4.16**.

Table 4.15 Goukou Estuary: Summary of the abiotic states that can occur

State	Flow range (m^3/s)	Description
State 1	< 0.3	Marine dominated, no REI
State 2	0.3 - 1	Full salinity gradient
State 3	1 - 5	Partial salinity gradient
State 4	5 - 15	Limited salinity penetration
State 5	> 15	Freshwater dominated

Table 4.16 Goukou Estuary: Summary of the changes in the hydrodynamics under the various scenarios

Parameter	Future scenarios
Mouth condition	No change as it is n permanently open estuary.
Inundation	Sc 1: Similar to present. Sc 2: Additional 2% reduction in inundation.

<table>
<tr><th>Parameter</th><th>Future scenarios</th></tr>
<tr><td></td><td>Sc 3: Additional 5% reduction in inundation.
Sc 4: Additional 11% reduction in inundation.</td></tr>
<tr><td>Tidal range</td><td>Shift in tidal amplitude under the future scenarios are driven by change in State 1 and 4.

<table>
<tr><th>Reference</th><th>Present</th><th>Sc 1</th><th>Sc 2</th><th>Sc 3</th><th>Sc 4</th></tr>
<tr><td>1.75</td><td>1.71</td><td>1.74</td><td>1.70</td><td>1.67</td><td>1.61</td></tr>
</table></td></tr>
<tr><td>Dominant circulation process</td><td>Under the Reference Conditions the tide was the dominant circulation process for about 79% of the time this has increase to about 83% of the time under the Present State.
Under Sc 1 to 4 will remain the dominant mixing process and occur for 81%, 85%, 86% and 89%, respectively.</td></tr>
<tr><td>Water column structure</td><td>From Reference to Present there has been some loss of stratification in in the lower reaches (Zone A and B) and a slight increase in the upper reaches (Zone D) as a result of decreasing flow.

Sc 1: The system becomes more homogenous, with a decrease in stratification the lower reaches (Zone A and B) and a slight increase in the upper reaches (Zone D) of the system.
Sc 2: The system becomes more homogenous, with an additional loss in stratification in the lower reaches (Zone A and B) and an increase in the upper reaches (Zone D).
Sc 3: The system becomes more homogenous, with an additional loss in stratification in the lower reaches (Zone A and B) and an increase in the upper reaches (Zone D).
Sc 4: The system becomes very homogenous, with a significant loss in stratification in the lower reaches and the upper reaches (Zone D) become more stratified as average flow decreases.

<table>
<tr><th rowspan="2">Zone</th><th colspan="6">ΔS</th></tr>
<tr><th>Reference</th><th>Present</th><th>Sc 1</th><th>Sc 2</th><th>Sc 3</th><th>Sc 4</th></tr>
<tr><td>A</td><td>10</td><td>8</td><td>9</td><td>8</td><td>7</td><td>5</td></tr>
<tr><td>B</td><td>15</td><td>11</td><td>13</td><td>10</td><td>9</td><td>6</td></tr>
<tr><td>C</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>D</td><td>2</td><td></td><td>3</td><td>4</td><td>4</td><td>5</td></tr>
</table></td></tr>
<tr><td>Retention</td><td>The high retention states (1 and 2) have increased from 17% under the Reference Condition to about 35% under the Present State.

Under Sc 1 to 4 high retention states (1 and 2) have increased from 17% under Reference to 28%, 43%, 51% and 65%, respectively.</td></tr>
<tr><td>Connectivity with the riparian area</td><td>The Goukou Estuary has a high degree of connectivity with the riparian areas in the form of permanently damp seeps and adjacent fountain habitat. These serve, for example, as eels habitat (Paling gat) and bathing areas for Cape Clawless Otters. Due to the damming and over-abstraction of the surrounding fountains and seeps, the direct riparian connectivity is estimated to be reduced by at least 50%.</td></tr>
</table>

The hydrodynamics and mouth condition health scores for the present and future scenarios are provided in **Table 4.17**.

Table 4.17 Goukou Estuary: Hydrodynamics and mouth condition health scores for present and future scenarios

Variable	Weight	Scenario					Confidence
		Present	Sc 1	Sc 2	Sc 3	Sc 4	
a. % similarity in abiotic states and mouth condition	34	100	100	100	100	100	Medium
b. % similarity in the water column structure	33	90	92	86	82	73	Medium
c. % similarity in water retention time	No data						
d. % similarity in tidal amplitude and symmetry)	33	99	100	99	98	96	Medium
Hydrodynamics and mouth weighted mean (a to d)		**95**	**99**	**98**	**98**	**96**	**Medium**

4.6 WATER QUALITY

Table 4.18 provides a summary the occurrence of various abiotic states under reference, present and each of the future scenarios for the Goukou Estuary.

Table 4.18 Goukou Estuary: Summary of the occurrence of the abiotic states under the Reference Condition, Present State and Sc 1 to 4

Abiotic state	Natural	Present	Scenario			
			Sc 1	Sc 2	Sc 3	Sc 4
State 1: Marine dominated, no REI	2	18	3	26	33	47
State 2: Full salinity gradient	14	17	25	17	18	18
State 3: Partial salinity gradient	62	48	53	42	35	24
State 4: Limited salinity penetration	19	15	17	14	12	9
State 5: Freshwater dominated	2	2	2	2	1	1

Table 4.19 provides a summary of the expected average changes in various water quality parameters in different zones under present and future scenarios, while **Table 4.20** summarised the cause of such changes.

Table 4.18 Goukou Estuary: Estimated changes in water quality in different zones under different scenarios

Zone	Volume weighting	Estimated salinity concentration based on distribution of abiotic states					
		Reference	Present	Sc 1	Sc 2	Sc 3	Sc 4
A (lower)	0.25	28	30	29	30	31	32
B	0.30	19	21	20	22	23	25
C	0.30	10	14	11	15	17	20
D (upper)	0.10	5	9	6	10	12	15

Freshwater micro-habitat	0.05	15	30	30	30	30	30
Zone	**Volume weighting**	**Estimated DIN concentration (µg/L) based on distribution of abiotic states**					
		Reference	**Present**	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
A (lower)	0.25	51	63	64	63	58	57
B	0.35	51	104	104	105	101	101
C	0.30	51	202	202	204	199	199
D (upper)	0.10	51	184	199	178	166	152
Zone	**Volume weighting**	**Estimated DIP concentration (µg/L) based on distribution of abiotic states**					
		Reference	**Present**	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
A (lower)	0.25	10	12	12	12	11	11
B	0.35	10	20	20	21	20	20
C	0.30	10	20	20	21	20	20
D (upper)	0.10	10	20	20	21	20	20
Zone	**Volume weighting**	**Estimated turbidity (NTU) based on distribution of abiotic states**					
		Reference	**Present**	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
A (lower)	0.25	10	11	11	11	10	10
B	0.35	10	11	11	11	10	10
C	0.30	10	12	12	12	11	11
D (upper)	0.10	10	17	18	16	15	14
Zone	**Volume weighting**	**Estimated dissolved oxygen (mg/L) based on distribution of abiotic states**					
		Reference	**Present**	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
A (lower)	0.25	8	8	8	8	8	8
B	0.35	8	6	6	6	6	6
C	0.30	8	6	6	6	6	6
D (upper)	0.10	7[1]	5[2]	5[3]	5[4]	5[5]	5[6]

1 Bottom water 2 mg/L for ~16 % of the time. 2Bottom water 2 mg/L for ~35 % of the time.
3 Bottom water 2 mg/L for ~28 % of the time. 4 Bottom water 2 mg/L for ~43 % of the time.
5 Bottom water 2 mg/L for ~51 % of the time. 6 Bottom water 2 mg/L for ~65 % of the time.

Table 4.19 Goukou Estuary: Summary of water quality changes under different scenarios

Parameter	Summary of changes
Changes salinity gradient	Estuary water column: Sc 1: While salinity ⇧ due to increase in low flow conditions from Reference, there is a well-established REI zone for most of the year under this scenario. Sc 2 to 4: ⇧ due to increase in low flow conditions, with REI not present for most of summer. Freshwater Habitats: Similar to present, salinity ⇧ due to reduction in flow from riparian fountains and seeps above and in EFZ.
Inorganic nutrients (DIN and DIP) in estuary	⇧ Due to agricultural activities in catchment (and WWTW), as well as effects of urban runoff along banks (Zones B and C). Similarity to reference “improve” from present in Sc 2 - 4 as less enriched river water becomes less.
Turbidity in estuary	⇧ Due to agricultural activities in catchment. Similarity to reference “increase” from present in scenarios where less enriched water reaching the estuary.

Parameter	Summary of changes
Dissolved oxygen in estuary	⇩ Due to agricultural activities in catchment (and WWTW), as well as effects of urban runoff along banks (Zones B and C). Similarity with reference "decreases" from present in Sc 2 - 4, as occurrence of low flow states increases
Toxic substances in estuary	⇧ Due to agricultural activities in catchment, also diffuse runoff from urban areas adjacent to estuary.

The EHI scores for water quality are presented in **Table 4.20**.

Table 4.20 Goukou Estuary: Water quality health scores for present and future scenarios

Variable	Weight	Scenario					
		Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
1 Similarity in salinity: weighted mean (a,b)	40	87	95	82	80	74	
a. Estuary water column	95	88	96	83	80	74	Medium
b. Freshwater micro-habitat	5	67	67	67	67	67	Low
2 General water quality min (a to d)	60	67	67	67	69	69	
a. DIN/DIP concentrations		67	67	67	69	69	Low/Medium
b. Turbidity		93	93	93	96	97	Medium
c. Dissolved oxygen		90	91	90	90	89	Medium
d. Toxic substances		80	80	80	80	80	Low
Water quality score weighted mean (1,2)		**75**	**78**	**73**	**73**	**71**	**Low/Medium**

4.7 MICROALGAE

A summary of the expected changes under various scenarios for the microalgae component in the Goukou Estuary is provided in **Table 4.21**.

Table 4.21 Goukou Estuary: Summary of change in microalgae under different scenarios

Scenario	Summary of changes
1	50% of the flow is restored to the estuary (MAR = 88%), flood volumes are similar to present (5% lost). Changes to low flows have virtually no impact on sediment dynamics and morphology within the estuary. **Phytoplankton**: The 12% decrease in river flow from reference is predicted to shift the system to have a higher proportion of low flows (40% reduction from reference) and a decrease in flood volume (5% decrease). Elevated turbidity (7% increase), particularly at high flows, limit phytoplankton growth, whereas increased residence time (11% higher than reference) and elevated nutrients (33% higher than reference) are likely to result a 22% increase in phytoplankton biomass from reference (half of the change from present). With regards to community composition the reduced river flow and elevated nutrients favour a decrease in the diatoms:flagellates ratio, and an increase in dinoflagellates, blue-greens and chlorophytes (32% change) **Benthic microalgae**: The largest factors affecting benthic microalgae are related to catchment flow reductions (incl. flood volume), sediment input (lower coarse sediment) and elevated nutrients. Assuming a 34% increase in biomass related to reduction in river flow (12%), floods (5%) and nutrients (33%*0.5; benthic microalgae dependent on water column and mineralised

Scenario	Summary of changes
	nutrients). The small decrease in flood volume is likely to have increased sedimentation in the upper reaches, farm dams are likely to have removed some coarse sediment, and the intrusion of marine sediment into the estuary is likely to have increased. The change in community composition related to sediment type (5%) and elevated nutrients (33%*0.5; benthic microalgae dependent on water column and mineralised nutrients) is likely to be 22%.
2	Additional 10% of flow is lost from present MAR (71%), flood volumes decrease further 2% from present (7% lost). Changes to low flows have virtually no impact on sediment dynamics and morphology within the estuary. **Phytoplankton**: Based on a regression of abundance scores (reference, present and scenario 1) the 29% decrease in river flow from reference is predicted to change the abundance by 54% (score = 46); the result of a higher proportion of low flows (83% reduction from reference) and a decrease in flood volume (7% decrease), elevated turbidity (7% increase), increased residence time (26% higher than reference), and elevated nutrients (32% higher than reference). With regards to community composition the reduced river flow (29%) and elevated nutrients (32%) favour a decrease in the diatoms:flagellates ratio, and an increase in dinoflagellates, blue-greens and chlorophytes (61%*0.70 = 57). **Benthic microalgae**: The largest factors affecting benthic microalgae are related to catchment flow reductions (incl. flood volume), sediment input (lower coarse sediment) and elevated nutrients. Assuming a 52% increase in biomass related to reduction in river flow (29%), floods (7%) and nutrients (32%*0.5; benthic microalgae dependent on water column and mineralised nutrients). The small decrease in flood volume is likely to have increased sedimentation in the upper reaches, farm dams are likely to have removed some coarse sediment, and the intrusion of marine sediment into the estuary is likely to have increased. The change in community composition related to sediment type (7%) and elevated nutrients (32%*0.5; benthic microalgae dependent on water column and mineralised nutrients) is likely to be 23%.
3	Additional 15% of flow is lost from present MAR (Sc 3 MAR = 63%) and flood volumes decrease 10% from reference. **Phytoplankton**: Based on a regression of abundance scores (reference, present and scenario 1) the 37% decrease in river flow from reference is predicted to change the abundance by 66% (score = 34); the result of a higher proportion of low flows (91% reduction from reference) and a decrease in flood volume (10% decrease), elevated turbidity (4% increase), increased residence time (34% higher than reference), and elevated nutrients (30% higher than reference). With regards to community composition the reduced river flow (37%) and elevated nutrients (30%) favour a decrease in the diatoms:flagellates ratio, and an increase in dinoflagellates, blue-greens and chlorophytes (67%*0.70 = 47% change). **Benthic microalgae**: The largest factors affecting benthic microalgae are related to catchment flow reductions (incl. flood volume), sediment input (lower coarse sediment) and elevated nutrients. Assuming a 62% increase in biomass related to reduction in river flow (37%), floods (10%) and nutrients (30%*0.5; benthic microalgae dependent on water column and mineralised nutrients). The small decrease in flood volume is likely to have increased sedimentation in the upper reaches, farm dams are likely to have removed some coarse sediment, and the intrusion of marine sediment into the estuary is likely to have increased. The change in community composition related to sediment type (10%) and elevated nutrients (30%*0.5; benthic microalgae dependent on water column and mineralised nutrients) is likely to be 25%.
4	Additional 30% of flow is lost from present MAR (Sc 4 MAR = 48%) and flood volumes decrease 16% from reference. **Phytoplankton**: Based on a regression of abundance scores (reference, present and scenario 1) the 52% decrease in river flow from reference is predicted to change the abundance by 85% (score = 15); the result of a higher proportion of low flows (93% reduction from reference) and a decrease in flood volume (16% decrease), elevated turbidity (3% increase), increased residence time (48% higher than reference), and elevated nutrients (29% higher than reference). With regards to community composition the reduced river flow (52%) and elevated nutrients (29%) favour a decrease in the diatoms:flagellates ratio, and an increase in dinoflagellates, blue-greens and chlorophytes (81%*0.70 = 57% change).

Scenario	Summary of changes
	Benthic microalgae: The largest factors affecting benthic microalgae are related to catchment flow reductions (incl. flood volume), sediment input (lower coarse sediment) and elevated nutrients. Assuming an 83% increase in biomass related to reduction in river flow (52%), floods (16%) and nutrients (29%*0.5; benthic microalgae dependent on water column and mineralised nutrients). The decrease in flood volume is likely to have increased sedimentation in the upper reaches, farm dams are likely to have removed some coarse sediment, and the intrusion of marine sediment into the estuary is likely to have increased. The change in community composition related to sediment type (21%) and elevated nutrients (29%*0.5; benthic microalgae dependent on water column and mineralised nutrients) is likely to be 36%.

The EHI scores for microalgale under the various scenarios are presented in **Table 4.22.**

Table 4.22 Goukou Estuary: Microalgae health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
Phytoplankton						
a. Species richness	95	95	95	95	95	Low
b Abundance	57	78	46	34	15	Medium
c. Community composition	63	68	57	53	43	Medium
Benthic microalgae						
a. Species richness	95	95	95	95	95	Low
b Abundance	58	66	48	38	17	Medium
c. Community composition	79	80	77	75	64	Medium
Microalgae score min (a to c)	**57**	**66**	**46**	**34**	**15**	**Medium**

4.8 MACROPHYTES

A summary of the expected changes under various scenarios for the macrophyte component in the Goukou Estuary is provided in **Table 4.23**.

Table 4.23 Goukou Estuary: Summary of change in macrophytes under different scenarios

Scenario	Summary of changes
1	The restoration of 50% of baseflow will improve conditions as salinity will decrease. Salinity in Zone C where the pondweed grows will decrease from 14 (present) to 11 bringing it closer to the optimum of 10; more in the salinity range of tolerance for this submerged macrophyte. The decrease in salinity in the upper reaches of the estuary from 9 - 6 will increase reed growth. Although there is an improvement in macrophyte abundance and community composition, the overall loss of habitat due to agriculture and development remains.
2	pMAR will decrease by 10% resulting in an increase in salinity in Zone C and D with some negative responses from the plants. The state of the macrophytes will be poorer compared to the present.
3	The 15% reduction in MAR, decrease in baseflow and increase in salinity will decrease growth of all macrophytes. In particular there will be a dieback of reeds, sedges and pondweed in Zone C where salinity is now 17 compared to 10 for Reference Conditions. The increase in salinity in

	Zone D from 5 (reference) to 12 is within the range of tolerance of the dominant plants located in this zone. However the increase in salinity will decrease macrophyte productivity as the plants cope with the salinity stress. The decrease in floods will prevent inundation of the supratidal marshes causing salt accumulation and die-back.
4	The 30% reduction in MAR, decrease in baseflow and increase in salinity will decrease growth of all macrophytes. There will be a further dieback of reeds, sedges and pondweed in Zone C where salinity is now 20 compared to 10 for Reference Conditions. The increase in salinity in Zone D from 5 (reference) to 15 is within the range of tolerance of the reeds in this zone but is not ideal for pondweed. However, the increase in salinity will decrease macrophyte productivity as the plants cope with the salinity stress. The decrease in floods will cause an 11% reduction in inundation of the supratidal marshes causing salt accumulation and die-back.

The EHI scores for marcophytes under the various scenarios are presented in **Table 4.24**.

Table 4.24 Goukou Estuary: Macrophyte health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	80	85	75	70	65	Medium
b. Abundance	72	74	67	611	55	Medium
c. Community composition	68	72	65	57	51	Medium
Macrophyte score min (a to c)	**68**	**72**	**65**	**57**	**51**	**Medium**

4.9 INVERTEBRATES

A summary of the expected changes under various scenarios for the invertebrate component in the Goukou Estuary is provided in **Table 4.25**, while the health scores for the present and future scenarios are provided in **Table 4.26**.

Table 4.25 Goukou Estuary: Summary of change in macrophytes under different scenarios

Scenario	Summary of changes
1	Under this scenario, the increase in baseflow leads to the presence of the REI for most of the year compared to present. Salinity along the estuary has otherwise barely changed, although there is a marginal increase in stratification. The greater persistence of the REI will lead to less temporal variability among invertebrate communities and an overall increase in biomass compared to present. Microhabitats will remain similar to present, thus the communities associated with them not change.
2	No REI is present during the summer months particularly, with salinity increasing slightly along the length of the estuary compared to Present State. No oligohaline community will be present and the increased plankton biomass associated with the REI will not develop. Low oxygen concentrations in deeper areas of the estuary will also increase. Variability among invertebrate groups decreases marginally and biomass remains similar to present. Microhabitats remain similar.
3 and 4	Sc 3 and Sc 4 follow the trajectory described under Sc 2, the net result leading to a decrease in invertebrate overall. Submerged macrophyte will increase and this will lead to a change in community composition among the benthic community particularly. Microhabitats remain similar to Present State, although their role as nodes of recruitment into adjacent parts of the estuary increases. Under Sc 4, some zooplankters (e.g. *Acartia natalensis*) will probably disappear from the main estuary (diapause eggs will not hatch), although the species will follow a normal life cycle in seep areas.

Scenario	Summary of changes
	Fringing reeds and sedges also decease in biomass, but will remain associated with seeps where invertebrates utilizing these habitats will become more isolated from the main estuary, particularly during summer (underlining the importance of the seeps to the estuary). Floods under Sc 4 also reduce further (by 11%) and the benthic community in the lower estuary will probably increase in biomass as flushing of sediment is reduced and sandy substrata extends further up-estuary.

Table 4.26 Goukou Estuary: Invertebrates health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
Zooplankton						
a. Species richness	100	100	100	100	95	Medium
b. Abundance	65	70	62	57	50	Medium
c. Community composition	65	70	62	57	50	Medium
Hyperbenthos						
a. Species richness	100	100	100	100	90	Medium
b. Abundance	65	70	62	57	50	Medium
c. Community composition	60	65	55	50	45	Medium
Benthos						
a. Species richness	100	100	100	100	90	Medium
b. Abundance	60	65	55	50	40	Medium
c. Community composition	60	65	55	50	40	Medium
Invertebrate score min (a to c)	**60**	**65**	**55**	**50**	**40**	**Medium**

4.10 FISH

A summary of the expected changes under various scenarios for the fish component in the Goukou Estuary is provided in **Table 4.27**, while the health scores for the present and future scenarios are provided in **Table 4.28**.

Table 4.27 Goukou Estuary: Summary of change in fish under different scenarios

Scenario	Summary of changes
Reference	The system will still be marine dominated to a certain degree especially for the lower 4 km of the estuary due to tidal/inflow dynamics. REI species will increase in range and biomass in the system. Change in prevalent salinity regimes ↓ will cause invertebrate organisms to burrow deeper becoming less available to estuary-associated marine species. Increase phyto- and zooplankton production should benefit juveniles of all species.
Present	Fish assemblages more marine dominated compared to Reference Condition Ia and Ib occur in lower to middle reaches. Estuary dependent marine species distributed throughout the system. Estuary associated and marine migrants associated with lower and middle reaches according to prevalent salinity regime. Fresh water species confined to upper reaches. Occasional low oxygen levels at depth in the upper reaches (Zone D) will exclude benthic species or restrict them to the marginal areas.

Scenario	Summary of changes
1	Population dynamics to change to a less marine dominated assembly and increase in REI species e.g. *G. aestuaria*, *M. capensis*. Marine migrants associated with lower reaches of the estuary. Estuary resident and breeding species (Ia, Ib) distributed throughout the system except mouth area (Zone A). Longer high flow periods, increased connectivity and recruitment with marine environment and other estuaries in region for estuary dependent and associated marine species. Freshwater species do penetrate down to middle reaches during high flow periods.
2 and 3	Loss of REI for extended periods during summer months. REI species located only at the head of the system and population threshold decreased. Estuary resident / breeding Ia species widely distributed through the system but in lower densities and biomass. Obligate estuary-dependent and estuary-associated marine species occur throughout the whole system during low flow summer periods. Recruitment does decline due to lesser volume and temporal high flow periods. Marine vagrants increase in occurrence towards middle/upper reaches of the system.
4	Loss of the REI for a large part of the year and REI species (if they still occur) confined mostly to the head of the system. An exception would be *G. aestuaria* (Ia) which would be distributed throughout the system but in much lower densities and biomass. Estuary-dependent and associated marine species occur throughout the whole system during low flow summer periods but recruitment much less due to decrease in flow volume (52% MAR) and duration of high-flow periods. Marine vagrants established in lower, middle reaches and become completely dominant section of population assembly.

Table 4.28 Goukou Estuary: Fish health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	90	95	80	75	60	High
b. Abundance	80	90	80	75	60	High
c. Community composition	75	90	70	70	50	High
Fish score min (a to c)	**75**	**90**	**70**	**70**	**50**	**High**

4.11 BIRDS

A summary of the expected changes under various scenarios for the bird component in the Goukou Estuary is provided in **Table 4.29**, while the health scores for the present and future scenarios are provided in **Table 4.30**.

Table 4.29 Goukou Estuary: Summary of change in birds under different scenarios

Scenario	Summary of changes
1	Estuary moves towards natural. Freshwater penetrates lower into the system. Abundance and productivity of all groups is higher. Expect increases in numbers of waterfowl and piscivorous bird groups.
2 and 3	Reduction in freshwater inflow means salinity penetrates further up the estuary. Reduced productivity, fish recruitment declines due to reduction in floods. Reductions in abundance of waterfowl and piscivorous groups relative to present.
4	Further reduction in flows. Trends described in above scenario are exacerbated.

Table 4.30 Goukou Estuary: Bird health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	95	95	95	90	90	Medium
b. Abundance	73	79	69	66	54	Medium
c. Community composition	84	88	82	79	70	Medium
Bird scores min (a to c)	**73**	**79**	**69**	**66**	**54**	**Medium**

4.12 ECOLOGICAL CATEGORIES ASSOCIATED WITH SCENARIOS

The individual health scores for the various abiotic and biotic components are used to determine the ecological status or ecological category for the Goukou Estuary under each of the future scenarios (**Table 4.31**), again using the EHI.

Table 4.31 Goukou Estuary: EHI score and corresponding Ecological Categories under present and future scenarios

Variable	Weight	Scenario					
		Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
Hydrology	25	54	60	46	40	37	Low/Medium
Hydrodynamics and mouth condition	25	95	99	98	98	96	Medium
Water quality	25	76	78	73	73	71	Medium/High
Physical habitat alteration	25	75	65	63	60	54	Low
Habitat health score	**50**	**72**	**76**	**70**	**68**	**65**	
Microalgae	20	57	66	46	34	15	Medium
Macrophytes	20	68	72	65	57	51	Medium
Invertebrates	20	60	65	55	50	40	Medium
Fish	20	75	90	70	70	50	High
Birds	20	73	79	69	66	54	Medium
Biotic health score	**50**	**67**	**74**	**61**	**55**	**42**	
ESTUARY HEALTH SCORE		**69**	**75**	**66**	**62**	**53**	**Medium**
ECOLOGICAL CATEGORY		**C**	**B/C**	**C**	**C/D**	**D**	**Medium**

4.13 RECOMMENDED ECOLOGICAL FLOW SCENARIO

In the case of the Goukou Estuary a Category B was proposed as the REC. Applying this guideline, none of the potential flow scenarios evaluated as part of this study were able to reverse modification in the ecological state to a Category B. This is mainly as a result of significant non-flow related impacts also contributing to the present ecological status in the estuary. However, Sc 1 could restore the estuary to a Category B/C (just below a Category B). Sc 1 assumes a 50% base flow return to the estuary, e.g. through removal of alien invasive plants, as well as reducing run-off river abstraction during the low flow season. Restoring some base flow addresses the key flow-related factor contributing to the changes in ecological health in this estuary, namely the re-establishment of the REI zone. Considering the significant contribution of non-flow related factors the present health in the Goukou Estuary, as well as the reversibility of some of these impacts, Sc 1 was identified as the recommended flow scenario from an ecological perspective. However, in order to improve from a Category B/C (Sc 1 only), additional intervention in terms of non-flow related impacts will be essential to improve the ecological health of the estuary to a Category B.

5 SCENARIO RESULTS: DUIWENHOKS ESTUARY

(This section is extracted from the Duiwenhoks estuary report for the study, as authored by the estuary team and compiled by Dr Susan Taljaard – DWS, 2014a.)

5.1 INTRODUCTION

The Duiwenhoks Estuary is a permanently open estuary located in the warm temperate region of the Western Cape between Riversdale and Heidelberg along the Cape south coast **(Figure 5.1)** (Carter and Brownlie, 1990). The geographical boundaries of the estuary are defined as follows:

Downstream boundary:	Estuary mouth: 34°21'54.31"S; 21° 0'0.51"E
Upstream boundary:	34°15'5.87"S; 20°59'30.95"E
Lateral boundaries:	5 m contour above MSL along each bank

5.1.1 Present Ecological State

The EHI score for the Duiwenhoks Estuary is 72, thus a PES of Category C (**Table 5.1**).

Table 5.1 Duiwenhoks Estuary: PES

Variable	Weight	Score
Hydrology	25	47
Hydrodynamics and mouth condition	25	95
Water quality	25	72
Physical habitat alteration	25	82
Habitat health score		**74**
Microalgae	20	73

Variable	Weight	Score
Macrophytes	20	60
Invertebrates	20	70
Fish	20	70
Birds	20	78
Biotic health score		**70**
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		**72**
PRESENT ECOLOGICAL STATUS (PES)		**C**
OVERALL CONFIDENCE		**Medium**

5.1.2 Ecological importance

The functional importance of the Duiwenhoks Estuary was high as it is an important fish nursery (with a number of Red data and exploited fish species occurring in high numbers in the system. The estuary is also a very important conduit for eels which are CITES listed species. Referring to the estuarine importance rating system (DWAF, 2008), the importance score of the Duiwenhoks Estuary – a score of 84 – translates into an importance rating of 'Highly Important'.

5.2 DESCRIPTION AND CONSEQUENCES OF SCENARIOS

The future scenarios that were assessed for the Duiwenhoks Estuary are summarised in **Table 5.2**.

Table 5.2 Duiwenhoks Estuary: Summary of flow scenarios

Scenario	Description	MAR (million m^3)	Percentage remaining
Reference	Natural.	89.29	100
Present	PD.	72.91	82
Sc 1	Returning 50% of natural base flows (↓ afforestation/water use).	85.43	96
Sc 2	With low flow EWR.	73.01	82
Sc 3	Dam with 1.5 million m^3 capacity, abstracting 9.5 million m^3/annum.	63.63	71
Sc 4	Worst case dam development.	49.93	56

The occurrences of the flow distributions (mean monthly flows in m^3/s) under the future Scenarios of the Duiwenhoks Estuary, derived from an 85-year simulated data set are provided in **Tables 5.3** to **5.6** and **Figures 5.1** to **5.4**. The full sets 85-year series of simulated monthly runoff data for the future Scenarios are provided in **Tables 5.7** to **5.10**.

Table 5.3 Duiwenhoks Estuary: Summary of the monthly flow distribution (in m³/s) for Sc 1

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	19.8	24.2	24.1	12.8	12.6	19.4	24.6	12.7	6.8	9.3	28.4	24.0
99	15.9	18.6	13.5	10.3	9.7	12.9	23.4	12.1	6.3	8.6	23.1	14.3
90	9.8	6.9	3.0	2.6	3.8	4.9	6.6	6.0	4.5	5.2	6.2	6.5
80	4.9	5.3	2.3	1.3	1.9	3.4	4.4	3.8	3.6	3.7	5.2	5.6
70	4.0	3.5	1.6	1.0	1.2	2.4	3.0	2.9	2.7	3.1	4.2	4.1
60	3.0	2.4	1.3	0.6	0.7	1.7	2.0	2.3	2.3	2.6	3.4	3.5
50	2.5	2.0	1.0	0.4	0.5	1.2	1.5	1.8	1.8	2.2	3.1	3.0
40	2.3	1.5	0.7	0.3	0.3	0.8	1.0	1.4	1.6	2.0	2.6	2.7
30	2.0	1.3	0.5	0.2	0.2	0.6	0.8	1.1	1.3	1.6	2.2	2.2
20	1.6	1.1	0.3	0.1	0.1	0.3	0.6	0.6	1.0	1.4	1.7	1.9
10	1.3	0.8	0.3	0.0	0.0	0.1	0.4	0.5	0.7	1.1	1.5	1.7
5	1.1	0.7	0.1	0.0	0.0	0.0	0.2	0.4	0.5	1.0	1.2	1.4
1	0.8	0.6	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.7	1.0	1.0
0.1	0.7	0.5	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.5	0.9	0.7

Table 5.4 Duiwenhoks Estuary: Summary of the monthly flow distribution (in m³/s) for Sc 2

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	19.1	23.2	23.5	12.4	9.9	16.5	22.2	11.5	6.5	9.0	26.3	23.1
99	15.2	17.9	13.1	9.5	8.8	11.9	21.2	11.4	6.0	8.3	22.1	13.6
90	9.3	6.6	2.5	1.8	2.7	4.1	5.4	5.7	4.3	4.6	6.0	6.3
80	4.8	4.8	1.6	0.5	0.7	2.4	3.2	3.0	3.5	3.5	5.0	5.5
70	3.8	3.0	0.6	0.4	0.4	1.7	2.5	2.4	2.4	2.8	4.0	3.9
60	2.6	1.9	0.5	0.3	0.3	1.1	1.6	1.9	2.0	2.4	3.3	3.3
50	2.3	1.4	0.4	0.2	0.2	0.5	1.0	1.3	1.6	2.1	2.8	2.8
40	1.8	0.7	0.4	0.2	0.1	0.2	0.6	1.1	1.2	1.6	2.4	2.5
30	1.5	0.5	0.3	0.1	0.1	0.1	0.6	0.8	1.1	1.4	2.1	1.9
20	1.1	0.5	0.2	0.1	0.0	0.1	0.4	0.5	0.8	1.1	1.5	1.7
10	0.8	0.4	0.2	0.0	0.0	0.0	0.2	0.3	0.5	0.9	1.1	1.3
1	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.4	0.7	0.5
0.1	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.6	0.3

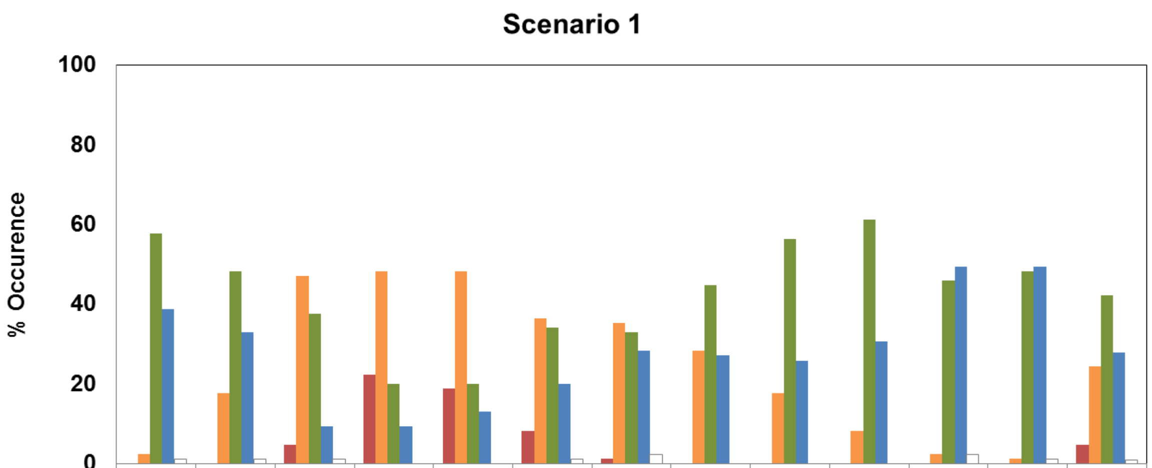
Table 5.5 Duiwenhoks Estuary: Summary of the monthly flow distribution (in m^3/s) for Sc 3

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	18.8	23.0	23.2	12.1	9.7	16.4	22.1	11.2	6.2	8.7	26.2	22.8
99	15.1	17.6	12.8	9.2	8.5	11.9	21.3	11.1	5.8	8.0	21.9	13.3
90	8.9	6.3	2.2	1.3	2.7	3.8	5.2	5.4	4.1	4.3	5.7	6.0
80	4.5	4.5	1.3	0.0	0.2	2.1	3.1	2.7	3.2	3.2	4.7	5.2
70	3.5	2.6	0.2	0.0	0.0	1.1	1.8	2.0	2.2	2.5	3.6	3.6
60	2.3	1.6	0.0	0.0	0.0	0.4	1.4	1.7	1.8	2.1	3.0	3.0
50	1.9	1.1	0.0	0.0	0.0	0.1	0.7	1.0	1.3	1.8	2.5	2.5
40	1.5	0.4	0.0	0.0	0.0	0.0	0.3	0.6	1.1	1.3	2.1	2.2
30	1.2	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.8	1.2	1.8	1.7
20	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.8	1.3	1.3
10	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	1.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.3
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1

Table 5.6 Duiwenhoks Estuary: Summary of the monthly flow distribution (in m^3/s) for Sc 4

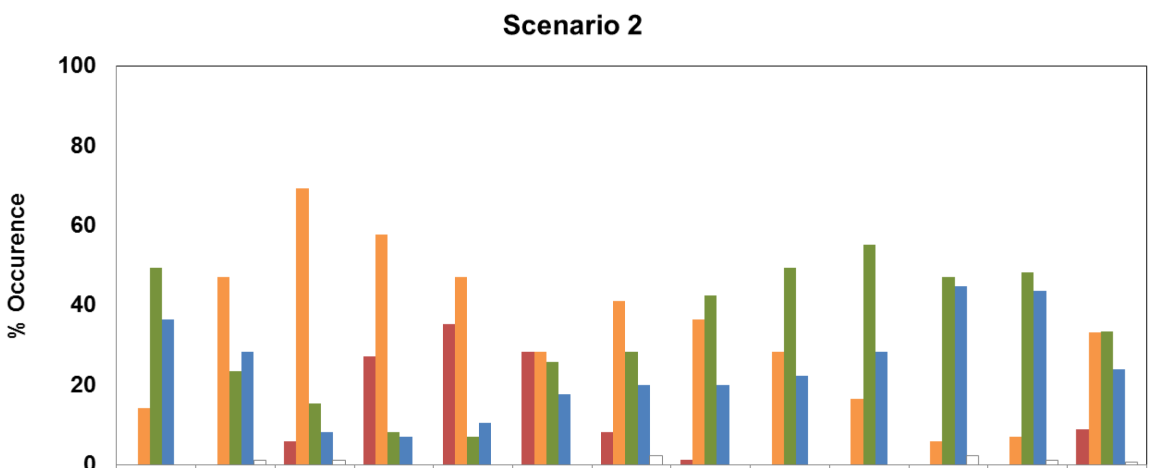
%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	17.9	22.3	22.5	10.4	5.7	14.8	21.4	11.0	6.0	8.5	24.7	22.1
99	12.8	16.9	12.0	7.5	5.5	10.0	19.7	10.9	5.6	7.8	21.5	12.6
90	8.2	5.4	1.3	0.0	0.0	2.6	4.5	5.2	3.8	4.1	5.5	5.3
80	3.8	3.3	0.2	0.0	0.0	0.8	2.3	2.4	2.8	3.0	4.5	4.4
70	2.8	1.9	0.0	0.0	0.0	0.0	1.2	1.6	1.9	2.3	3.4	2.9
60	1.6	0.9	0.0	0.0	0.0	0.0	0.5	0.9	1.4	1.9	2.8	2.3
50	1.2	0.2	0.0	0.0	0.0	0.0	0.0	0.4	1.0	1.6	2.2	1.8
40	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.1	1.9	1.5
30	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.5	1.0
20	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

A graphic representation of the occurrence of the various abiotic states for the Future scenarios is presented below in **Figures 5.1 to 5.4**.



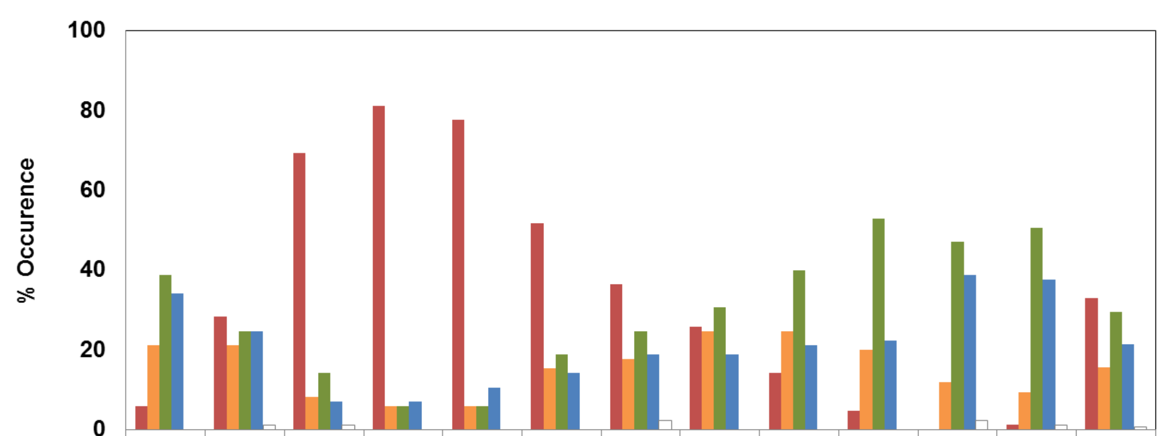
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	5	22	19	8	1	0	0	0	0	0	5
State 2	2	18	47	48	48	36	35	28	18	8	2	1	24
State 3	58	48	38	20	20	34	33	45	56	61	46	48	42
State 4	39	33	9	9	13	20	28	27	26	31	49	49	28
State 5	1	1	1	0	0	1	2	0	0	0	2	1	1

Figure 5.1 Duiwenhoks Estuary: Occurrence of abiotic states under the Sc 1



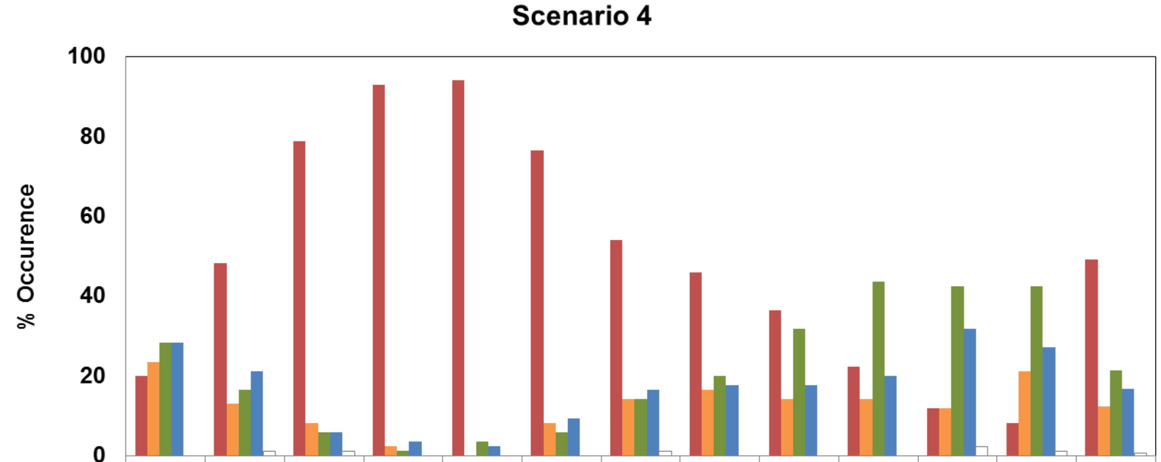
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	6	27	35	28	8	1	0	0	0	0	9
State 2	14	47	69	58	47	28	41	36	28	16	6	7	33
State 3	49	24	15	8	7	26	28	42	49	55	47	48	33
State 4	36	28	8	7	11	18	20	20	22	28	45	44	24
State 5	0	1	1	0	0	0	2	0	0	0	2	1	1

Figure 5.2 Duiwenhoks Estuary: Occurrence of abiotic states under the Sc 2



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	6	28	69	81	78	52	36	26	14	5	0	1	33
State 2	21	21	8	6	6	15	18	25	25	20	12	9	15
State 3	39	25	14	6	6	19	25	31	40	53	47	51	30
State 4	34	25	7	7	11	14	19	19	21	22	39	38	21
State 5	0	1	1	0	0	0	2	0	0	0	2	1	1

Figure 5.3 Duiwenhoks Estuary: Occurrence of abiotic states under the Sc 3



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	20	48	79	93	94	76	54	46	36	22	12	8	49
State 2	24	13	8	2	0	8	14	16	14	14	12	21	12
State 3	28	16	6	1	4	6	14	20	32	44	42	42	21
State 4	28	21	6	4	2	9	16	18	18	20	32	27	17
State 5	0	1	1	0	0	0	1	0	0	0	2	1	1

Figure 5.4 Duiwenhoks Estuary: Occurrence of abiotic states under the Sc 4

Table 5.7 Duiwenhoks Estuary: Simulated monthly flows (in m^3/s) for Sc 1

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	1.4	0.8	2.8	1.0	5.0	2.5	5.6	2.9	4.5	3.9	4.1	3.9
1921	2.0	0.6	1.1	4.5	1.8	4.2	2.2	1.1	1.2	2.1	2.2	1.7
1922	1.4	2.5	0.8	0.2	0.1	0.0	3.7	4.6	4.0	3.2	2.7	1.8
1923	2.2	2.7	0.7	0.1	0.3	0.2	0.3	0.4	1.0	1.1	4.8	3.0
1924	1.3	1.3	0.6	0.2	0.0	2.0	1.1	0.5	1.5	1.6	1.6	2.8
1925	2.6	1.6	0.5	0.2	0.1	0.4	0.9	0.7	0.8	2.0	2.6	2.6
1926	6.1	3.5	0.6	0.0	0.3	0.6	0.6	1.4	1.4	1.1	2.2	1.7
1927	0.8	1.3	0.6	0.1	0.0	5.3	2.3	0.6	0.9	1.0	1.7	2.9
1928	1.7	24.9	11.3	1.2	0.5	0.7	0.8	1.6	1.8	5.4	5.5	3.7
1929	2.2	0.8	0.7	0.3	12.9	5.7	1.4	2.7	2.4	1.9	2.3	2.1
1930	3.4	1.5	0.2	0.3	0.1	4.8	7.6	3.1	1.4	3.7	3.3	3.0
1931	6.4	2.7	7.8	2.8	2.6	1.3	0.4	0.4	1.0	1.5	1.5	25.1
1932	10.0	1.6	0.4	0.0	0.2	0.7	0.5	1.7	1.7	1.4	5.4	3.3
1933	1.0	5.3	1.7	1.8	1.9	4.0	1.7	0.4	0.3	2.8	3.4	2.6
1934	20.2	11.2	1.7	0.1	0.0	0.6	1.0	5.1	5.3	3.8	2.9	3.9
1935	2.6	3.1	1.3	0.2	0.4	0.3	0.1	1.6	1.1	1.7	1.7	3.4
1936	2.5	14.8	6.3	1.0	0.1	3.8	1.6	0.3	0.5	1.2	1.2	2.0
1937	1.1	1.1	2.3	1.2	0.2	1.7	2.0	1.2	1.2	1.6	1.7	2.0
1938	2.6	6.0	2.3	0.5	2.0	7.0	3.1	0.9	0.6	1.9	9.9	5.9
1939	2.3	1.3	0.3	0.5	9.0	3.8	2.1	1.4	1.2	1.3	1.0	1.7
1940	1.1	4.0	1.3	0.5	0.3	0.1	5.0	2.7	2.6	2.7	2.8	3.1
1941	4.4	2.3	0.7	1.3	0.5	0.8	0.9	1.5	1.7	1.5	1.5	1.7
1942	1.6	0.8	1.5	6.3	2.7	0.7	0.6	0.4	0.4	0.4	1.0	5.4
1943	2.8	6.3	2.3	0.1	0.0	1.7	1.0	3.2	2.7	2.8	3.4	5.9
1944	4.3	1.5	0.1	0.0	0.0	0.0	0.1	4.0	4.2	3.1	3.9	3.7
1945	5.9	2.4	0.3	0.0	0.0	8.0	3.3	0.5	0.6	1.1	1.5	1.4
1946	1.1	0.7	0.1	0.0	0.3	8.9	4.4	2.2	2.2	4.0	3.0	3.1
1947	2.5	2.0	0.5	1.4	0.5	2.8	3.8	1.7	1.2	1.4	1.2	1.8
1948	9.5	4.0	0.4	0.6	0.2	0.0	0.6	1.8	1.3	1.1	1.1	1.1
1949	0.7	8.7	2.7	0.0	0.0	0.0	0.6	1.0	0.7	1.5	2.1	2.1
1950	4.3	6.0	1.8	8.0	3.2	1.5	0.9	1.1	2.1	5.7	4.5	6.5
1951	3.3	0.8	0.1	0.4	0.5	0.2	0.5	0.5	0.7	1.0	2.0	8.6
1952	4.3	4.9	1.9	0.4	0.7	0.2	1.0	0.6	1.1	5.4	4.2	5.0
1953	5.2	3.6	0.8	0.0	0.0	0.4	4.2	7.9	4.6	3.4	10.9	6.3
1954	2.1	1.6	0.4	1.3	8.0	2.5	0.4	0.5	0.9	1.7	2.5	3.0
1955	2.2	1.3	0.3	0.0	0.0	1.9	1.3	5.9	3.7	2.6	3.0	2.7
1956	4.4	1.8	2.8	0.9	1.6	1.2	0.8	2.2	6.1	4.8	5.4	7.7
1957	4.6	1.4	0.1	0.0	0.0	2.6	1.9	12.8	6.8	2.7	5.3	3.7
1958	2.4	1.1	0.3	1.9	4.0	4.2	7.5	5.6	3.2	8.4	7.8	4.9
1959	7.3	2.9	0.3	0.4	0.2	1.6	1.4	2.0	2.7	2.9	2.5	2.6
1960	1.6	2.5	2.3	1.9	0.8	1.0	1.0	1.9	1.8	2.4	3.4	3.4
1961	3.8	1.8	0.3	0.4	1.2	2.6	2.4	1.4	1.5	1.6	21.9	9.5
1962	7.0	6.6	1.6	0.8	0.2	4.8	2.7	2.0	1.7	2.5	2.3	1.4
1963	1.8	1.2	2.4	1.6	0.9	2.0	1.1	0.7	4.5	3.0	3.9	6.4
1964	4.0	2.4	0.6	0.1	0.9	1.6	1.6	3.2	2.4	2.1	2.4	1.8
1965	10.1	8.3	2.6	1.1	0.2	0.5	0.8	3.7	2.7	1.8	7.5	6.5
1966	2.6	0.7	0.0	0.0	0.6	3.0	24.7	11.9	5.4	5.7	5.3	5.6
1967	2.9	2.2	0.6	0.0	0.0	0.3	0.8	2.4	5.3	3.4	5.5	4.2
1968	2.2	3.5	1.0	0.0	0.2	0.3	0.6	0.6	3.0	2.5	2.6	2.2
1969	1.3	0.5	0.0	0.2	1.2	0.3	0.0	0.1	0.5	0.8	3.4	2.2
1970	1.8	0.8	0.8	0.3	3.6	3.3	5.9	5.2	3.9	9.4	12.5	6.4
1971	2.5	3.7	1.2	0.1	1.7	1.5	2.1	2.4	2.3	2.5	5.1	5.6
1972	2.4	1.4	0.4	0.0	0.0	0.0	0.7	0.9	1.9	2.4	3.1	2.8
1973	1.6	1.1	1.0	2.5	4.5	4.2	1.5	6.1	3.6	1.7	5.1	4.2
1974	2.2	1.4	0.2	0.4	0.1	0.1	0.4	1.3	2.3	3.1	6.3	7.4
1975	3.5	2.4	1.0	0.3	1.9	2.6	2.1	2.5	6.2	5.6	4.2	3.6
1976	10.0	6.0	1.6	0.2	5.7	2.4	1.8	10.2	6.0	3.3	3.4	3.4
1977	2.5	3.1	1.3	0.2	0.0	0.1	1.5	1.1	1.7	2.2	3.3	3.0
1978	2.5	1.3	1.4	0.6	2.0	0.7	0.1	1.8	1.5	5.9	6.1	5.4
1979	3.9	1.6	1.1	1.0	0.5	0.2	0.5	0.4	1.5	1.4	1.7	2.3
1980	2.4	8.9	3.2	13.1	8.9	7.8	15.9	8.9	4.5	4.1	10.9	6.6
1981	2.4	1.0	2.3	0.7	0.5	1.2	23.2	8.5	2.7	3.7	4.2	8.2
1982	4.6	1.4	0.4	0.0	0.4	0.2	0.5	2.2	3.6	4.9	3.9	6.1
1983	3.6	3.3	1.1	0.2	0.4	1.7	1.0	0.6	0.7	1.6	1.5	1.0
1984	1.6	0.8	0.3	5.8	4.7	1.1	2.7	1.6	1.9	6.3	4.3	2.1
1985	10.0	6.3	2.8	0.7	0.4	0.5	0.6	0.5	0.5	0.7	29.0	12.2
1986	4.8	2.4	0.4	0.0	0.0	0.1	6.7	3.1	1.8	1.9	3.4	4.4
1987	2.3	0.6	0.7	0.1	0.0	0.8	4.5	2.3	2.2	2.4	3.0	2.6
1988	1.9	0.9	1.3	1.0	0.4	1.2	6.4	2.9	1.5	1.6	2.1	1.7
1989	10.4	6.7	1.2	0.0	0.5	0.4	8.2	4.3	4.4	3.3	2.4	1.9
1990	1.5	0.8	0.7	1.1	1.6	0.6	0.2	0.4	0.6	1.0	0.9	0.7
1991	15.1	5.5	0.8	0.4	0.8	0.9	0.7	0.8	2.5	3.6	3.3	2.7
1992	10.3	7.0	1.4	0.1	0.1	0.1	12.5	6.0	2.4	2.4	2.7	3.9
1993	2.2	0.9	3.7	1.3	1.2	1.3	1.7	1.3	1.5	2.0	5.5	4.0
1994	3.0	1.2	6.3	2.3	1.5	2.4	3.6	4.1	2.8	2.2	2.2	2.4
1995	1.6	9.4	10.9	3.0	0.3	1.1	0.6	0.3	0.3	1.3	1.2	1.4
1996	6.1	17.4	5.3	0.2	0.4	1.7	1.5	2.8	2.9	4.7	5.2	3.5
1997	1.7	1.0	0.3	0.5	0.6	4.9	4.8	3.0	2.1	2.2	2.2	1.8
1998	1.0	2.1	2.2	1.5	2.7	2.2	1.7	1.3	1.2	1.6	1.6	2.0
1999	2.9	1.2	0.3	3.1	1.5	11.5	4.5	2.4	1.8	1.3	1.3	1.2
2000	1.3	2.4	1.4	0.4	0.1	0.6	4.1	2.1	1.0	0.9	3.5	2.8
2001	1.5	1.9	0.7	0.6	0.7	0.2	0.6	1.4	1.6	2.1	3.7	4.1
2002	1.9	0.9	0.7	0.6	0.3	20.1	8.0	6.2	4.1	2.7	3.3	2.4
2003	3.6	1.5	0.3	0.6	1.2	0.7	4.1	2.3	1.7	2.2	2.0	1.9
2004	12.5	4.8	25.3	9.7	0.8	1.2	5.1	3.7	3.6	2.7	2.4	1.9

Table 5.8 Duiwenhoks Estuary: Simulated monthly flows (in m^3/s) for Sc 2

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.8	0.4	2.1	0.4	4.1	2.0	5.3	2.8	4.4	3.8	4.0	3.8
1921	1.3	0.3	0.5	3.7	0.5	4.1	2.1	1.0	1.2	2.1	2.1	1.4
1922	1.2	2.4	0.4	0.1	0.0	0.0	2.3	3.5	3.9	3.1	2.6	1.4
1923	2.1	2.4	0.4	0.1	0.1	0.0	0.1	0.3	0.6	0.7	3.3	2.7
1924	0.7	0.8	0.3	0.1	0.0	1.3	0.6	0.3	1.0	1.0	1.5	2.7
1925	2.5	0.9	0.2	0.1	0.0	0.1	0.6	0.4	0.5	1.3	1.7	2.4
1926	5.8	2.9	0.3	0.0	0.1	0.1	0.4	0.9	0.9	0.7	1.4	1.2
1927	0.4	0.7	0.3	0.1	0.0	3.3	1.6	0.6	0.9	0.9	1.6	2.8
1928	1.1	23.8	10.9	0.5	0.2	0.2	0.5	1.0	1.2	5.3	5.3	3.6
1929	1.8	0.4	0.3	0.2	10.0	5.4	1.3	2.6	2.3	1.8	2.2	2.1
1930	3.3	0.6	0.1	0.1	0.0	3.0	6.8	2.9	1.4	3.5	3.2	2.9
1931	6.2	1.4	7.7	1.7	2.1	0.7	0.1	0.2	1.0	1.4	1.5	24.2
1932	9.3	0.7	0.2	0.0	0.1	0.2	0.1	1.1	1.1	0.9	4.6	2.8
1933	0.4	4.9	0.6	1.1	1.1	4.0	1.3	0.3	0.3	2.7	3.3	2.5
1934	19.5	10.9	0.6	0.1	0.0	0.1	0.6	3.3	5.1	3.7	2.8	3.8
1935	2.3	3.0	0.6	0.1	0.1	0.1	0.0	1.0	0.7	1.1	1.1	3.0
1936	2.3	14.3	5.6	0.4	0.1	2.4	0.7	0.1	0.5	1.2	1.1	1.9
1937	0.4	0.6	2.0	0.5	0.1	1.1	1.3	0.8	1.1	1.6	1.6	1.9
1938	2.5	5.8	1.4	0.3	0.8	6.7	3.0	0.8	0.6	1.8	9.6	5.7
1939	1.8	0.5	0.2	0.3	6.7	3.5	2.0	1.3	1.2	1.2	0.7	1.6
1940	0.5	3.9	0.6	0.3	0.1	0.0	3.1	1.9	2.5	2.6	2.7	2.9
1941	4.2	1.5	0.4	0.5	0.2	0.2	0.6	1.0	1.1	1.4	1.4	1.7
1942	1.3	0.4	0.6	5.9	1.4	0.1	0.5	0.4	0.4	0.4	1.0	5.2
1943	2.1	6.1	1.3	0.1	0.0	1.1	0.6	2.0	2.2	2.7	3.3	5.7
1944	4.2	0.6	0.1	0.0	0.0	0.0	0.1	2.8	2.9	3.0	3.7	3.6
1945	5.8	1.2	0.2	0.0	0.0	5.3	2.9	0.4	0.5	1.1	1.4	1.2
1946	0.7	0.3	0.1	0.0	0.2	6.3	4.2	2.1	2.1	3.8	2.7	3.0
1947	2.3	1.5	0.3	0.5	0.2	1.8	2.8	1.7	1.1	1.3	1.0	1.7
1948	9.1	2.9	0.2	0.3	0.1	0.0	0.4	1.1	0.9	0.7	0.7	0.7
1949	0.4	7.7	1.1	0.0	0.0	0.0	0.5	0.6	0.4	1.0	1.4	1.7
1950	4.2	5.8	0.6	7.6	1.8	1.4	0.6	1.1	2.0	5.6	4.3	6.3
1951	2.6	0.4	0.0	0.3	0.2	0.0	0.3	0.3	0.4	0.6	1.3	7.4
1952	3.9	4.7	0.9	0.2	0.3	0.1	0.6	0.4	0.7	3.8	4.0	4.9
1953	5.1	3.2	0.4	0.0	0.0	0.1	2.7	6.9	4.5	3.3	10.5	5.9
1954	1.3	1.1	0.2	0.5	6.8	1.5	0.3	0.5	0.9	1.6	2.4	2.9
1955	1.8	0.6	0.2	0.1	0.0	1.2	0.8	4.4	3.5	2.4	2.9	2.5
1956	4.3	0.7	2.7	0.4	0.5	0.4	0.6	2.1	5.7	4.6	5.2	7.5
1957	4.3	0.6	0.1	0.0	0.0	1.8	1.2	11.4	6.5	2.5	5.0	3.3
1958	2.2	0.5	0.2	1.0	3.0	4.2	7.3	5.4	3.1	8.1	7.6	4.7
1959	7.1	1.7	0.2	0.2	0.1	1.1	0.9	1.3	2.0	2.8	2.4	2.5
1960	1.1	2.3	1.9	1.3	0.3	0.3	0.9	1.8	1.7	2.3	3.3	3.3
1961	3.7	0.9	0.2	0.2	0.4	1.7	1.5	1.0	1.4	1.5	21.2	8.7
1962	6.8	6.4	0.6	0.4	0.1	3.0	2.2	2.0	1.7	2.4	2.2	0.8
1963	1.7	0.5	2.2	0.9	0.3	1.6	0.9	0.6	4.2	2.8	3.8	6.2
1964	3.8	1.9	0.3	0.1	0.3	0.9	1.0	2.0	2.0	2.0	2.4	1.4
1965	9.9	8.2	1.8	0.5	0.1	0.1	0.5	2.4	2.6	1.7	7.3	6.3
1966	1.8	0.4	0.1	0.0	0.3	1.9	22.4	11.6	5.3	5.5	5.2	5.5
1967	2.2	1.8	0.3	0.0	0.0	0.1	0.7	1.5	3.9	3.2	5.4	4.0
1968	1.7	3.4	0.5	0.0	0.1	0.1	0.4	0.4	1.9	1.6	2.4	2.0
1969	0.8	0.3	0.0	0.2	0.4	0.1	0.0	0.1	0.3	0.5	2.2	1.0
1970	1.7	0.4	0.4	0.2	2.2	2.3	5.7	5.1	3.8	9.1	11.8	5.8
1971	2.0	3.7	0.5	0.1	0.6	0.7	1.3	2.3	2.2	2.4	5.0	5.5
1972	1.5	0.8	0.2	0.1	0.0	0.0	0.5	0.6	1.2	1.5	2.6	2.7
1973	1.1	0.5	0.4	2.0	4.4	4.1	1.1	6.0	3.5	1.6	5.0	4.1
1974	1.7	0.7	0.2	0.2	0.1	0.0	0.2	0.9	1.4	2.0	6.1	7.2
1975	2.7	2.0	0.4	0.2	0.7	1.9	2.1	2.5	5.9	5.4	4.1	3.5
1976	9.8	5.7	0.7	0.2	4.2	1.9	1.7	10.0	5.8	3.2	3.3	3.3
1977	2.3	2.9	0.6	0.1	0.0	0.0	0.9	0.7	1.2	1.5	2.6	2.8
1978	2.3	0.5	0.8	0.4	0.7	0.2	0.0	1.2	1.1	5.6	5.9	5.2
1979	3.8	0.6	0.5	0.5	0.2	0.0	0.3	0.3	1.0	0.9	1.1	1.8
1980	2.3	8.7	2.2	12.7	8.6	7.7	15.4	8.7	4.4	4.0	10.7	6.3
1981	1.8	0.5	1.5	0.4	0.2	0.5	21.0	8.0	2.6	3.7	4.1	8.0
1982	4.3	0.5	0.2	0.0	0.2	0.1	0.3	1.4	2.4	3.9	3.7	5.9
1983	3.2	3.1	0.5	0.1	0.1	1.1	0.6	0.4	0.4	1.0	0.9	0.5
1984	1.6	0.4	0.2	4.2	4.3	0.3	2.5	1.5	1.8	6.1	4.1	1.6
1985	9.7	6.2	2.3	0.4	0.1	0.1	0.4	0.3	0.3	0.4	26.7	11.6
1986	4.7	1.5	0.2	0.0	0.0	0.0	4.3	2.8	1.7	1.8	3.3	4.3
1987	1.5	0.3	0.4	0.1	0.0	0.3	2.8	1.8	2.1	2.3	2.9	2.5
1988	1.6	0.4	0.5	0.4	0.2	0.5	5.0	2.8	1.4	1.6	2.0	1.5
1989	10.0	6.5	0.5	0.0	0.3	0.1	5.4	4.2	4.2	3.1	2.3	1.7
1990	1.2	0.4	0.4	0.5	0.5	0.1	0.0	0.3	0.4	0.6	0.5	0.3
1991	14.3	4.1	0.4	0.2	0.3	0.2	0.4	0.5	1.6	3.2	3.2	2.6
1992	10.1	6.7	0.6	0.1	0.1	0.0	9.6	5.9	2.4	2.4	2.6	3.7
1993	1.5	0.4	3.1	0.5	0.4	0.7	1.6	1.3	1.5	1.9	5.3	3.9
1994	2.9	0.5	5.6	1.2	0.8	2.4	3.5	4.1	2.7	2.1	2.1	2.3
1995	1.1	9.1	10.6	1.9	0.1	0.5	0.2	0.2	0.2	1.0	1.0	1.3
1996	5.9	16.8	3.9	0.1	0.1	1.0	1.0	1.8	2.6	4.5	5.0	3.1
1997	1.1	0.4	0.2	0.2	0.2	3.1	4.1	2.8	2.0	2.1	2.2	1.5
1998	0.4	1.8	1.7	0.8	2.3	2.0	1.7	1.3	1.2	1.5	1.6	1.9
1999	2.9	0.4	0.2	1.9	0.4	11.0	4.2	2.3	1.8	1.2	1.2	1.0
2000	1.0	2.1	0.6	0.2	0.0	0.1	2.6	1.3	0.8	0.9	3.4	2.7
2001	1.0	1.5	0.3	0.4	0.3	0.0	0.4	0.9	1.1	1.4	3.0	3.9
2002	1.0	0.4	0.3	0.3	0.1	17.0	7.8	6.0	4.0	2.6	3.2	2.1
2003	3.5	0.5	0.1	0.3	0.4	0.2	2.6	1.5	1.6	2.2	2.0	1.8
2004	12.0	3.2	24.7	8.9	0.3	0.6	4.5	3.6	3.4	2.6	2.3	1.7

Table 5.9 Duiwenhoks Estuary: Simulated monthly flows (in m^3/s) for Sc 3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.5	0.0	1.8	0.0	3.8	1.7	5.1	2.5	4.2	3.5	3.7	3.4
1921	1.0	0.0	0.0	3.5	0.2	3.8	1.8	0.7	0.9	1.8	1.8	1.1
1922	0.9	2.1	0.0	0.0	0.0	0.0	1.5	3.2	3.6	2.8	2.3	1.1
1923	1.8	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.1	2.4
1924	0.4	0.5	0.0	0.0	0.0	0.4	0.3	0.0	0.7	0.7	1.2	2.4
1925	2.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.4	2.1
1926	5.5	2.6	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.4	1.3	1.0
1927	0.0	0.4	0.0	0.0	0.0	2.4	1.3	0.3	0.6	0.6	1.4	2.5
1928	0.8	23.6	10.5	0.0	0.0	0.0	0.0	0.5	1.5	5.0	5.0	3.2
1929	1.4	0.0	0.0	0.0	9.8	5.1	1.0	2.3	2.0	1.5	1.9	1.7
1930	3.0	0.1	0.0	0.0	0.0	2.1	6.5	2.6	1.1	3.2	2.9	2.6
1931	5.9	1.1	7.3	1.4	1.8	0.4	0.0	0.0	0.3	1.1	1.1	23.9
1932	9.0	0.4	0.0	0.0	0.0	0.0	0.0	0.3	0.8	0.6	4.5	2.4
1933	0.1	4.6	0.0	1.0	0.8	3.7	1.0	0.0	0.0	2.4	3.0	2.2
1934	19.2	10.6	0.0	0.0	0.0	0.0	0.0	2.8	4.8	3.4	2.5	3.5
1935	2.0	2.6	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.8	0.8	2.8
1936	2.0	14.1	5.3	0.0	0.0	1.6	0.7	0.0	0.0	0.9	0.8	1.6
1937	0.0	0.3	1.7	0.0	0.0	0.5	1.0	0.7	0.8	1.3	1.3	1.6
1938	2.2	5.5	1.0	0.0	0.2	6.6	2.7	0.5	0.3	1.5	9.3	5.4
1939	1.5	0.2	0.0	0.0	6.3	3.1	1.7	1.0	0.9	0.9	0.4	1.3
1940	0.2	3.6	0.0	0.0	0.0	0.0	2.2	1.7	2.2	2.3	2.4	2.6
1941	3.9	1.2	0.0	0.0	0.0	0.0	0.0	0.5	1.3	1.1	1.1	1.3
1942	1.0	0.0	0.0	5.9	1.1	0.0	0.0	0.1	0.1	0.1	0.7	4.9
1943	1.8	5.8	0.9	0.0	0.0	0.3	0.3	1.8	1.9	2.4	3.0	5.4
1944	3.8	0.1	0.0	0.0	0.0	0.0	0.0	1.9	2.6	2.6	3.4	3.3
1945	5.4	0.9	0.0	0.0	0.0	4.5	2.5	0.1	0.2	0.8	1.1	0.9
1946	0.4	0.0	0.0	0.0	0.0	5.5	3.9	1.8	1.9	3.5	2.4	2.7
1947	2.0	1.1	0.0	0.0	0.0	1.0	3.1	1.4	0.8	1.0	0.7	1.4
1948	8.8	2.6	0.0	0.0	0.0	0.0	0.0	0.4	0.6	0.4	0.4	0.4
1949	0.0	7.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.1	1.3
1950	3.9	5.5	0.2	7.4	1.4	1.1	0.3	0.8	1.7	5.3	4.0	6.0
1951	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	7.2
1952	3.5	4.4	0.5	0.0	0.0	0.0	0.0	0.0	0.2	4.2	3.7	4.5
1953	4.7	2.9	0.0	0.0	0.0	0.0	1.8	6.7	4.1	3.0	10.2	5.6
1954	1.0	0.8	0.0	0.0	6.6	1.2	0.0	0.1	0.6	1.3	2.1	2.6
1955	1.5	0.2	0.0	0.0	0.0	0.4	0.5	4.1	3.2	2.1	2.6	2.2
1956	4.0	0.3	2.3	0.0	0.0	0.1	0.3	1.8	5.5	4.3	4.9	7.2
1957	4.0	0.1	0.0	0.0	0.0	0.9	0.9	11.1	6.2	2.2	4.7	3.0
1958	1.9	0.0	0.0	0.3	3.1	3.9	7.0	5.1	2.8	7.8	7.3	4.4
1959	6.8	1.3	0.0	0.0	0.0	0.2	0.6	1.0	1.7	2.5	2.1	2.2
1960	0.8	1.9	1.5	1.0	0.0	0.0	0.4	1.6	1.5	2.0	3.0	3.0
1961	3.4	0.6	0.0	0.0	0.0	0.8	1.7	1.0	1.1	1.2	21.0	8.4
1962	6.5	6.1	0.0	0.0	0.0	2.7	2.4	1.7	1.3	2.1	1.9	0.5
1963	1.4	0.2	1.8	0.6	0.0	1.2	0.6	0.3	4.0	2.5	3.5	5.9
1964	3.4	1.6	0.0	0.0	0.0	0.1	0.7	2.0	2.0	1.8	2.0	1.1
1965	9.6	7.9	1.5	0.0	0.0	0.0	0.0	2.1	2.3	1.4	7.0	6.0
1966	1.5	0.0	0.0	0.0	0.0	1.0	22.2	11.3	5.0	5.2	4.9	5.2
1967	1.9	1.5	0.0	0.0	0.0	0.0	0.0	1.0	3.7	2.9	5.1	3.7
1968	1.4	3.1	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.3	2.1	1.7
1969	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.7
1970	1.4	0.0	0.0	0.0	1.3	2.9	5.4	4.8	3.5	8.8	11.5	5.5
1971	1.7	3.3	0.0	0.0	0.0	0.1	1.6	2.0	1.9	2.1	4.7	5.1
1972	1.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.3	2.3	2.4
1973	0.7	0.2	0.0	1.8	4.1	3.8	0.8	5.7	3.2	1.3	4.7	3.8
1974	1.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.8	5.8	6.9
1975	2.3	1.7	0.0	0.0	0.0	1.9	1.8	2.2	5.7	5.1	3.8	3.1
1976	9.5	5.4	0.4	0.0	3.7	1.6	1.4	9.7	5.5	2.9	3.0	3.0
1977	1.9	2.6	0.1	0.0	0.0	0.0	0.1	0.4	0.9	1.2	2.3	2.5
1978	2.0	0.1	0.5	0.0	0.3	0.0	0.0	0.4	1.1	5.4	5.6	4.9
1979	3.5	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.6	1.2	1.9
1980	2.0	8.4	1.8	12.4	8.2	7.3	15.1	8.4	4.1	3.7	10.4	6.0
1981	1.5	0.1	1.3	0.0	0.0	0.0	21.1	7.7	2.3	3.4	3.8	7.7
1982	4.0	0.1	0.0	0.0	0.0	0.0	0.0	0.7	2.2	3.6	3.4	5.6
1983	2.9	2.8	0.0	0.0	0.0	0.2	0.3	0.1	0.2	0.8	1.1	0.3
1984	1.3	0.0	0.0	3.9	4.0	0.0	2.2	1.2	1.5	5.8	3.8	1.3
1985	9.4	5.8	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.7	11.3
1986	4.4	1.2	0.0	0.0	0.0	0.0	3.5	2.5	1.4	1.5	3.0	4.0
1987	1.2	0.0	0.0	0.0	0.0	0.0	2.0	1.5	1.8	2.0	2.6	2.2
1988	1.3	0.0	0.0	0.0	0.0	0.0	5.4	2.5	1.1	1.3	1.7	1.2
1989	9.7	6.1	0.0	0.0	0.0	0.0	4.7	3.9	3.9	2.8	2.0	1.4
1990	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1
1991	14.3	3.8	0.0	0.0	0.0	0.0	0.0	0.0	2.0	3.2	2.9	2.3
1992	9.8	6.4	0.1	0.0	0.0	0.0	8.8	5.6	2.1	2.0	2.3	3.4
1993	1.2	0.0	2.9	0.0	0.0	0.6	1.3	1.0	1.2	1.6	5.0	3.6
1994	2.6	0.0	5.4	0.8	0.5	2.1	3.2	3.8	2.4	1.8	1.8	2.0
1995	0.8	8.8	10.3	1.6	0.0	0.0	0.0	0.0	0.0	0.3	0.7	1.0
1996	5.6	16.5	3.6	0.0	0.0	0.2	0.7	1.5	2.4	4.2	4.7	2.8
1997	0.8	0.0	0.0	0.0	0.0	2.2	4.1	2.6	1.7	1.8	1.8	1.2
1998	0.1	1.5	1.4	0.5	2.0	1.7	1.4	1.0	0.9	1.2	1.3	1.6
1999	2.5	0.0	0.0	1.3	0.0	10.9	3.9	2.1	1.5	1.0	0.9	0.7
2000	0.7	1.8	0.3	0.0	0.0	0.0	1.7	1.1	0.7	0.6	3.1	2.4
2001	0.7	1.2	0.0	0.0	0.0	0.0	0.0	0.2	0.8	1.1	2.7	3.6
2002	0.6	0.0	0.0	0.0	0.0	16.9	7.5	5.7	3.7	2.3	2.9	1.7
2003	3.2	0.0	0.0	0.0	0.0	0.0	2.0	1.9	1.3	1.9	1.7	1.5
2004	11.7	2.9	24.4	8.6	0.0	0.1	4.3	3.3	3.2	2.3	2.0	1.4

Table 5.10 Duiwenhoks Estuary: Simulated monthly flows (in m^3/s) for Sc 4

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.0	0.0	0.2	0.0	0.0	0.9	4.9	2.3	4.0	3.3	3.5	2.7
1921	0.2	0.0	0.0	0.4	0.0	1.8	1.6	0.5	0.7	1.6	1.6	0.4
1922	0.2	1.3	0.0	0.0	0.0	0.0	0.0	2.9	3.4	2.6	2.1	0.4
1923	1.1	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.7
1924	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.7
1925	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.4
1926	4.8	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3
1927	0.0	0.0	0.0	0.0	0.0	0.9	1.1	0.1	0.4	0.4	1.2	1.8
1928	0.1	22.9	9.8	0.0	0.0	0.0	0.0	0.0	0.0	4.8	4.8	2.5
1929	0.7	0.0	0.0	0.0	5.7	4.9	0.8	2.1	1.8	1.3	1.7	1.0
1930	2.3	0.0	0.0	0.0	0.0	0.6	6.3	2.4	0.9	3.0	2.7	1.8
1931	5.2	0.3	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	23.2
1932	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	1.7
1933	0.0	3.3	0.0	0.0	0.0	1.6	0.8	0.0	0.0	1.8	2.8	1.5
1934	18.5	9.9	0.0	0.0	0.0	0.0	0.0	1.1	4.6	3.2	2.3	2.8
1935	1.3	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
1936	1.3	13.4	4.6	0.0	0.0	0.0	0.5	0.0	0.0	0.3	0.6	0.9
1937	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.1	1.1	0.9
1938	1.5	4.8	0.3	0.0	0.0	4.5	2.5	0.3	0.1	1.3	9.1	4.7
1939	0.8	0.0	0.0	0.0	2.2	2.9	1.5	0.8	0.7	0.7	0.2	0.6
1940	0.0	2.3	0.0	0.0	0.0	0.0	0.7	1.5	2.0	2.1	2.2	1.9
1941	3.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.9	0.6
1942	0.3	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8
1943	1.1	5.1	0.2	0.0	0.0	0.0	0.0	0.4	1.7	2.2	2.8	4.7
1944	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.4	2.4	3.2	2.6
1945	4.7	0.2	0.0	0.0	0.0	3.0	2.3	0.0	0.0	0.4	0.9	0.2
1946	0.0	0.0	0.0	0.0	0.0	3.9	3.7	1.6	1.7	3.4	2.2	2.0
1947	1.2	0.4	0.0	0.0	0.0	0.0	2.3	1.2	0.6	0.8	0.5	0.7
1948	8.1	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1949	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
1950	3.2	4.8	0.0	5.2	0.0	0.0	0.0	0.4	1.5	5.1	3.8	5.3
1951	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6
1952	2.8	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	3.5	3.8
1953	4.0	2.2	0.0	0.0	0.0	0.0	0.3	6.5	3.9	2.8	10.1	4.9
1954	0.3	0.0	0.0	0.0	2.1	0.9	0.0	0.0	0.1	1.1	1.9	1.9
1955	0.8	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.0	1.9	2.3	1.5
1956	3.3	0.0	1.2	0.0	0.0	0.0	0.0	0.1	5.4	4.1	4.7	6.5
1957	3.3	0.0	0.0	0.0	0.0	0.0	0.2	10.9	6.0	2.0	4.6	2.2
1958	1.1	0.0	0.0	0.0	0.0	2.2	6.8	4.9	2.6	7.6	7.1	3.7
1959	6.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.3	1.9	1.5
1960	0.0	1.2	0.8	0.0	0.0	0.0	0.0	0.0	1.2	1.8	2.8	2.3
1961	2.7	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.9	1.0	20.8	7.7
1962	5.8	5.4	0.0	0.0	0.0	1.2	2.1	1.5	1.1	1.9	1.7	0.0
1963	0.5	0.0	0.6	0.0	0.0	0.0	0.0	0.0	3.8	2.3	3.3	5.2
1964	2.7	0.8	0.0	0.0	0.0	0.0	0.0	0.8	1.8	1.6	1.8	0.4
1965	8.9	7.2	0.8	0.0	0.0	0.0	0.0	0.4	2.1	1.2	6.8	5.3
1966	0.8	0.0	0.0	0.0	0.0	0.0	21.5	11.1	4.8	5.0	4.7	4.5
1967	1.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	2.8	2.7	4.9	3.0
1968	0.7	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.9	1.0
1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1970	0.5	0.0	0.0	0.0	0.0	0.8	5.2	4.6	3.3	8.6	11.3	4.8
1971	1.0	2.6	0.0	0.0	0.0	0.0	0.0	1.5	1.7	1.9	4.5	4.4
1972	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.7
1973	0.0	0.0	0.0	0.0	0.1	3.6	0.6	5.5	3.0	1.1	4.5	3.1
1974	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	5.6	6.2
1975	1.6	1.0	0.0	0.0	0.0	0.0	1.6	2.0	5.5	4.9	3.6	2.4
1976	8.8	4.7	0.0	0.0	0.0	0.8	1.2	9.5	5.3	2.7	2.8	2.3
1977	1.2	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.1	1.8
1978	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	5.4	4.2
1979	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
1980	1.3	7.7	1.1	10.7	5.5	7.1	15.0	8.2	3.9	3.5	10.2	5.3
1981	0.8	0.0	0.0	0.0	0.0	0.0	19.3	7.5	2.1	3.2	3.6	7.0
1982	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	3.4	3.2	4.9
1983	2.2	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
1984	0.2	0.0	0.0	0.8	1.3	0.0	1.8	1.0	1.3	5.6	3.6	0.6
1985	8.7	5.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	10.6
1986	3.7	0.5	0.0	0.0	0.0	0.0	1.9	2.3	1.2	1.3	2.8	3.3
1987	0.5	0.0	0.0	0.0	0.0	0.0	0.4	1.3	1.6	1.8	2.4	1.5
1988	0.5	0.0	0.0	0.0	0.0	0.0	3.6	2.3	0.9	1.0	1.5	0.5
1989	9.0	5.4	0.0	0.0	0.0	0.0	3.2	3.7	3.7	2.6	1.8	0.7
1990	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	11.7	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.0	2.7	1.6
1992	9.1	5.7	0.0	0.0	0.0	0.0	7.2	5.3	1.9	1.8	2.1	2.7
1993	0.4	0.0	1.4	0.0	0.0	0.0	0.0	0.5	1.0	1.4	4.8	2.9
1994	1.9	0.0	3.9	0.0	0.0	0.0	3.0	3.6	2.2	1.6	1.6	1.3
1995	0.0	8.1	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	4.3	15.8	2.8	0.0	0.0	0.0	0.0	0.5	2.2	4.0	4.5	2.1
1997	0.1	0.0	0.0	0.0	0.0	0.7	3.9	2.4	1.5	1.6	1.6	0.5
1998	0.0	0.2	0.7	0.0	0.0	0.0	0.8	0.8	0.6	1.0	1.1	0.9
1999	1.8	0.0	0.0	0.0	0.0	9.0	3.7	1.9	1.3	0.8	0.7	0.0
2000	0.0	1.0	0.0	0.0	0.0	0.0	0.2	0.9	0.5	0.4	2.9	1.6
2001	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	2.9
2002	0.0	0.0	0.0	0.0	0.0	15.4	7.2	5.5	3.5	2.1	2.7	1.0
2003	2.5	0.0	0.0	0.0	0.0	0.0	0.5	1.7	1.1	1.7	1.5	0.8
2004	11.0	2.2	23.7	6.9	0.0	0.0	2.3	3.1	3.0	2.1	1.8	0.6

5.3 HYDROLOGY

Tables 5.11 and **5.12** provide a summary of the changes in low flows and flood regime that have occurred under the different scenarios.

Table 5.11 Duiwenhoks Estuary: Summary of the change in low flow conditions under a range of flow scenarios

Percentile	Monthly flow (m^3/s)					
	Natural	Present	Sc 1	Sc 2	Sc 3	Sc 4
30%	1.2	0.3	1.0	0.5	0.0	0.0
20%	0.8	0.1	0.6	0.3	0.0	0.0
10%	0.5	0.0	0.3	0.1	0.0	0.0
% Similarity in low flows		**13.5**	**77.1**	**37.1**	**0.0**	**0.0***

*No base flows up to 40%ile

An evaluation of the 20 highest monthly flow volumes (as a proxy for floods) in the simulated data set show that floods occur relatively untransformed from Reference Condition to Present State and Sc 1 to Sc 3 (**Table 5.12**), while under Sc 4 there is about a 10% decrease from present.

Table 5.12 Duiwenhoks Estuary: Summary of the ten highest simulated monthly volumes under Reference Condition, Present State and a range of flow scenarios

Date	Monthly volume (million m^3/month)					
	Natural	Present	Sc 1	Sc 2	Sc 3	Sc 4
Aug-86	77.8	75.0	77.8	71.6	71.6	67.06
Dec-04	67.7	66.2	67.7	66.2	65.3	63.44
Sep-32	65.0	62.6	65.1	62.6	61.9	60.13
Nov-28	64.4	61.9	64.4	61.8	61.1	59.34
Apr-67	64.3	61.8	64.0	57.9	57.6	55.84
Apr-82	60.3	58.0	60.1	54.5	54.7	55.63
Aug-62	58.6	56.9	58.8	56.9	56.1	50.08
Mar-03	54.3	52.0	53.9	45.6	45.2	49.56
Oct-34	54.0	52.2	54.1	52.2	51.4	41.12
Nov-96	45.1	43.5	45.0	43.5	42.7	40.86
Apr-81	41.2	40.0	41.3	40.0	39.3	38.77
Oct-91	40.4	39.1	40.3	38.4	38.3	34.71
Nov-36	38.3	37.3	38.3	37.2	36.5	31.38
Jan-81	35.3	34.0	35.2	34.0	33.2	30.28
May-58	34.3	32.4	34.2	30.4	29.7	29.61
Oct-04	33.5	32.2	33.5	32.2	31.4	29.57
Aug-71	33.5	31.6	33.4	31.6	30.8	29.19

Date	Monthly volume (million m^3/month)					
	Natural	Present	Sc 1	Sc 2	Sc 3	Sc 4
Apr-93	32.7	30.5	32.3	25.0	22.8	28.63
May-67	32.0	30.9	31.9	30.9	30.1	27.54
Dec-04	67.7	66.2	67.7	66.2	65.3	27.30
% Similarity in floods		**96**	**99**	**94**	**92**	**86**

The hydrology health scores for the present and future scenarios are provided in **Table 5.13**.

Table 5.13 Duiwenhoks Estuary: Hydrology health scores for present and future scenarios

Variable	Weight	Scenario					
		Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. % Similarity in low flows	60	14	77	37	0	0	Medium
b. % Similarity in flood volumes	40	96	99	94	92	86	Medium
Hydrology weighted mean (a,b)		**47**	**86**	**60**	**37**	**34**	**Medium**

5.4 PHYSICAL HABITAT

A summary of the expected changes in the physical habitat of the Duiwenhoks Estuary under each of the future scenarios are provided in **Table 5.14**.

Table 5.14 Duiwenhoks Estuary: Summary of physical habitat changes under different scenarios

Parameter	Scenario
a. Supratidal area and sediments	The only potential new changes are related to changes in flood regime. Changes to low flows have virtually no impact on sediment dynamics and morphology within the estuary. Thus, Sc 2 is not significantly different from the Present State (too small a change in effects to distinguish in the scoring). Sc 1 and Sc 3 have additional 3% (positive) and 4% (negative) change effect respectively on flood regime which will translate into direct associated effects on sediment dynamics and morphology in the estuary. Similarly, Sc 4 has a 10% negative change regarding floods w.r.t. present, with similar greater effects.
b. Intertidal areas and sediments	Same as for supratidal.
c. Subtidal area and sediments	Same as for supratidal.
d. Estuary bathymetry (relates to water volume)	Flood flows have relatively very short retention/traverse times within the estuary, thus virtually zero additional effect due to small flood regime changes. Increased low flows for Sc 1 would tend to counter the small effect of the slightly larger ingress of marine waters due to the channel blasted through the rocks seaward of the mouth. Sc 3 would also allow slightly larger marine waters and sediment ingress. Yet, overall all these effects are considered too small to alter the score from present (small percentage change on top of only a 5% change). Under Sc 4 there would be slightly less flushing of sediments due to further floods reduction, thus reduced water volume.

The physical habitat health scores for the present and future scenarios are provided in **Table 5.15**.

Table 5.15 Duiwenhoks Estuary: Physical habitat health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Supratidal area and sediments	82	85	82	78	72	Low
b. Intertidal areas and sediments	82	85	82	78	72	Low
c. Subtidal area and sediments	82	85	82	78	72	Low
d. Estuary bathymetry/water volume	95	95	95	95	93	Low
Physical habitat score minimum (a to d)	**82**	**85**	**82**	**78**	**72**	**Low**

5.5 HYDRODYNAMICS AND MOUTH CONDITION

Based on current understanding, a number of characteristic 'abiotic states' were identified for the Duiwenhoks Estuary, associated with specific flow ranges, also taking into account the variability in characteristics such as tidal exchange, salinity distribution and water quality. The different abiotic states are listed in **Table 5.16**. The hydrodynamics and mouth condition health scores for the present and future scenarios are provided in **Table 5.17**.

Table 5.16 Duiwenhoks Estuary: Summary of the abiotic states that can occur

State	Flow range (m^3/s)	Description
State 1	< 0.1	Marine dominated, no REI
State 2	0.1 – 1	Full salinity gradient
State 3	1 – 3	Partial salinity gradient
State 4	3 –20	Limited salinity penetration
State 5	> 20	Freshwater dominated

Table 5.17 Duiwenhoks Estuary: Hydrodynamics and mouth condition health scores for present and future scenarios

Variable	Weight	Scenario					Confidence
		Present	Sc 1	Sc 2	Sc 3	Sc 4	
a. % similarity in abiotic states and mouth condition	50	100	100	100	100	95	High
b. % similarity in the water column structure		No resolution					
c. % similarity in water retention time	No data						
d. % similarity in tidal amplitude and symmetry)	50	90	90	90	90	92	Medium
Hydrodynamics and mouth weighted mean (a to d)		**95**	**95**	**95**	**95**	**94**	**Medium**

5.6 WATER QUALITY

Table 5.18 provides a summary the occurrence of various abiotic states under reference, present and each of the future scenarios for the Duiwenhoks Estuary.

Table 5.18 Duiwenhoks Estuary: Summary of the occurrence of the abiotic states under the Reference Condition, Present State and Scenarios 1 to 4

Abiotic state	Natural	Present	Scenario			
			Sc 1	Sc 2	Sc 3	Sc 4
State 1: Marine dominated, no REI	0	22	5	9	33	49
State 2: Full salinity gradient	25	21	24	33	15	12
State 3: Partial salinity gradient	44	31	42	33	30	21
State 4: Limited salinity penetration	29	25	28	24	21	17
State 5: Freshwater dominated	1	1	1	1	1	1

Table 5.19 provides a summary of the expected average changes in various water quality parameters in different zones under present and future scenarios, while **Table 5.20** summarises the cause of such changes.

Table 5.19 Duiwenhoks Estuary: Expected average changes in various water quality parameters in different zones under present and future scenarios

Zone	Volume weighting	Estimated salinity concentration based on distribution of abiotic states					
		Reference	Present	Sc 1	Sc 2	Sc 3	Sc 4
A	0.25	25	29	28	30	30	32
B	0.35	15	22	20	21	23	24
C	0.30	6	16	14	15	17	17
D	0.10	2	9	7	9	11	13
Zone	**Volume weighting**	**Estimated DIN concentration (µg/L) based on distribution of abiotic states**					
		Reference	**Present**	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
A	0.25	50	64	66	64	62	61
B	0.35	50	90	99	97	85	78
C	0.30	50	179	196	192	168	152
D	0.10	50	179	196	192	168	152
Zone	**Volume weighting**	**Estimated DIP concentration (µg/L) based on distribution of abiotic states**					
		Reference	**Present**	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
A	0.25	10	13	13	13	12	12
B	0.35	10	16	17	16	15	14
C	0.30	10	18	20	19	17	15
D	0.10	10	18	20	20	20	20
Zone	**Volume weighting**	**Estimated turbidity (NTU) based on distribution of abiotic states**					
		Reference	**Present**	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
A	0.25	10	10	11	10	10	11
B	0.35	10	10	11	10	10	11
C	0.30	10	30	30	30	30	31
D	0.10	10	20	21	20	20	21
Zone	**Volume weighting**	**Estimated dissolved oxygen (mg/L) based on distribution of abiotic states**					
		Reference	**Present**	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
A	0.25	6	6	6	6	6	6
B	0.35	6	6	6	6	6	6
C	0.30	6	6	6	6	5	5
D	0.10	6	6	6	6	5	5

Table 5.20 Duiwenhoks Estuary: Summary of water quality changes under future scenarios

Parameter	Summary of changes
Changes in longitudinal salinity gradient and vertical stratification	⇧ Due to increase in low flow conditions, the mouth manipulations and the loss of the peat wetlands in the catchments that would have moderated baseflows. Sc 1 and Sc 2 show a ⇩ in salinity in Zone D similar to the Reference Conditions. While Sc 3 and Sc 4 shows and ⇧ due to significant increases in low flow conditions.
Inorganic nutrients in estuary	⇧ Due to agricultural activity in the catchment and along the banks (Vermaaklikheid opposite Zone C). Slight "improvement" from Present in Sc 4 as a result of reduction in enriched inflows.
Turbidity in estuary	⇧ Due to agricultural activity in the catchment and along the banks (Vermaaklikheid opposite Zone C).
Dissolved oxygen in estuary	No marked changes.
Toxic substances in estuary	⇧ Due to agricultural activity in the catchment and along the banks (Vermaaklikheid opposite Zone C).

The EHI scores for water quality are presented in **Table 5.21**.

Table 5.21 Duiwenhoks Estuary: Water quality health scores for present and future scenarios

Variable		Weight	Scenario					
			Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
1	**Similarity in salinity**	**40**	73	77	74	70	68	Medium
2	**General water quality min (a to d)**	**60**	71	68	70	73	76	Medium
a	DIN/DIP concentrations		71	68	70	73	76	Medium
b	Turbidity		81	81	81	81	80	Medium
c	Dissolved oxygen		99	100	99	98	96	Medium
d	Toxic substances		80	80	80	80	80	Low
Water quality score weighted mean (1,2)			**72**	**72**	**72**	**72**	**73**	**Medium**

5.7 MICROALGAE

A summary of the expected changes under various scenarios for the microalgae component in the Duiwenhoks Estuary is provided in **Table 5.22**.

Table 5.22 Duiwenhoks Estuary: Summary of change in microalgae under future scenarios

Scenario	Summary of changes
1	**Abundance:** Turbidity and herbicide levels are expected to remain unchanged. Flow is likely to decrease by 4% from reference resulting in slightly elevated nutrient levels compared to present (average weighted P; present = 16.1 µg/L and State 1 = 17.2 µg/L). This is likely to support microalgal growth, particularly in States 2 and 3. If a [P] of 16.1 µg/L resulted in a 27% increase in microalgal biomass (present), then a 17.2 µg/L is likely to result in a 29% increase. **Richness:** Elevated presence of dinoflagellates (stratified middle reaches), cyanobacteria and chlorophytes in response to 4% decrease in river flow and elevated nutrients (3% increase allowed for slight increase in nutrients).
2	**Abundance:** Turbidity and herbicide levels are expected to remain unchanged. Flow is likely to decrease by 18% from reference (similar to present). However, the shift in flow states is likely to result in slightly elevated nutrient levels compared to present (average weighted P; present = 16.1 µg/L and State 2 = 16.6 µg/l). This is likely to support microalgal growth, particularly in States 2 and 3. If a [P] of 16.1 µg/L resulted in a 27% increase in microalgal biomass (present), then a 16.6 µg/L is likely to result in a 28% increase. **Richness:** Elevated presence of dinoflagellates (stratified middle reaches), cyanobacteria and chlorophytes in response to 18% decrease in river flow and elevated nutrients (3% increase allowed for slight increase in nutrients).
3	**Abundance:** Turbidity and herbicide levels are expected to remain unchanged. Flow is likely to decrease by 29% from reference. The decreased flow and shift in flow states is likely to result in slightly decreased nutrient levels compared to present (average weighted P; present = 16.1 µg/L and State 3 = 15.4 µg/l). This is likely to support microalgal growth, particularly in States 2 and 3. If a [P] of 16.1 µg/L resulted in a 27% increase in microalgal biomass (present), then a 15.4 µg/L is likely to result in a 26% increase. **Richness:** Elevated presence of dinoflagellates (stratified middle reaches), cyanobacteria and chlorophytes in response to 29% decrease in river flow and elevated nutrients (3% decrease allowed for slight decrease in nutrients).
4	**Abundance:** Turbidity and herbicide levels are expected to remain unchanged. Flow is likely to decrease by 44% from reference. The decreased flow and shift in flow states is likely to result in slightly decreased nutrient levels compared to present (average weighted P; present = 16.1 µg/L and State 4 = 14.5 µg/l). This is likely to support microalgal growth, particularly in States 2, 3 and 4. If a [P] of 16.1 µg/L resulted in a 27% increase in microalgal biomass (present), then a 15.4 µg/L is likely to result in a 24% increase. **Richness:** Elevated presence of dinoflagellates (stratified middle reaches), cyanobacteria and chlorophytes in response to 44% decrease in river flow and elevated nutrients (5% decrease allowed for slight decrease in nutrients).

The EHI scores for microalgale under the various scenarios are presented in **Table 5.23**.

Table 5.23 Duiwenhoks Estuary: Microalgae health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
Phytoplankton						
a. Species richness	100	100	100	100	100	Medium
b Abundance	73	71	72	74	76	Medium
c. Community composition	82	93	79	74	59	Medium
Benthic microalgae						

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	85	97	85	76	95	Low
b Abundance	73	71	72	74	76	Medium
c. Community composition	95	95	95	95	63	Low
Microalgae score min (a to c)	**73**	**71**	**72**	**74**	**56**	**Medium/Low**

5.8 MACROPHYTES

Species richness will likely stay the same between the different scenarios. Macrophyte abundance and community composition will change as described below (**Table 5.24**). Sc 3 represents a significant increase in low flow conditions that will increase salinity leading to some loss of macrophyte biomass and productivity. However Duiwenhoks has always been a marine dominated estuary. Salt marsh will replace reeds and sedges as the estuary becomes more saline upstream. It is assumed that agricultural activities, grazing and trampling will remain in the floodplain areas.

Table 5.24 Duiwenhoks Estuary: Summary of change in macrophytes under future scenarios

Scenario	Summary of changes
1	Sc 1 shows a ⇩ in salinity in Zone D similar to the Reference Conditions because 50% of the low flow is returned due to a decrease in afforestation and water use. Reeds and sedges will flourish in the upper reaches however the largest macrophyte component i.e. the floodplain remains degraded.
2	Sc 2 shows a slight ⇩ in salinity in Zone D. However, the shift in salinity was not sufficient to improve from Present State.
3	Sc 3 shows an ⇧ in salinity due to increase in low flow conditions as there is a dam and water abstraction in place. There will be a loss of reeds and sedges in the upper reaches of the estuary. Salt marsh cover would be reduced with an increase in bare patches.
4	Sc 4 shows an ⇧ in salinity due to increase in low flow conditions as this is a worst case dam scenario. There will be a loss of reeds and sedges in the upper reaches of the estuary. Salt marsh cover would be reduced with an increase in bare patches. Reduced flooding would cause saline conditions in the supratidal salt marsh.

The EHI scores for marcophytes under the various scenarios are presented in **Table 5.25**.

Table 5.25 Duiwenhoks Estuary: Macrophyte health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	85	85	85	85	80	Medium
b. Abundance	60	63	60	57	50	Medium
c. Community composition	63	66	63	60	55	Medium
Macrophyte score min (a to c)	**60**	**63**	**60**	**57**	**50**	**Medium**

5.9 INVERTEBRATES

A summary of the expected changes under various scenarios for the invertebrate component in the Duiwenhoks Estuary is provided in **Table 5.26**, while the health scores for the present and future scenarios are provided in **Table 5.27**.

Table 5.26 Duiwenhoks Estuary: Summary of change in invertebrates under different scenarios

Scenario	Summary of changes
1	This scenario will result in a decrease in marine dominance during the summer months and the development of the REI. Consequently, the scenario represents a return towards the natural state. In the upper estuary, when there is marine dominance the REI will remain for much of the time and together with an increase in phytoplankton biomass, lead to an increase in zooplankton biomass. Reeds and sedges will extend further downstream compared to present, providing habitat for carid shrimps (increased biomass) such *as Palaemon capensis*. Reduced salinity and less development of macrophytes (compared to present) in the upper estuary it will lead to more available habitat for benthic species such as amphipods (*Corophium triaenonyx*, *Grandidierella lignorum* and *Melita zeylanica*). In summary, the invertebrate community will move along a trajectory more similar to natural when compared to Present State.
2	Under this scenario, marine dominance in summer will increase slightly compared to Scenario 1, but will remain significantly lower relative to the Present State. State 2 under his scenario (full salinity gradient present) is similar to the natural state and consequently, invertebrate response will result in a community similar to Sc 1, but not reaching the same state of recovery towards the natural state.
3	There is a significant increase in low flow conditions under this scenario, particularly in summer. Marine dominance will also persist during most summers, and will occasionally occur during the winter months as well. Consequently, the scenario represents significantly greater marine dominance compared to present and therefore a greater deviation from natural. The absence of a REI zone during most summers will lead to suppressed zooplankton biomass. The reduction in the extent of reeds and sedges downstream will lead to a lower biomass of carid shrimps (*Palaemon capensis*) and therefore impact higher trophic levels negatively.
4	Low flow conditions persist for longer and marine dominance (State 1) occurs for 49% of the time, with a significant increase in spring –early summer The REI now occurs once every ten years. The scenario therefore, represents increasing marine dominance and loss of REI. Zooplankton biomass remains persistently low and invertebrates associated with the low salinity zone shrinks. Associated with increased marine dominance will be the decrease in the fringing vegetation and hence habitat available for carid shrimps (*Palaemon capensis*).

Table 5.27 Duiwenhoks Estuary: Invertebrate health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
Zooplankton						
a. Species richness	100	100	100	100	100	Medium
b. Abundance	80	85	83	75	70	Medium
c. Community composition	75	80	78	70	65	Medium
Hyperbenthos						
a. Species richness	100	100	100	100	100	Medium

Variable	Scenario					
	Present	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**	**Confidence**
b. Abundance	80	85	83	75	70	Medium
c. Community composition	75	80	78	70	65	Medium
Benthos						
a. Species richness	100	100	100	100	100	Medium
b. Abundance	70	80	75	65	55	Medium
c. Community composition	70	80	75	65	55	Medium
Invertebrate score min (a to c)	**70**	**80**	**75**	**65**	**55**	**Medium**

5.10 FISH

A summary of the expected changes under various scenarios for the fish component in the Duiwenhoks Estuary is provided in **Table 5.28**, while the health scores for the present and future scenarios are provided in **Table 5.29**.

Table 5.28 Duiwenhoks Estuary: Summary of change in fish under different scenarios

Scenario	Summary of changes
1	More developed and persistent REI during the summer will see estuary residents e.g. *G. aestuaria* and those typical of the REI e.g. *M. capensis* be more dispersed in the estuary instead of being confined mostly to Zone D as in the PD. The fish community will shift slightly closer to reference with increased dominance of REI species. Increased micro-algal (benthic?) production should favour all mullet species and increased zooplankton production should favour juveniles and larvae of all fish species. Prey availability for adult benthic feeders e.g. *L. lithognathus* may decrease in that burrowing invertebrates may burrow deeper to preferred salinities, probably closer to Reference Conditions. Slight attenuation of floods by rehabilitation in catchment therefore cueing, connectivity and recruitment window incrementally enhanced.
2	Given seasonal and interannual variability, the salinity regime is identical to the PD. The REI fish community will remain dominant as it was under reference through to present but may benefit from a slight increase in the strength and persistence of the REI.
3	Loss of the REI for a large part of the year will see a switch to a fish assemblage dominated by the opportunistic *L. richardsonii* and two orders of magnitude decline in abundance of the REI species specifically *G. aestuaria* and *M. capensis*. Floods to be shorter and sharper than present therefore cueing, connectivity and recruitment windows likely to be dampened and shorter. New recruits have a slightly bigger chance of being flushed from the system. Increase in microalgae (benthic) will favour mullet grazers, but a decline in zooplankton abundance will mean food scarcity for all juvenile fish. Burrowing invertebrates are likely to become more available as prey to benthic feeders.
4	Complete loss of the REI and a more extreme version of Scenario 3 i.e. a switch to a fish assemblage dominated by the opportunistic *L. richardsonii* and REI species *G. aestuaria* and *M. capensis* disappear from the estuary. Floods lost and remaining ones shorter and sharper than present therefore cueing, connectivity and recruitment windows are likely to be dampened and shorter. New recruits have a slightly bigger chance of being flushed from the system. Increase in microalgae (benthic) will favour mullet grazers but a decline in zooplankton abundance will mean food scarcity for all juvenile fish. Burrowing invertebrates are likely to become more available as prey to benthic feeders.

Table 5.27 Duiwenhoks Estuary: Fish health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	89	90	89	70	60	Medium
b. Abundance	70	80	75	60	50	Medium
c. Community composition	70	80	70	60	50	Medium
Fish score min (a to c)	**70**	**80**	**70**	**60**	**50**	**Medium**

5.11 BIRDS

A summary of the expected changes under various scenarios for the bird component in the Duiwenhoks Estuary is provided in **Table 5.29**, while the health scores for the present and future scenarios are provided in **Table 5.30**.

Table 5.29 Duiwenhoks Estuary: Summary of change in birds under different scenarios

Scenario	Summary of changes
1	Fish abundance lower than present, reducing numbers of piscivorous birds (majority of groups); waterfowl recover slightly due to fresher conditions; inverts lower, reducing wader numbers.
2	Conditions similar to Present State.
3	More saline, less favourable for waterfowl than present; big decrease in smaller fish species has negative impact on many groups.
4	Same trajectory as Scenario 3, but more extreme changes.

Table 5.30 Duiwenhoks Estuary: Bird health scores for present and future scenarios

Variable	Scenario					
	Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
a. Species richness	95	95	95	90	90	Low
b. Abundance	78	74	78	54	44	Low
c. Community composition	80	79	80	66	58	Low
Bird scores min (a to c)	**78**	**74**	**78**	**54**	**44**	**Low**

5.12 ECOLOGICAL CATEGORIES ASSOCIATED WITH SCENARIOS

The individual health scores for the various abiotic and biotic components are used to determine the ecological status or ecological category for the Duiwenhoks Estuary under each of the future scenarios (**Table 5.30**), again using the EHI.

Table 5.31 Duiwenhoks Estuary: EHI score and corresponding Ecological Categories under present and future scenarios

Variable	Weight	Scenario					
		Present	Sc 1	Sc 2	Sc 3	Sc 4	Confidence
Hydrology	25	47	86	60	37	34	Medium
Hydrodynamics and mouth condition	25	95	95	95	95	94	Medium
Water quality	25	72	72	72	72	73	Medium
Physical habitat alteration	25	82	85	82	78	72	Low
Habitat health score	**50**	**74**	**84**	**77**	**70**	**68**	
Microalgae	20	73	71	72	74	59	Medium/Low
Macrophytes	20	60	63	60	57	50	Medium
Invertebrates	20	70	80	75	65	55	Medium
Fish	20	70	80	70	60	50	Medium
Birds	20	78	74	78	54	44	Low
Biotic health score	**50**	**70**	**74**	**71**	**62**	**52**	
ESTUARY HEALTH SCORE		**72**	**79**	**74**	**66**	**60**	**Medium**
ECOLOGICAL CATEGORY		**C**	**B**	**B/C**	**C**	**C/D**	**Medium**

5.13 RECOMMENDED ECOLOGICAL FLOW SCENARIO

In the case of the Duiwenhoks Estuary a **Category B** was proposed as the REC. Applying this guideline, only Sc 1 (see **Table 5.32**) in the suite of scenarios evaluated as part of this study meets these criteria. However, Sc 1 was a hypothetical scenario assuming that 50% of the base flow could be returned to the estuary through removal of alien invasive plants, deforestation, as well as reducing run-off river abstraction during the low flow season. Considering the high demand for water in the catchment, this may not be a realistic option.

Sc 2 (present flow including the river low flow EWR) resulted in a slight improvement in health, from a Category C to a Category B/C (just below a Category B). Sc 2 returns some low flows to the estuary, and in doing so, addresses the key flow-related factor contributing to the changes in ecological health in this estuary. Considering the significant contribution of non-flow related factors to changes in the present ecosystem health in the Duiwenhoks Estuary, as well as the reversibility of some of these impacts, **Sc 2 was identified as the recommended flow requirement scenario.**

However, in order to improve from a Category B/C, additional intervention in terms of non-flow related impacts will be essential to improve the ecological health of the estuary to a Category B.

6 RIVER SCENARIOS: WADRIF DAM

This section is authored by Delana Louw.

6.1 AREA OF IMPACT

The locality of the proposed Wadrif dam was sourced from the following report: Freshwater Assessment for the proposed Wadrif Dam at Farm Doukamma 221, Plettenberg Bay (Belcher *et al*., 2012).

According to Belcher *et al.* (2012) the proposed off-channel dam is situated on a tributary of the Bitou River (**Figure 6.1**). The Bitou River flows into the Keurbooms Estuary. The off-take of the dam is at the most downstream gauge in the Keurbooms River which is very close to the head of the estuary.

In terms of flow, the area of impact is therefore the following:

- Downstream of the off-take in the Keurbooms River.
- Downstream of the Wadrif Dam (tributary of the Bitou River).
- Bitou River downstream of the confluence of the tributary with the Bitou River.

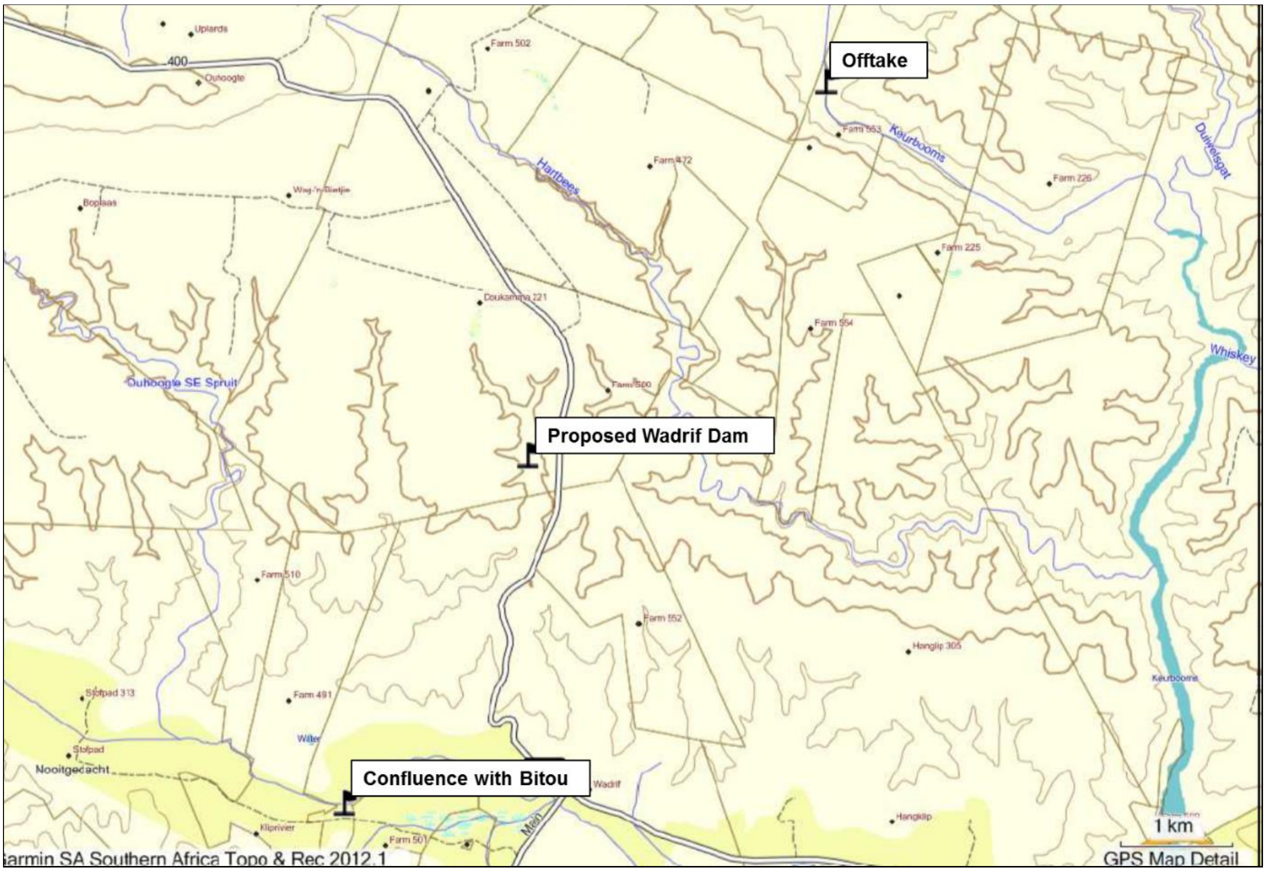


Figure 6.1 Map showing the position of the proposed Wadrif Dam

6.2 PROCESS OF SCENARIO DETERMINATION

To undertake a detailed scenario evaluation, an EWR site should be situated in each of the three reaches mentioned above. However, EWR sites are selected according to the accepted criteria and in a significant resource (DWA, 2014a). Scenario evaluation can only be undertaken at a detailed level if an EWR site and an EWR assessment is situated in the reach of evaluation. To undertake an EWR assessment, hydrology of reasonable confidence is required at the EWR site. Most importantly, the river characteristics must be such that ecohydraulic modelling can be undertaken at the EWR site.

6.3 RATIONALE FOR NOT ASSESSING RIVER CONSEQUENCES FOR WADRIF DAM

6.3.1 Tributary downstream of Wadrif Dam

The tributary is not a significant resource as it is a drainage line and therefore does not require a Reserve determination. The river (drainage line) is not included in the PES – Environmental Importance - Environmental Sensitivity (EI-ES) assessment (undertaken by Southern Waters; DWA, 2013). The most significant issue, however, is that there is no hydrology available for the tributary to undertake an evaluation. Furthermore, the river is so small that an EWR assessment will be of very low confidence. **Figure 6.2** indicates how unclear the river is even at the confluence. It is likely that the confluence is to the right of the label.

Figure 6.2 Google Earth image showing the confluence of the tributary and the Bitou River

6.3.2 Bitou River

Most of the Bitou River downstream of the confluence consists of a wetland and then the estuary. A wetland or estuarine Reserve is therefore required rather than a river Reserve. Furthermore, it is likely that the hydrological impact will be minimal due to the likely small contribution of the tributary. **Figure 6.3** indicates the wetland surrounding the blue river line and showing the inflow into the estuary.

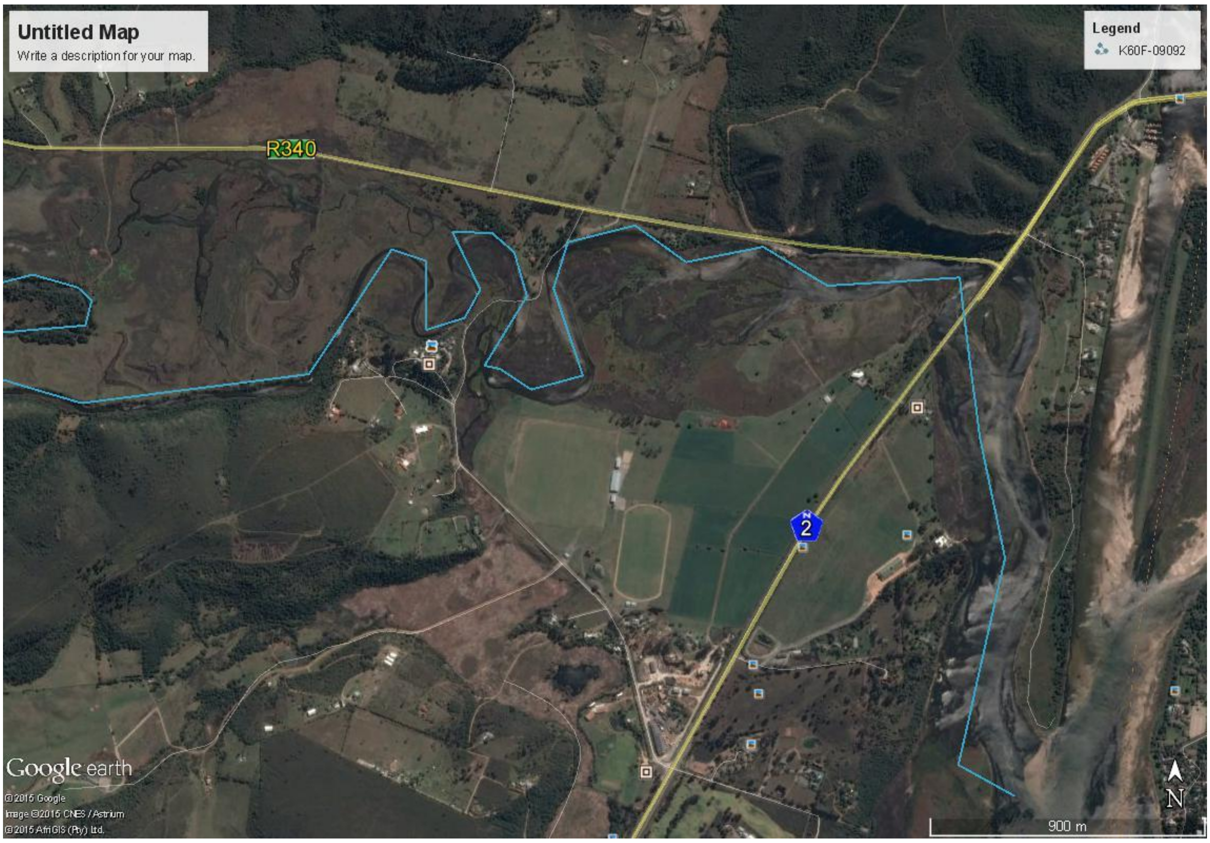


Figure 6.3 A Google Earth image showing the position of the Bitou wetlands along the blue river line and the inflow to the estuary

6.3.3 Keurbooms River

The major impact of the proposed development would be on the decreased baseflows to the Keurbooms Estuary and it therefore follows that an estuary assessment of the scenario is required rather than for the river. However, for the purposes of river EWR assessment for the Keurbooms River as a whole, a site downstream of the lower gauge was investigated in detail and the reasons why the site was not selected is documented in the GRDS Desktop EcoClassification and Delineation reports (DWA, 2014a, b). A site further upstream was selected. This site could, however, have been used to determine the river consequences if one assumed that the hydraulic nature of the site is representative further downstream. This was, however, deemed to be unnecessary as the river section outside of the tidal influence below the off-take is short (4 km). The estuary consequences of the scenario would therefore override the river requirements. This is demonstrated in **Figure 6.4** which shows the off-take position on the Keurbooms River and the upstream boundary of the estuary.

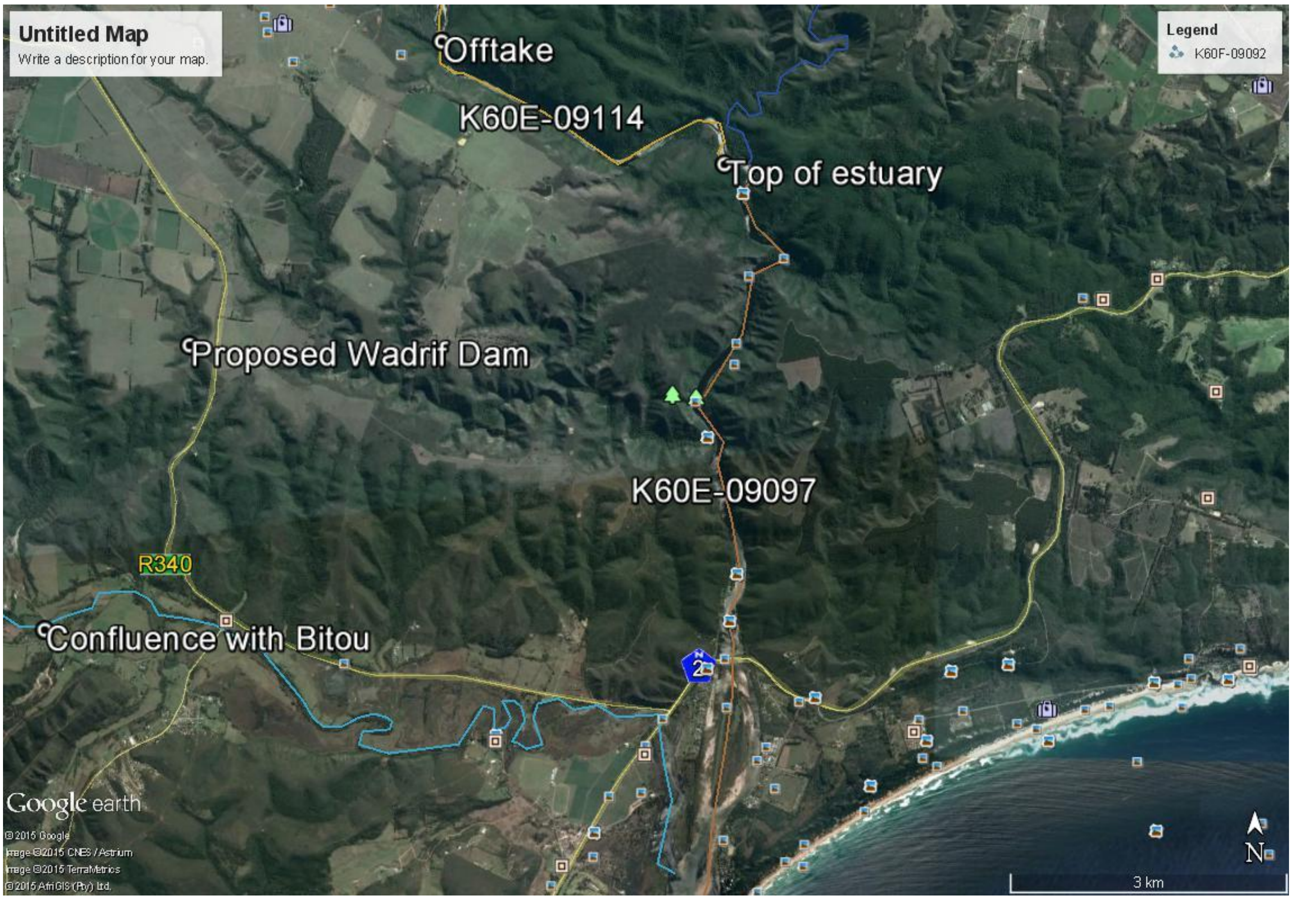


Figure 6.4 A Google Earth image showing the area of the proposed Wadrif Dam in relation to the Keurbooms Estuary

6.4 CONCLUSION

No evaluation of river consequences of the proposed development was undertaken. The results of this scenario are discussed in the GRDS Keurbooms Estuary Report for the study (DWS, 2015).

7 OTHER WATER RESOURCE DEVELOPMENTS CONSIDERED

7.1 INTRODUCTION

Appendix B outlines a number of proposed water resource developments mentioned at the Scenario Workshop in August 2014. A few of these were considered for a river consequences assessment.

7.2 SWARTBERG DAM: LADISMITH

The proposed Swartberg Dam is to be located in the Klein Karoo, with its objective being to ensure an increase in assured yield and assurance of supply to the town of Ladismith. The proposed Swartberg River Diversion channel will divert water from the Swartberg River to the Swartberg Dam on an unnamed tributary of the Swartberg River. A feasibility level assessment was carried out as Phase II of the Ladismith Regional Bulk Infrastructure Grant (RBIG) Project Feasibility Study (Element Consulting Engineers, 2013). One of the comments made in this document was that the dam would not need to release water for environmental requirements, as virgin runoff and EWRs from the 0.51 km^2 catchment are calculated to be insignificant. Although the GRDS did not evaluate the impact of this dam on the Swartberg River, a point such as this would need to be verified, particularly as a 0.5 million m^3 dam could be significant for such a small catchment.

Note that the Buffels River and Touws River EWR sites would not be impacted by this proposed dam development. Only the Gouritz River EWR site could be impacted on, but as the site is very far downstream of the proposed dam, significant impacts are unlikely. Ideally an EWR site should have been located on the Swartberg River so that ecological consequences of a dam scenario could have been evaluated, but the team had not been informed of the proposed dam at the time of site selection.

7.3 VET DAM: RIVERSDAL, GOUKOU SYSTEM

The following information was provided at the Scenario Workshop of August 2014:

- Proposed instream dam on Korinte River (below Korinte-Vet Dam) (capacity 1.5 million m^3), with contributions from Kristalkloof.
- Proposed off-channel dam (below Korinte-Vet Dam) (capacity 3 million m^3); with contributions from Kristalkloof.

When information was sought to develop a realistic dam scenario, only the following extracts could be found in the Reconciliation Strategy for Riversdal in relation to dam developments (DWS, 2014b).

"The following potential sources were identified to augment the current water supply:

- *Increasing supply from the Korentepoort Dam, through one of the following measures:*
    - *An additional allocation from the system, or*
    - *By increasing the storage and diversion capacity at the present site.*

- *The option of pumping water from the Goukou River which located 1 m from Riversdal, and storage at a new localised dam or a possible off-channel storage dam is dependent on the quantity of water available in the Goukou River.*
- *Potential abstraction from the proposed Wydesrivier Dam."*

Figure 7.1 shows the position of the Korintepoort Dam, Vet, Naroo and Kristalkloof rivers.

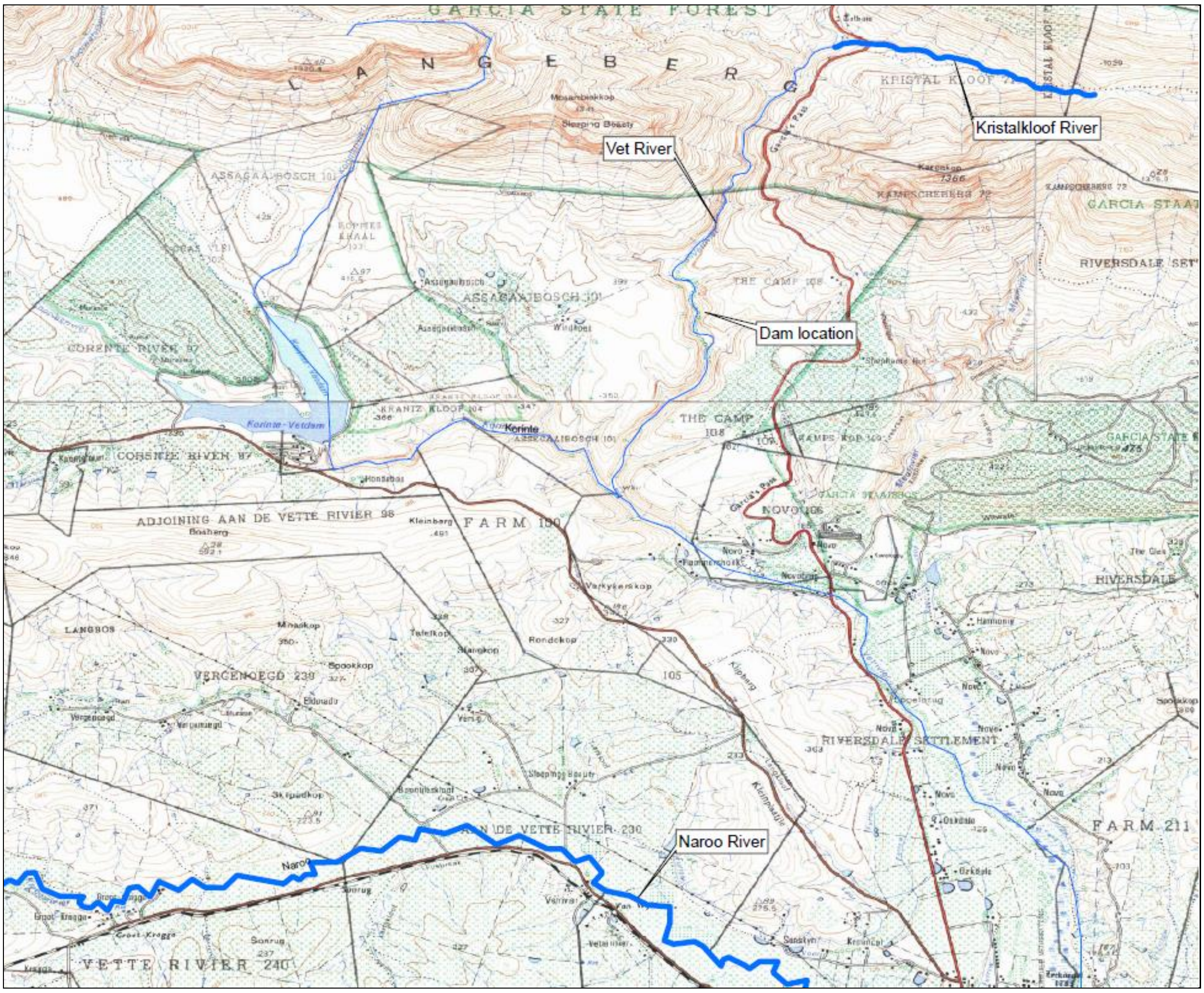


Figure 7.1 Map showing the location of the Korintepoort Dam, Vet, Naroo and Kristalkloof rivers

Some assumptions were then made regading possible locations of the “Vet” Dam.

- Scenario 1, Vet Dam: 1 MAR dam abstracting the historical yield, with a catchment area of 33.7 km^2 (**Figure 7.2**).

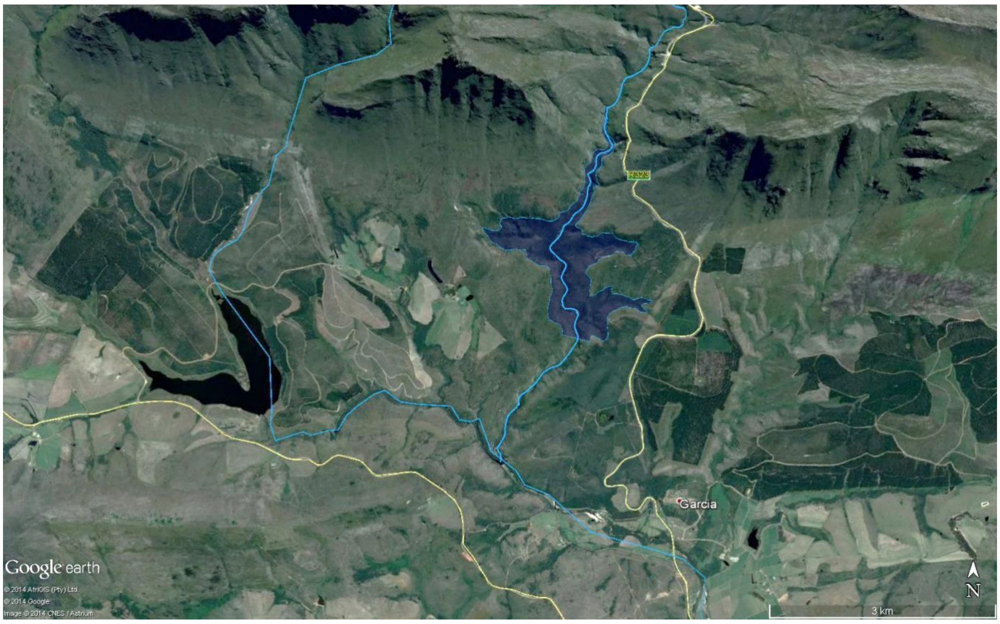


Figure 7.2 Google Earth image showing the existing Korintepoort Dam and the proposed “Vet Dam” (shaded in blue)

- Vet2 Dam: 1 MAR dam downstream of the Korinte and Vet confluence, abstracting the historical yield, with a catchment area of 89.2 km^2 (**Figure 7.3**).

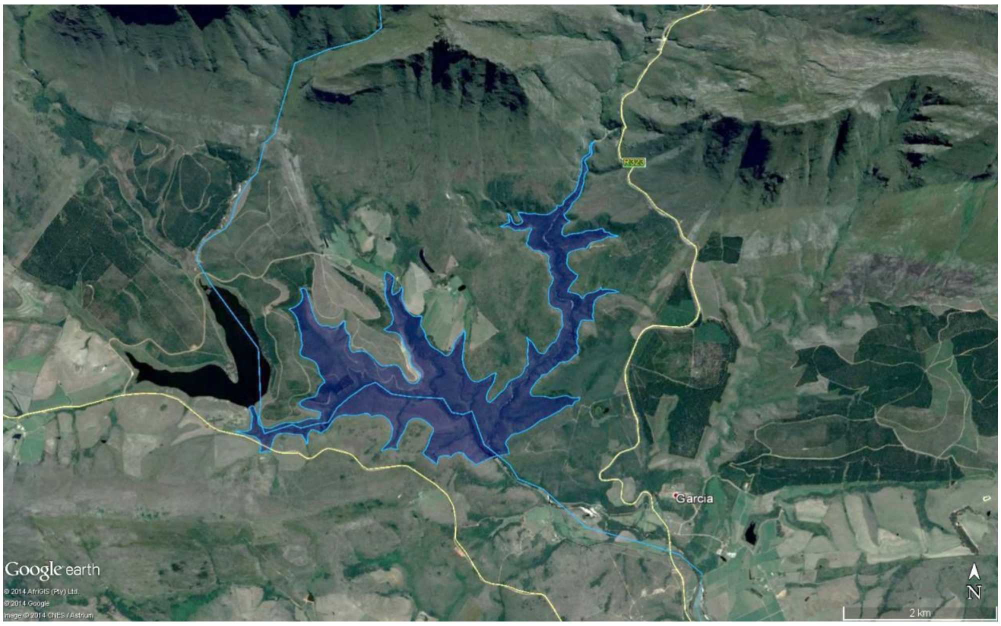


Figure 7.3 Google Earth image showing the existing Korintepoort Dam and the proposed “Vet2 Dam” (shaded in blue)

Results of the scenario analyses showed the following:

- The PD scenario with and without (low flow) river EWR is exactly the same.
- Full river EWR flows are not always met under the PD scenario, but there are no upstream dams to supply the EWR from, and low confidence hydrology.
- This scenario may be significant for the Goukou Estuary, but not for the river.

7.4 DUIWENHOKS DAM: HEIDELBERG

Information provided at the Scenario Workshop of August 2014 considered an off-channel dam on the Duiwenhoks system, 10km upstream of the N2 and with a capacity of 1.5 million m^3.

The Reconciliation Strategy (DWS, 2014c) only referred to increased abstraction from the existing Duiwenhoks Dam (**Figure 7.4**), with no other information available on the proposed off-channel dam.

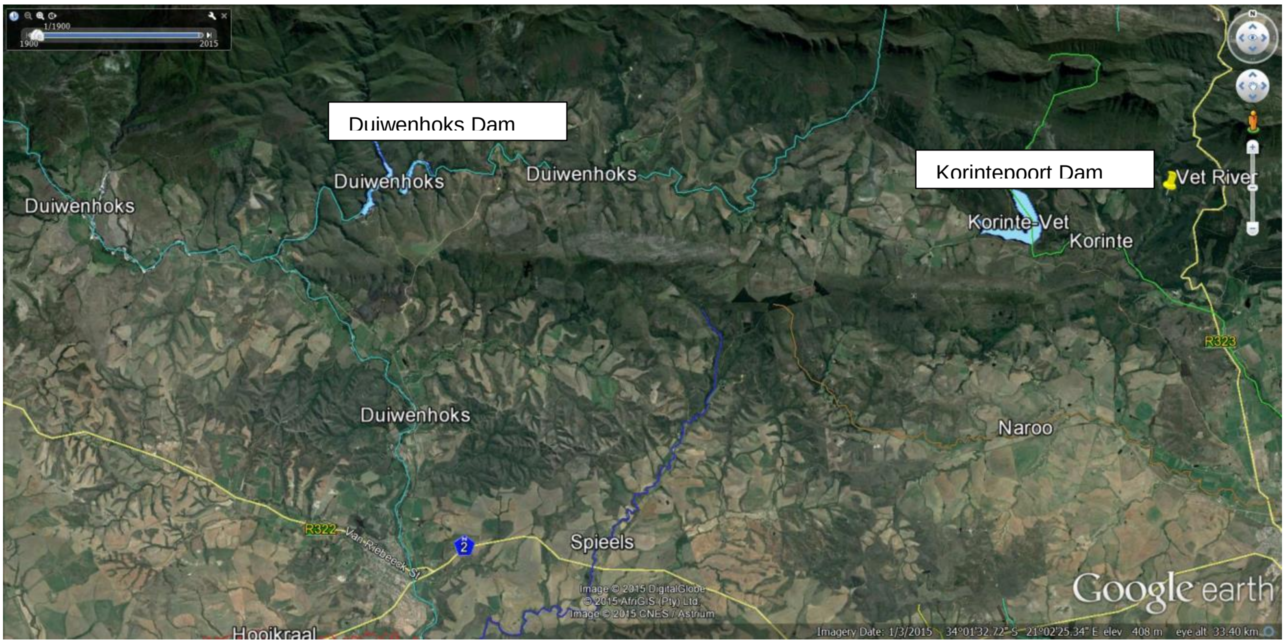


Figure 7.4 Google Earth image showing the existing Duiwenhoks Dam in relation to the N2

Due to the position of the river EWR site on the Duiwenhoks River being close to the head of the estuary, the estuary requirements would override that of the river, and the dam scenario was not assessed further for riverine consequences.

7.5 CONCLUSION

The proposed Wadrif Dam was the only development with sufficient technical data to support a riverine ecological consequences assessment. However, the main impact area is the Keurbooms Estuary, with its requirements overriding those of the Keurbooms and Bitou rivers.

8 OVERALL CONCLUSIONS

This report presents the approach taken to the scenario assessment phase of the study. Little information was available to enable the yield modeller to develop operational scenarios to be assessed by the river team. River economic and ecological services impacts were therefore also not assessed. It is assumed that more detailed information may be available during the scenario assessment phase of the Water Resource Classification study for the area.

A recommendation from this study is that the spread of gauging weirs across the study area be reassessed. Few gauging weirs are found across a highly variable study area, thereby impacting on the confidence of the hydrological assessments and the yield modelling undertaken.

A second recommendation would be an assessment of the EWRs for the Swartberg River, should the proposed Swartberg Dam go ahead. Information on this proposed water resource development was not available at the time of EWR site selection during the GRDS study.

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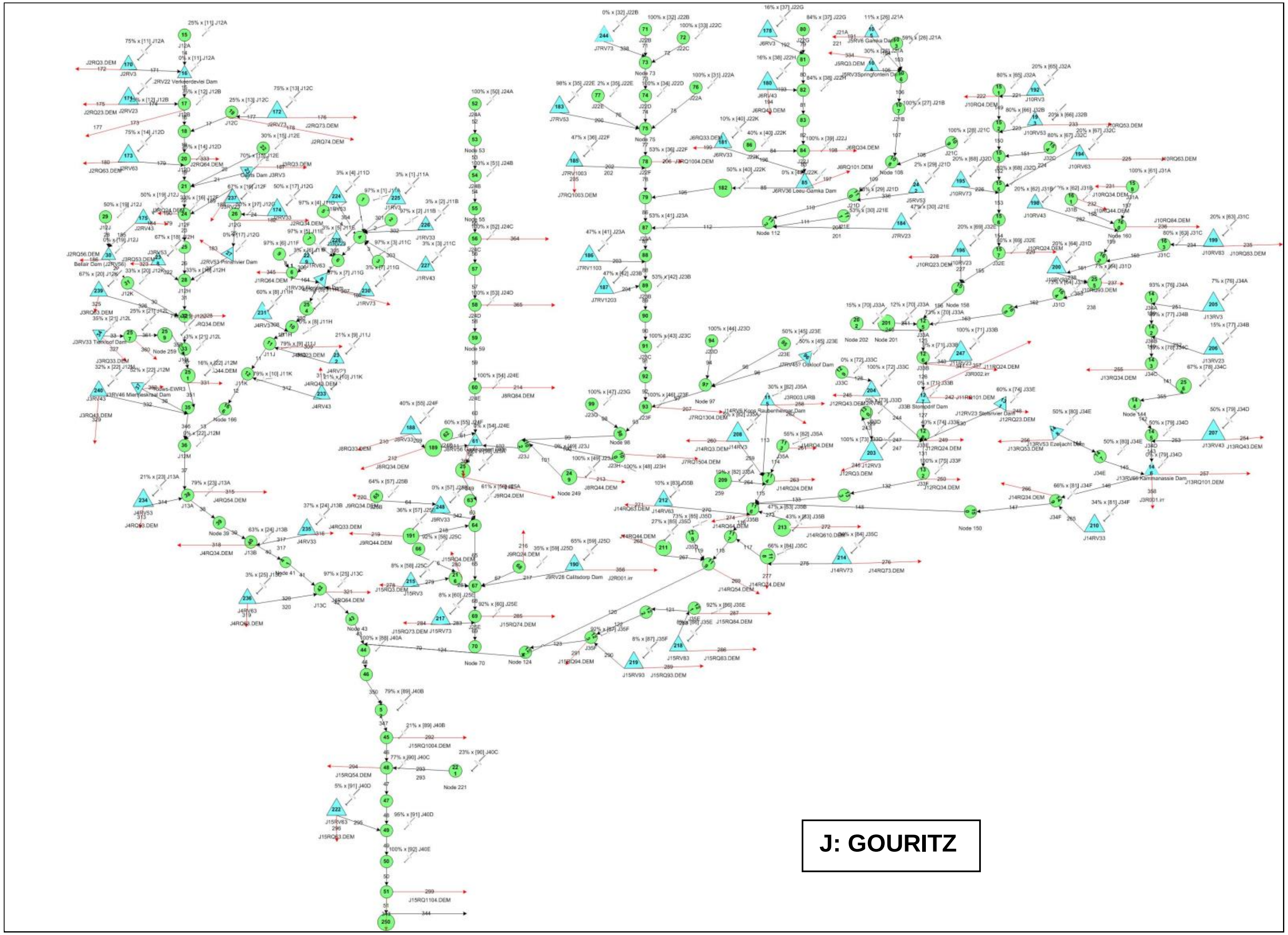
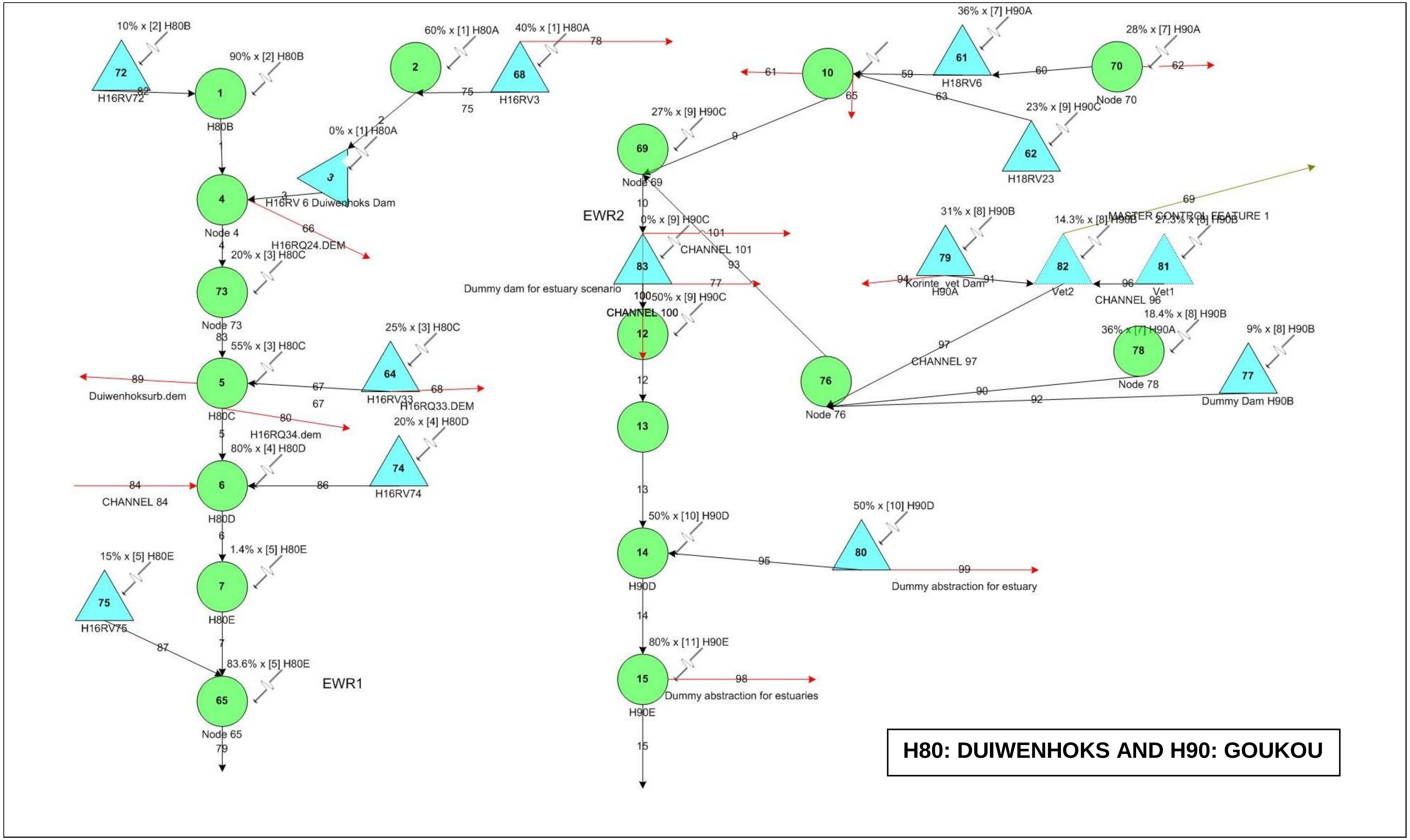
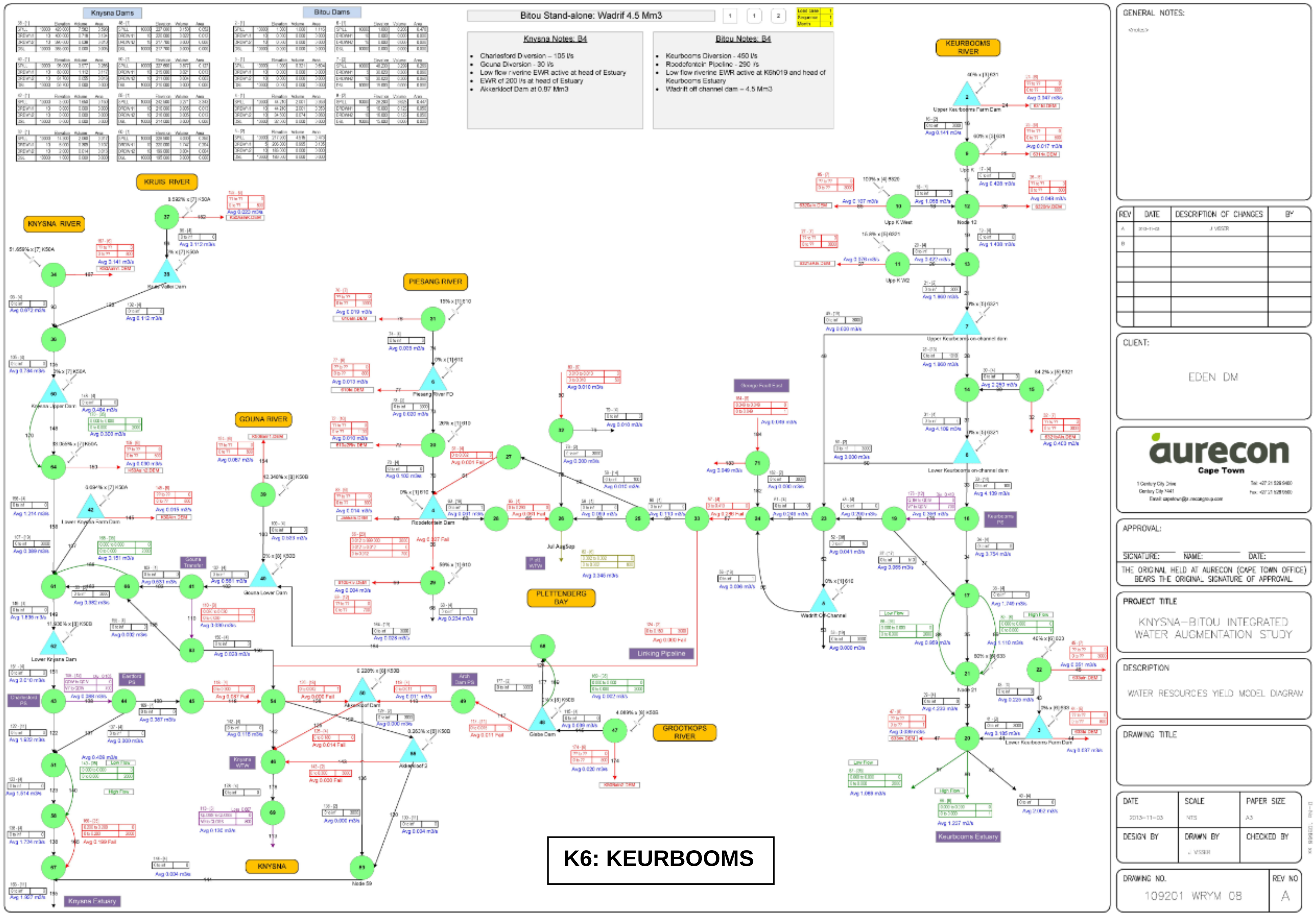
APPENDIX A: WRYM SCHEMATIC DIAGRAMS




H80: DUIWENHOKS AND H90: GOUKOU
EWR1
EWR2
10% x [2] H80B
90% x [2] H80B
60% x [1] H80A
40% x [1] H80A
0% x [1] H80A
H16RV72
H80B
H16RV3
H16RV 6 Duiwenhoks Dam
Node 4
H16RQ24.DEM
20% x [3] H80C
Node 73
55% x [3] H80C
25% x [3] H80C
Duiwenhoksurb.dem
H80C
H16RV33
H16RQ33.DEM
H16RQ34.dem
80% x [4] H80D
20% x [4] H80D
CHANNEL 84
H80D
H16RV74
1.4% x [5] H80E
15% x [5] H80E
H16RV75
H80E
83.6% x [5] H80E
Node 65
36% x [7] H90A
28% x [7] H90A
H18RV6
Node 70
23% x [9] H90C
H18RV23
27% x [9] H90C
Node 69
0% x [9] H90C
CHANNEL 101
Dummy dam for estuary scenario
50% x [9] H90C
CHANNEL 100
31% x [8] H90B
Korinte_vet Dam
H90A
14.3% x [8] H90B
27.3% x [8] H90B
MASTER CONTROL FEATURE 1
Vet2
Vet1
CHANNEL 96
CHANNEL 97
18.4% x [8] H90B
36% x [7] H90A
9% x [8] H90B
Node 78
Node 76
Dummy Dam H90B
50% x [10] H90D
50% x [10] H90D
H90D
Dummy abstraction for estuary
80% x [11] H90E
H90E
Dummy abstraction for estuaries



Knysna Dams
Bitou Dams
Bitou Stand-alone: Wadrif 4.5 Mm3
Knysna Notes: B4
Charlesford Diversion – 105 l/s
Gouna Diversion - 30 l/s
Low flow riverine EWR active at head of Estuary
EWR of 200 l/s at head of Estuary
Akkerkloof Dam at 0.87 Mm3
Bitou Notes: B4
Keurbooms Diversion - 450 l/s
Roodefontein Pipeline - 290 l/s
Low flow riverine EWR active at K6h019 and head of Keurbooms Estuary
Wadrift off channel dam – 4.5 Mm3
KEURBOOMS RIVER
KRUIS RIVER
KNYSNA RIVER
PIESANG RIVER
GOUNA RIVER
PLETTENBERG BAY
GROOTKOPS RIVER
KNYSNA
Linking Pipeline
Keurbooms Estuary
Knysna Estuary
K6: KEURBOOMS
GENERAL NOTES:
REV
DATE
DESCRIPTION OF CHANGES
BY
CLIENT:
EDEN DM
Cape Town
APPROVAL:
SIGNATURE:
NAME:
DATE:
THE ORIGINAL HELD AT AURECON (CAPE TOWN OFFICE) BEARS THE ORIGINAL SIGNATURE OF APPROVAL
PROJECT TITLE
KNYSNA–BITOU INTEGRATED WATER AUGMENTATION STUDY
DESCRIPTION
WATER RESOURCES YIELD MODEL DIAGRAM
DRAWING TITLE
DATE
2013–11–03
SCALE
NTS
PAPER SIZE
A3
DESIGN BY
DRAWN BY
CHECKED BY
DRAWING NO.
109201 WRYM 08
REV NO
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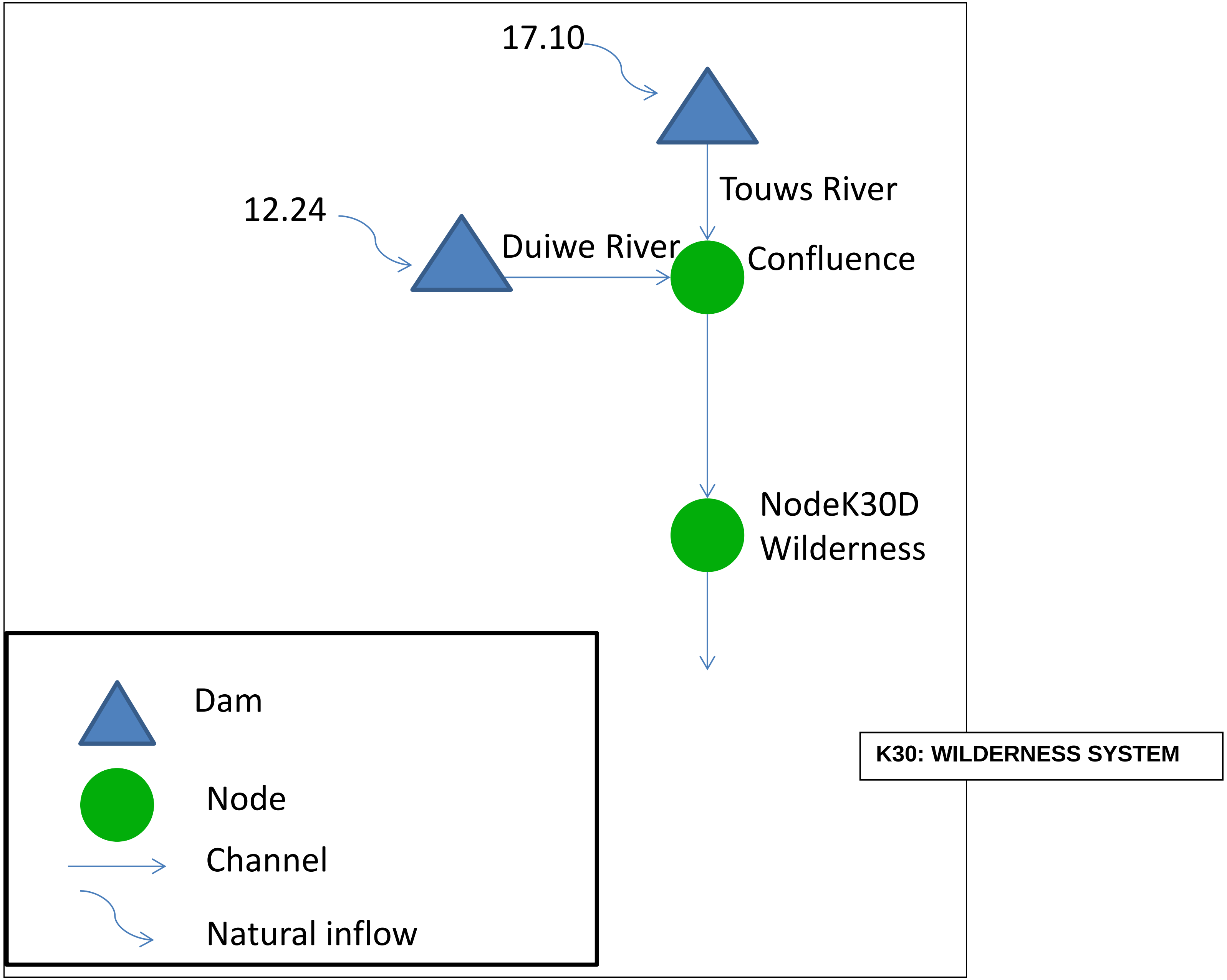
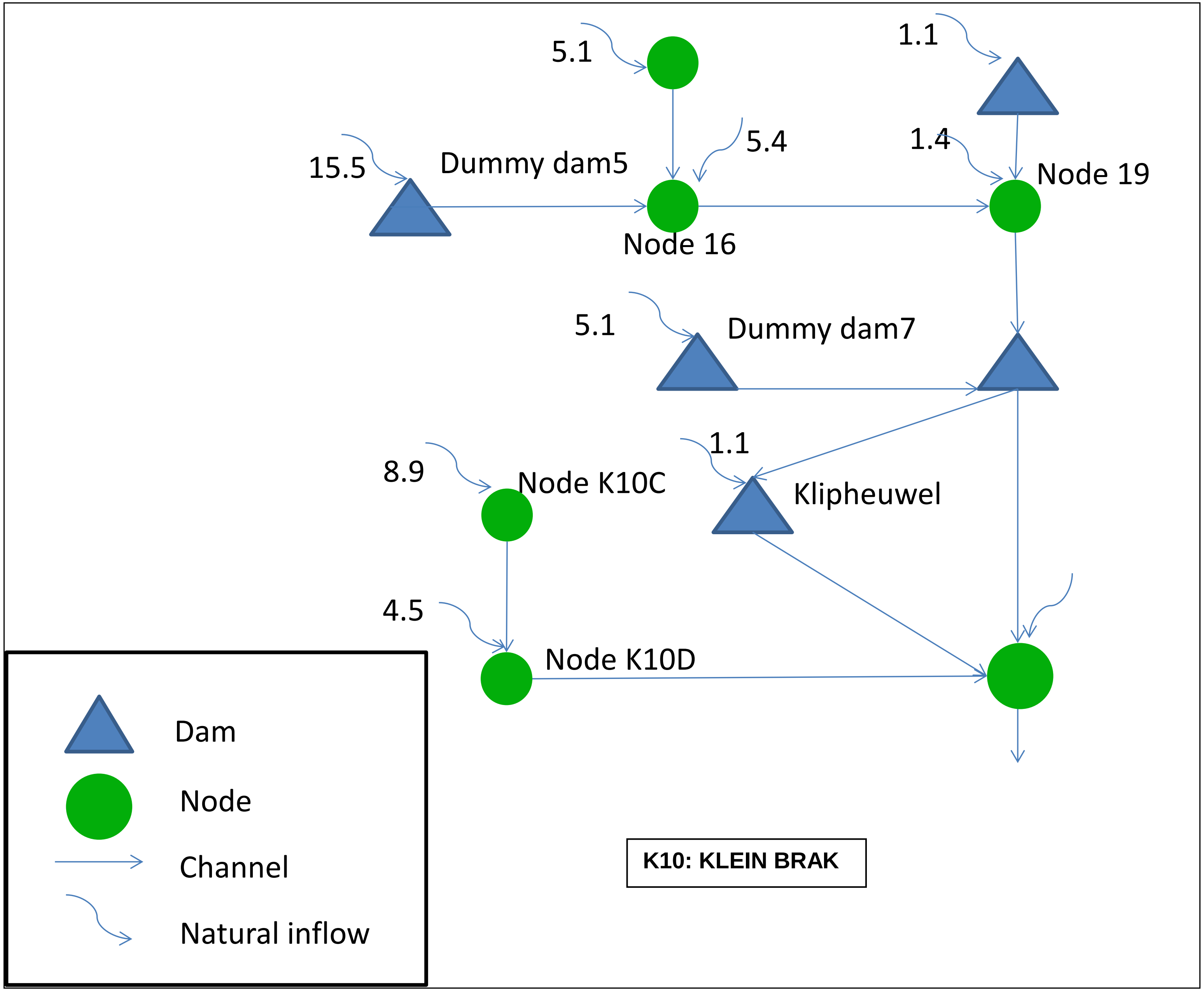

17.10
Touws River
12.24
Duiwe River
Confluence
NodeK30D
Wilderness
Dam
Node
Channel
Natural inflow
K30: WILDERNESS SYSTEM


5.1
1.1
5.4
1.4
15.5
Dummy dam5
Node 19
Node 16
5.1
Dummy dam7
8.9
1.1
Node K10C
Klipheuwel
4.5
Node K10D
Dam
Node
Channel
Natural inflow
K10: KLEIN BRAK

APPENDIX B: NOTES FROM AUGUST 2014 SCENARIO MEETING

AGENDA

WP10543: PRELIMINARY RESERVE DETERMINATION STUDIES FOR SELECTED SURFACE WATER (RIVERS, ESTUARIES AND WETLANDS) AND GROUNDWATER RESOURCES IN THE GOURITZ WATER MANAGEMENT AREA

SCENARIO MEETING

VENUE: **Main boardroom at AECOM offices in Bellville, Cape Town**

DATE: **25 August 2014**

TIME: **Starting 10:00 – 15:30**

CHAIRPERSON: Aldu le Grange, AECOM

Aim and Objective of Scenario Meeting:

The Scenario Meeting is being held specifically to identify development scenarios for the Gouritz section (previously WMA 16) of the Breede-Gouritz WMA, WMA 8. The most feasible and probable scenarios will be selected for evaluation by the Reserve team in consultation with the Department of Water and Sanitation.

09:30	Tea/Coffee	
10:00	Welcome, Introduction + Apologies	Aldu le Grange
10:15	Background + Reserve Process The Reserve + Classification Objective of meeting + criteria for selection of scenarios	Patsy Scherman Delana Louw Delana Louw
10:40	Current state of Gouritz study Location of study sites	Patsy Scherman

11:00	**Joint session:** Information / feedback on known development options	

1. DWS Regional Office: Wilna Kloppers
2. Regional municipalities
3. Catchment Management Office: John Roberts
4. DWS Planning: Isa Thompson / Fanus Fourie
5. Other

12:30	Lunch	
13:30	Further discussion on development options	
15:00	Wrapping up + identification of final scenarios for review	Aldu le Grange

PROPOSED GOURITZ SCENARIOS PER SECONDARY CATCHMENT:
Scenario Meeting, 24 August 2014

Green text: priority 1, Rivers and Estuaries
Red text: priority 1 Rivers only
Purple text: priority 1 Estuaries only
Blue text: priority 2

H8: Duiwenhoks River
(Heidelberg area)

- **Off-channel dam 10 km upstream from N2 (capacity 1.5 Mm^3) for domestic and industrial use, so impact on river and estuary**
    -

H9: Goukou River
(Riversdale area)
Current allocation is from the Kristalkloof, but town ran out of water 5 yrs ago. Dam will be mostly to meet irrigation requirements and will be operated together with abstraction from the Kristalkloof.

- **Proposed instream dam on Korinte River (below Korinte-Vet Dam) (capacity 1.5 Mm^3), with contributions from Kristalkloof**
- **Proposed off-channel dam (below Korinte-Vet Dam) (capacity 3 Mm^3); with contributions from Kristalkloof**

J1: Buffels, Touws and Doring rivers

- Possible off-channel dam (capacity 50 000 m^3) to provide for Ladismith
    - Move abstraction higher up in river
    - Abstraction from Klein Swart(berg?) River (current / future?) – alluvial aquifer underneath the river bed
- Supply for Zoar: proposed supply from a Buffels River tributary
    - Off-channel: 4 Mm^3
    - Instream: 1.5 Mm^3

J2: Gamka River
Beaufort-West area: Groundwater notes

- Define no-go areas in terms of fracking
- Quality limits quantity available for use
- Note planned uranium mine south west of Beaufort West
- Define remainder of groundwater sources available in areas dependent on groundwater

J3: Olifants and Kammanassie rivers

- Tributary CC Dam a possible future option; near Oudtshoorn.
- Shortage in De Rust. How much water is available from the Huis River?
- Raising of Calitzdorp Dam being considered, but very costly. Groundwater use is possible.

J4: Gouritz River

K1: Brak River systems

Mosselbay area

- Off-channel Kleinplaas Dam with abstraction from the Moordkuil (planned? Covered in ORDS?)
- Groot Brak: operational rules needed (Wolwedans Dam?)

K3: Touw/Wilderness; Kaaimans systems

George area

- Reuse of treated effluent?
- Malgas Dam: n/a as a future potential development
- Raising of Garden Route Dam: n/a as existing license application
- Groundwater use as augmentation during droughts (Swart River)

Sedgefied area

- **Off-channel Hoëkraal Dam; transfer to Karatara, so potential impact on Swartvlei (n/a as considered during the ORDS?)**

K5: Knysna River

- **Off-channel dam at Concordia (Akkerkloof 2)**
- Reuse of treated effluent?

K6: Keurbooms and Bitou rivers; NB for Keurbooms Estuary

Option 1: Off-channel Wadrif Dam, 4.5 Mm^3

- **Existing abstraction from the Keurbooms: 5.3 Mm^3/a**
- **Additional 7.2 Mm^3/a + 600 000 m^3/a for agriculture**
- **Total proposed abstraction: 12.6 Mm^3/a**

Option 2

Groundwater recharge during winter months (Figures: Fanus Fourie)

Plettenberg Bay: Re-use of treated effluent?

APPENDIX C: COMMENTS AND RESPONSE REGISTER

Section	Report Statement	Comments	Addressed in Report?	Author Comment
Comments: Andrew Gordon - DWS WC : Resource Protection, received 06 November 2015				
1.1	The National Water Act (Act No. 36 of 1998) (NWA), Section 3 requires that the Reserve be determined for water resources, i.e. the quantity, quality and reliability of water needed to sustain both human use and aquatic ecosystems, so as to meet the requirements for economic development without seriously impacting on the long-term integrity of ecosystems.	Reserve has the quantity and quality component. What is being referred to as reliability in terms of the Reserve?	No	This refers to assurance of supply.
2.6.1.4	**Present streamflow**: The present day flow data were based on the WR2005 hydrological data. Surface/groundwater interaction required more detailed modelling. Abstraction is mostly from groundwater but was assumed to be modelled as from surface water to compensate for the groundwater-surface water interaction.	Will this be a true reflection if ground water information is used as surface water?	No	There are not enough groundwater info on this scale to do groundwater abstraction modelling. This will be a very detailed study if possible.
Table 2.3	Simulation nMAR² (million m^3/a): Not available for K6KEUR-EWR8	Text on page 2-9 suggests representative MAR was determined from Aurecon data?	Yes	
2.7.5	Scenarios to illustrate the present, natural and the reduction of 10%, 20%, 30%, 40% and 6% in the natural streamflow were presented to the estuary specialists.	Typos? this does not match up with table.	Yes	Mistakes corrected.
	Reduce Present MAR by about 10%	Scenario 1 says reduce present MAR by 10% and gives result as 26.2. A value that is higher than the present day MAR of 25.2 given in the table?	No	The reductions are in terms of natural and not PD.
		Typos? The %reduction for scenarios 3-5 are the same.	Yes	Mistakes corrected.
Table 3.28		Various editorial comments.	Yes	
Table 4.28		Various editorial comments.	Yes	
Table 5.28		Various editorial comments.	Yes	
5.1.3		Scenario 1 or 2	Yes	
6.4		Sentence incomplete	Yes	
Comments: Thapelo Machaba – DWS: CD: SWRR, received 20 November 2015				
2.6	Buffels River: J1BUFF-EWR5 Measured streamflow: The flow gauge J1H028 is downstream of Floriskraal Dam.	Table 2.3 above indicates 'None"	Yes	Corrected information in Table 2.3.

Section	Report Statement	Comments	Addressed in Report?	Author Comment
Chapter 3-5		As the information is extracted from Estuary report, an assumption is made that all the comments that were given have been incorporated in this report.		Yes.
Whole report		Grammatical errors	Yes	
Table 2.3		Table sub-scripts do not reflect.	Yes	
2.7.5		Are all the scenarios the same?	Yes	Corrected mistakes.
Comments: Aldu le Grange - AECOM SA (Pty) Ltd, received 11 November 2015				
		General editorial comments and suggested changes.	Yes	