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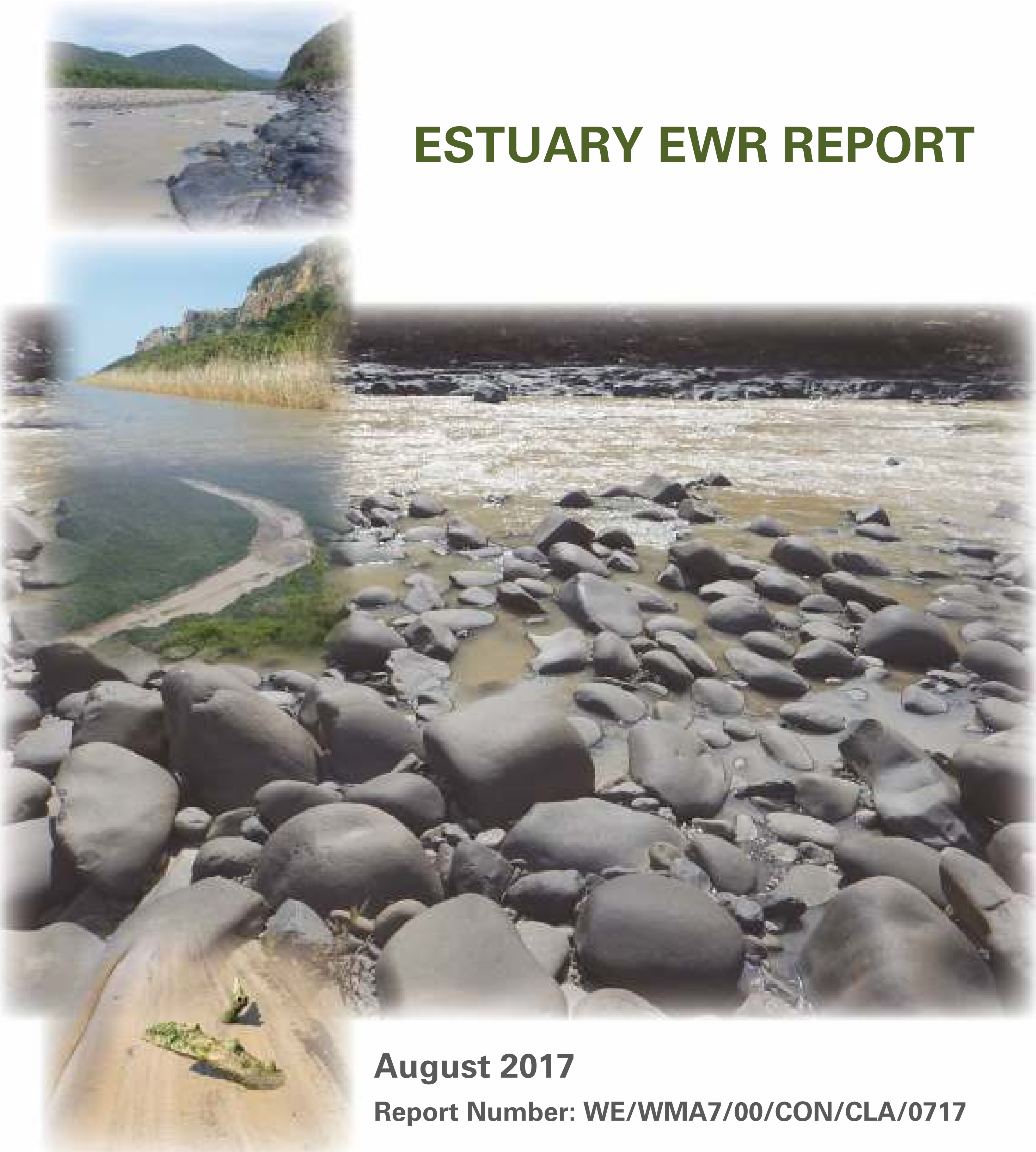
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

WP 11004

DETERMINATION OF WATER RESOURCE CLASSES AND RESOURCE QUALITY OBJECTIVES FOR THE WATER RESOURCES IN THE MZIMVUBU CATCHMENT



ESTUARY EWR REPORT

August 2017

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Bold indicates this report

APPROVAL

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Version	Date
First draft	August 2017
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EXECUTIVE SUMMARY

GEOGRAPHICAL BOUNDARIES

The Mzimvubu Estuary (31°37'52” S, 29°32'59” E) falls within the subtropical biogeographical coastal region of South Africa and enters the Indian Ocean at Port St Johns. The official Estuarine Functional Zone (EFZ) boundary of the Mzimvubu Estuary as per the national requirement is indicated below (blue line), and is defined by:

Downstream boundary:	31°37'52” S, 29°32'59” E (Estuary mouth)
Upstream boundary:	31°29'7.15" S, 29°22'59.66" E
Lateral boundaries:	5 m contour above mean sea level (MSL) along each bank

However, given the nature of the estuary (freshwater-dominated and minimal saline intrusion), the upper limit 5 m contour was not applied. Instead, a modified boundary of the system was applied for the purpose of this assessment that encompasses the major estuarine habitats and estuarine support habitats found within the EFZ (green line) that is closely aligned with the historical references.

NOTE: The official EFZ should be adhered to in terms of development under the Environmental Impact Assessment (EIA) Regulations

PRESENT ECOLOGICAL STATUS

The Estuarine Health Score for the Mzimvubu Estuary is **81**, corresponding to a **Present Ecological Status (PES)** of **Category B.**

Variable	Weight	Score
Hydrology	25	89
Physical habitat alteration	25	98
Hydrodynamics and mouth condition	25	75
Water quality	25	94
Habitat health score		**89**

Variable	Weight	Score
Microalgae	20	65
Macrophytes	20	63
Invertebrates	20	95
Fish	20	77
Birds	20	61
Biotic health score		**72**
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		**81**
PRESENT ECOLOGICAL STATUS (PES)		**B**

ECOLOGICAL IMPORTANCE

The Mzimvubu Estuary is rated a system of **"High Importance"**. A number of features contributed to the high importance score of the estuary include (DWS, 2014a):

- Significantly, this estuary lies in the only Water Management Area (WMA) not linked to another Water Management Area through cross-catchment transfers and is largely unregulated.
- This catchment has been identified as supplying high levels of ecological services nationally, and the South African National Biodiversity Institute (SANBI) is currently undertaking an assessment of the economic importance of the system. There is confirmed use of the estuary by Zambezi sharks (*Carcharhinus leucas*) as a pupping/nursery ground, and as a nursery for white steenbras (*Lithognathus lithognathus*) and dusky kob (*Argyrosomus japonicus*). The latter two species are of conservation and fisheries concern and there is highly limited available nursery habitat for these species in South Africa.
- The estuary plays a significant role in the delivery of sediments and nutrients/detritus to the marine environment, elevating its importance in geological terms to the local beaches and marine environments.

The system is also designated as a priority estuary in need of protection to meet South Africa's biodiversity targets in the National Estuaries Biodiversity Plan (National Biodiversity Assessment (NBA), 2011).

RECOMMENDED ECOLOGICAL CATEGORY (REC)

It is considered that the Best Attainable State (BAS) for the estuary is a Category B, i.e. within the PES category. Most of the changes in this estuary have not been as a result of flow modification, but rather related to non-flow related pressures such as habitat destruction, alien invasive plants, nutrient enrichment (pollution), over-fishing and human disturbances to birds. Some of these anthropogenic impacts would be difficult to remove such as the status of marine fish stocks, therefore the REC is set as a **Category B**.

However the following anthropogenic pressures should be addressed to ensure that the system maintains a Category B, namely:

- Return some variability to the mouth dynamics through removal of the access road behind the area formerly known as 'First Beach', which has effectively entrained the estuary mouth.
- Reinstating local sediment dynamics (also through the removal of the abovementioned access road). The realistic possibility of reversing the loss of 'First Beach' could potentially re-establish this once-popular recreational beach for the town of Port St Johns.

- Institute land-use management regulation within the EFZ zone that focuses on restricting the loss of further habitat within this zone and the estuary floodplain up to the 10 m contour (or 10 m above mean sea level).
- Rehabilitate disturbed areas of the estuary EFZ where impacts are reversible; rehabilitation would significantly enhance the functional integrity and importance of the estuary as a whole.
- Establish a programme for invasive alien plant management within the estuary floodplain, which would make a significant contribution towards addressing this and enhancing the functional importance of the floodplain as a feature of the estuary.
- Manage fishing pressure in the estuary through the possible partial closure of the estuary to fishing in order to protect important fish stocks and sensitive habitats.
- Address possible point-source pollution risks from the canalised creek that flows from the town of Port St Johns, as the study has suggested that this canal may be compromising water quality.

RECOMMENDED ECOLOGICAL FLOW SCENARIO

In the case of the Mzimvubu Estuary a **Category B** was proposed as the REC, similar to PES. The recommended ecological flow scenario was set as that equivalent to Scenario 53 with a flow distribution as follows:

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	324	449	401	611	672	970	487	391	297	314	155	747
99	279	406	392	599	619	691	374	235	295	232	143	272
95	129	275	300	446	541	526	264	81	81	103	56	83
90	92	189	254	310	508	369	174	65	47	34	37	51
85	80	129	201	222	381	278	131	55	34	29	27	29
80	58	92	176	178	272	237	111	45	28	25	23	23
70	41	67	130	147	188	201	102	33	21	20	17	19
60	32	57	71	107	153	162	81	25	18	17	14	15
50	27	47	53	82	121	133	70	23	16	14	13	14
40	24	39	43	70	86	113	58	20	14	12	12	12
30	23	37	39	58	70	80	52	18	13	12	11	11
20	21	35	34	52	58	68	48	17	12	10	10	10
15	20	32	33	43	54	63	44	16	11	10	10	10
10	19	31	31	37	46	57	40	15	11	10	10	9
5	18	30	27	35	40	47	35	15	11	10	9	8
1	16	28	26	30	31	37	31	13	10	9	8	8

CONSEQUENCES OF FUTURE SCENARIOS

The consequeces of various future scenarios and associated ecological categories are as follows:

Variable	Scenario											
	Pres	2a	2b	32	33	41	42	51	52	53	Pres W1	Pres W2	Dam (1.5 MAR)
Hydrology	89	85	86	85	85	86	85	87	86	97	90	90	84
Physical habitat	98	97	97	97	97	97	97	97	97	99	98	98	98
Hydrodynamics/ mouth condition	75	67	67	66	66	67	66	67	66	77	64	61	70
Water quality	94	92	89	79	84	89	84	89	79	89	93	94	89
Habitat health score	**89**	**85**	**85**	**82**	**83**	**85**	**83**	**85**	**82**	**90**	**86**	**86**	**85**
Microalgae	65	74	73	68	73	75	73	75	68	68	60	58	63

Variable	Scenario												
	Pres	2a	2b	32	33	41	42	51	52	53	Pres W1	Pres W2	Dam (1.5 MAR)
Macrophytes	63	63	62	58	59	62	59	62	58	62	60	58	62
Invertebrates	95	75	75	75	75	75	75	75	70	75	85	80	92
Fish	77	64	64	62	64	64	62	64	62	72	72	68	73
Birds	61	62	62	62	62	62	62	62	62	62	62	62	62
Biotic health score	**72**	**68**	**67**	**65**	**67**	**68**	**66**	**68**	**64**	**68**	**68**	**65**	**70**
ESTUARY HEALTH SCORE	**81**	**76**	**76**	**73**	**75**	**76**	**75**	**76**	**73**	**79**	**77**	**75**	**78**
ECOLOGICAL CATEGORY	**B**	**B/C**	**B/C**	**B/C**	**B/C**	**B/C**	**B/C**	**B/C**	**B/C**	**B**	**B/C**	**B/C**	**B/C**

Pres: Present

OVERALL CONFIDENCE

The overall confidence of the study is **medium**. The confidence levels of different components, for present state and future scenarios, as well as an indication of data availability, is summarised below:

Component	Data availability	Confidence in ecological category	
		PES	Future scenarios
Hydrology	M	M	M
Hydrodynamics	M	M	M
Physical habitat	L/M	M	M
Water quality	L/M	L/M	L
Microalgae	M	M	M
Macrophytes	M	M	M
Invertebrates	M	M	M
Fish	L/M	M	L
Birds	M	M	M
Overall confidence		**Medium**	**Medium**

M: Medium; L: Large

ECOLOGICAL SPECIFICATIONS (ECOSPECS)

The EcoSpecs, as well as the Threshold of Potential Concern (TPCs), representative of a Category B (PES/REC) for the Mzimvubu Estuary are as follows:

Component	EcoSpecs	TPCs
Hydrology	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	River inflow distribution patterns differ by more than 5% from that of scenario 53 (i.e. the recommended flow scenario).
Hydrodynamics	Maintain mouth condition and hydrodynamics to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ The mouth of the estuary becomes very constricted or closed. ▪ Changes in tidal amplitude at the tidal gauge of more than 20% from the PES (2017).
Sediment dynamics	Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as to not exceed TPCs for biota (see above).	▪ River inflow distribution patterns (flood components) differ by more than 20% (in terms of magnitude, timing and variability) from that of the PES (2017). ▪ Suspended sediment concentration from river inflow deviates by more than 20% of the sediment load-discharge relationship to be determined as part of baseline studies (PES 2017). ▪ Findings from the bathymetric surveys undertaken as part of a monitoring programme indicate changes in the sedimentation and erosion patterns in the estuary have occurred (± 0.5 m).
	Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates (see above).	▪ The median bed sediment diameter deviates by more than a factor of two from levels to be determined as part of baseline studies (PES 2017). ▪ Sand/mud distribution in middle and upper reaches changes by more than 20% from PES (2017). ▪ Changes in tidal amplitude at the tidal gauge of more than 20% from PES (2017).
Water quality	Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae.	▪ Salinity in the winter months remains low for more than 50% of the time (4 to 6 months): – Lower reaches: < 20 ▪ Salinity in winter months remains low for more than 80% of the time (1 to 2 months): – Lower reaches: < 25 – Middle reaches: < 15
	System variables (pH, dissolved oxygen and transparency) not to exceed TPCs for biota.	▪ River inflow and estuary: – 7.0 < pH > 8.5 – Dissolved Oxygen (DO) less than 6 mg/ℓ – Turbidity (naturally turbid)
	Inorganic nutrient concentrations not to cause exceedance of TPCs for macrophytes and microalgae.	▪ River inflow: – Average Dissolved Inorganic Nitrogen (DIN) > 200 µg/ℓ; Dissolved Inorganic Phosphate (DIP) > 30 µg/ℓ ▪ Estuary: – Average DIN > 150 µg/ℓ; DIP > 20 µg/ℓ

Component	EcoSpecs	TPCs
	Presence of toxic substances not to cause exceedance of TPCs for biota.	▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995). ▪ Substance concentrations in estuarine sediment not to exceed targets as per Western Indian Ocean (WIO) Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Microalgae	Maintain low phytoplankton biomass (average chlorophyll *a* < 20 µg/ℓ or median chlorophyll *a* < 3.5 µg/ℓ) and a diversity of phytoplankton groups (cyanobacteria excluded). Maintain medium intertidal benthic microalgal biomass (median chlorophyll a < 23 mg/m^2).	▪ Observable blooms and scums in the estuary. Consistent high phytoplankton biomass (average chlorophyll a > 20 µg/ℓ or median chlorophyll a > 3.5 µg/ℓ) as a result of high nutrient inputs and increase in water retention. ▪ Presence of cyanobacteria.
Macrophytes	Maintain the diversity of macrophyte habitats in the estuary. Reeds and sedges covering approximately 16 ha. Prevent further disturbance and development of the floodplain habitat	▪ Sedimentation in main channel and colonisation by vegetation. 50% loss of reed and sedge habitats in non-flood year due to salinity changes. No increase in invasive species in riparian zone.
Invertebrates	The low-diversity invertebrate community should have representatives of the original freshwater, opportunistic taxa.	▪ The invertebrate community is structured by the physico-chemical drivers of the system, more specifically the periodic high flow levels which result in periods of low salinities and sediment instability that are inimical to the expansion of a benthic community. ▪ The channel-like nature of the estuary results in very few intertidal areas while the edges, especially amongst the reed beds, are characterised by soft sediments that support only suitably specialised species.
Fish	▪ The lower reaches (zone) in its entirety acts as a nursery to a diversity of estuarine dependence category IIa (Whitfield, 1998) species. ▪ The middle reaches of the estuary are used as a nursery to the same species during the low flow period and over the months June – October, for 4 out of 5 years on average. ▪ A good trophic basis exists for predatory estuarine dependant marine species (most notably *Agyrosomus japonicus* and *Pomadasys commersonnii*) ▪ Estuarine resident species represented by core group (*Glossogobius* spp., *Oligolepis* spp. *Ambassis* spp. and *Gilchistella aestuaria*). The upper reaches of the estuary are	▪ An abundance (to be defined as an average with prediction limits) of estuarine dependence category IIa species as young juveniles in winter and spring and early summer (*Solea bleekeri*, *Acanthopagrus vagus*, *Pomadasys commersonnii*, *Agyrosomus japonicus*, *Rhabdosargus holubi*) ▪ Mullet occur throughout the system, throughout the year, represented by a full array of size classes. ▪ Any one of these species does not occur in the estuary in two consecutive years. ▪ *Oreochromis mossambicus* distribution extends into the lower reaches of the estuary for more than two consecutive years. ▪ Alien fish species occur. ▪ A decline in catches (*Agyrosomus japonicus* or *Pomadasys commersonnii*) (not related to gear changes or bag limit restrictions). Estuarine-dependent marine species occurring abundantly in the upper reaches.

Component	EcoSpecs	TPCs
	used by these species as well. ▪ *Oreochromis mossambicus* limited to the lower reaches of middle zone in the low flow period for most of the time. ▪ Species assemblage comprises indigenous species only. ▪ Connectivity to healthy transitional marine-estuarine waters (the offshore estuary) is maintained. Connectivity down the full length of the estuary and into the marine environment is maintained.	
Birds	The estuary should contain an avifaunal community that includes representatives of all the original groups. Tern roosts should be seen from time to time.	▪ Number of waterbird species recorded per count drops below 10 for 3 consecutive seasons. ▪ Summer numbers of waterbirds other than gulls and terns drop below 50 for 3 consecutive seasons. ▪ Once enough winter counts have been made, an appropriate winter threshold will need to be identified.

BASELINE SURVEYS

Additional baseline studies that are important to the improvement of the confidence of the EWR study for the estuary, are as follows: **Note that a monitoring programme will be outlined in the Monitoring and Implementation Report (Report no. WE/WMA7/00/CON/CLA/0418) for the study.**

Component	Action	Temporal scale (frequency and when)	Spatial scale (stations)
Hydrology	Freshwater inflow	Continuous	Station added to DWS water quality (WQ) monitoring network closer to head of estuary, 15 km from mouth.
Hydrodynamics	Record water levels in estuary	Continuous	As close to estuary mouth as possible to capture tidal rise and fall – currently on road bridge and sufficient for needs.
	Aerial photographs of estuary (spring low tide)	Bi-annual	Low spring tide during winter and summer.
Sediment dynamics	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but more detailed in the mouth (every 100 m). The vertical accuracy should be about 5 cm.	Every 3 years	Entire estuary.

Component	Action	Temporal scale (frequency and when)	Spatial scale (stations)
	Set sediment grab samples (at cross-section profiles) for analysis of particle-size distribution and origin (i.e. using microscopic observations).	Every 3 years	Entire estuary.
Water quality	Electrical conductivity, pH, inorganic nutrients and organic content (e.g. TP and Kjeldahl N) in river inflow *(preferably also suspended solids and temperature).*	Monthly	Station added to DWS WQ monitoring network closer to head of estuary, 15 km from mouth.
	2 in situ salinity and temperature recoders	Continuous	Lower and middle reaches.
	Salinity and temperature profiles (surface to bottom) (and any other in situ measurements possible, e.g. pH, DO, turbidity).	Once during high flow and low flow season	At selected stations.
	Total suspended solids and inorganic nutrient concentrations in surface and bottom waters (together with above).	Once during high flow and low flow season	Along entire length of estuary in deepest areas (6–10 stations).
	Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – see Newman and Watling, 2007).	Once-off	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae	Phytoplankton biomass (using chlorophyll *a* as an index). Determine phytoplankton group structure; diatoms, dinoflagellates, flagellates, chlorophytes and cyanobacteria using Utermohl method. Determine benthic chlorophyll *a* and diatom community structure in the intertidal and subtidal zones.	Once-off during low flow conditions; < 3 m^3/s.	At least 5 sites along the full salinity gradient (estuary mouth to fresh upper reaches (< 1 PSU).
Macrophytes	No additional baseline surveys required		
Invertebrates	Record benthic invertebrate species and abundance, based on subtidal grab and intertidal core samples at a series of stations along the entire length of the estuary. Include observations of macrocrustacean fauna such as sesarmid crabs and sandprawns (hole counts).	At least three low flow samples	Entire estuary.
Fish	Record species and abundance of fish, based on seine-net and gill-net sampling. The data will establish baselines and provide a measure of natural variability. They should be based on replicate sampling of stations and wet and dry seasons. Sampling during floods and freshettes should be avoided (and discounted in the baseline data set*).* In situ physico-chemical measurements should be made of temperature, salinity, turbidity, dissolved oxygen and pH throughout the water column concurrent with fish sampling. Some focus should be given to sampling habitats for freshwater fish species using dip-nets (and possibly electroshocking) in vegetated (or elsewise structured) habitats.	Early winter, late winter, spring (i.e. 3 surveys annually) every year for 3 years	Entire estuary (minimum 12 stations, replicate hauls and sets at each).

Component	Action	Temporal scale (frequency and when)	Spatial scale (stations)
Birds	Count all the waterbirds on the estuary.	Every summer and winter	Counts should be divided into upper, middle and lower estuary.

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LIST OF ACRONYMS

BAS	Best Attainable State
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphate
DO	Dissolved Oxygen
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation (name change from DWAF after March 2014)
EC	Ecological Category
EcoSpecs	Ecological Specifications
EFZ	Estuarine Functional Zone
EHI	Estuarine Health Index
EIA	Environmental Impact Assessment
EWR	Ecological Water Requirement
MAR	Mean Annual Runoff
MCM	million m^3 (million cubic metres)
MSL	Mean Sea Level
MWP	Mzimvubu Water Project
NMU	Nelson Mandela University
NBA	National Biodiversity Assessment
NTU	Nephelometric Turbidity Units
PES	Present Ecological Status (or State)
REC	Recommended Ecological Category
REI	River Estuary Interface
RQOs	Resource Quality Objectives
SA	South Africa
SANBI	South African National Biodiversity Institute
TEC	Target Ecological Category
TPC	Threshold of Potential Concern
UNEP	United Nations Environmental Programme
WIO	Western Indian Ocean
WMA	Water Management Area
WQ	Water Quality
WWTW	Waste Water Treatment Works
%ILE	Percentile

GLOSSARY

Abundance	The total number of individuals of an animal group in an area.
Anthropogenic	Originated from human activities, e.g. contaminated urban stormwater is an anthropogenic source of pollution to the sea.
Benthic invertebrates	Invertebrate organisms living in or on sediments of aquatic habitats and typically retained by a 500 micron sieve. Benthic refers to ‘bottom-dwelling’.
Biodiversity	The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems.
Biomass	The mass of living matter, including stored food, in terms of a given area or volume of habitat.
Catchment	In relation to a watercourse or watercourses or part of a watercourse, this term means the area from which any runoff will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points.
Community	Assemblage of organisms characterised by a distinctive combination of species that occupy a common environment and interact with one another. All taxa, plants and animals, present in a community composition.
Contact recreation	Refers to activities such as swimming, diving (scuba and snorkelling), water skiing, surfing, paddle skiing, windsurfing, kite-surfing, parasailing and wet biking. During these activities full body contact with the water and ingestion of water is likely to occur frequently. Tidal pools are also classified as contact recreation sites.
Cumulative impact	Impact on the environment which results from the incremental or combined effects of one or more developmental activities in a specified area over a particular time period, which may occur simultaneously, sequentially, or in an interactive manner.
EcoClassification	EcoClassification (or the Ecological Classification process) refers to the determination and categorisation of the Present Ecological State or Status (PES; health or integrity) of various physical attributes of water resources relative to the natural reference condition.
Ecological Water Requirements (EWR)	The flow patterns (magnitude, timing and duration) and water quality of river inflow needed to maintain a water resource ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.

Filter feeder	An organism that uses complex filtering mechanisms to trap food particles suspended in water, e.g. mussels and oysters.
Intertidal	Area of the shore between the highest and lowest tides.
Invasive species	A species whose introduction into a previously unoccupied area has or is likely to cause economic or environmental harm or harm to human health.
Macrophyte	Macroscopic plant life especially of a body of water.
Microalgae	Microscopic algae, typically found in freshwater, estuarine and marine systems living in both the water column and sediment.
Phytoplankton	Free-floating, unicellular plant life.
Present Ecological State or Status (PES)	The current state or condition of a water resource in terms of its biophysical components (drivers) such as hydrology, geomorphology and water quality and biological responses in terms of microalgale, macrophytes, fish, invertebrates and birds). The degree to which ecological conditions of an area have been modified from natural (reference) conditions.
Recommended Ecological Category (REC)	The Recommended Ecological Category is the future ecological state (Ecological Categories A to D) that can be recommended depending on the PES and Importance. The REC is determined based on ecological criteria and considers the importance, the restoration potential of the system and attainability thereof.
Runoff	Runoff is the water yield from an individual catchment – the sub-catchment plus the runoff from all upstream sub-catchments. Runoff includes any seepage, environmental flow releases and overflows from reservoirs in a catchment, if they are present – which is not the case in any of the simulations in this project in which baseline catchment conditions are assumed.
Submerged	Covered by water.
Sub-tidal	Area of water body always covered by water and never exposed at low tides
.	
Supratidal	Area above the spring high tide line on coastlines and estuaries that is regularly splashed but not submerged by ocean water.
Wastewater	Water containing solid, suspended or dissolved material (including sediment) in such volumes, composition or manner that, if spilled or deposited in the natural environment, will cause, or is reasonably likely to cause, a negative impact.
Zooplankton	Plankton composed of animals.

1 INTRODUCTION

1.1 BACKGROUND

The Department of Water and Sanitation (DWS) initiated a study to determine Water Resource Classes and associated Resource Quality Objectives (RQOs) for the Mzimvubu catchment in Water Management Area 7 (WMA 7) with a focus on the Mzimvubu Estuary. A preliminary reserve determination at an intermediate level was done on this estuary in 2014 (DWS, 2014a and 2014b). Results from the 2014 Reserve study therefore inform this Classification study. For the estuary component the following was undertaken:

- Assess consequences of future development scenarios for the Mzimvubu Estuary, building on the results from the previous EWR study (DWS, 2014a and 2014b) and prepare a Scenario Consequences Report.
- Define RQOs for the Recommended Ecological Category (REC)/Target Ecological Category (TEC) – to be defined in the RQO Report for the study.
- Define implementation and monitoring requirements as pertaining to the Mzimvubu Estuary – to be reported in the Monitoring and Implementation Report for the study.

This report confirms the Present Ecological Status (PES) and REC allocated to the estuary in 2014, as well as the ecological consequences of the scenarios provided for this Classification study. Also included is the Ecological Specification (EcoSpecs) for the PES and REC. Once a TEC has been allocated to the estuary, RQOs will be confirmed for that category, based on the EcoSpecs provided here, or an amendment thereof.

1.2 ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations should be taken into account:

- The accuracy and confidence of an Estuarine EWR study is strongly dependant on the quality of the simulated hydrology. The overall confidence in the hydrology supplied is of a medium level (60–80%).
- A detailed flood analysis was not conducted as it is not a requirement of an Intermediate level assessment. The simulated runoff data were used to estimate flood conditions.
- Accurate inflow data were not available at the head of the estuary to allow for a good correlation between mouth state and salinity distribution patterns.
- An Intermediate level assessment is suitable for individual licensing in relatively unstressed catchments, but a comprehensive level assessment is required for individual licensing for large impacts in any catchment (e.g. dams), as well as small or large impacts in very important and/or sensitive catchments (DWAF, 2008).

1.3 EWR METHODS FOR ESTUARIES

The EWR assessment has been conducted as per the official methods for estuaries (DWAF 2008, as amended in DWA, 2012). The official method for estuaries (Version 2) is documented in DWAF (2008). A Version 3 of the method has been published as part of a Water Research Commission project (DWA, 2012). Pending the official approval by the DWS, Version 2 has been applied in this study (DWAF, 2008), with due consideration of obvious improvements proposed in Version 3.

The generic steps of the EWR methods for estuaries include:

Step 1: Initiate study by defining the study area, project team and level of study (see DWS, 2016a, **Inception Report** for this study).

Step 2: Delineate the geographical boundaries of the resource units (see DWS, 2016b, **Delineation Report** for this study).

Step 3a: Determine the **Present Ecological Status** (PES) of resource health (water quantity, water quality, habitat and biota) assessed in terms of the degree of similarity to the reference condition (referring to natural, un-impacted characteristics of a water resource, and must represent a stable baseline based on expert judgement in conjunction with local knowledge and historical data). An Estuarine Health Index (EHI) is used (see **Section 5**).

The EHI score, in turn, corresponds to an ecological category that describes the health using six categories, ranging from natural (A) to critically modified (F) (**Table 1.1**). The A to F scale represents a continuum, where the boundaries between categories are conceptual points along the continuum. To reflect this, straddling categories (+/- 3 from the category scoring range) were therefore introduced in this study, denoted by A/B, B/C, C/D, and so on.

Table 1.1 Translation of EHI scores into ecological categories

EHI score	Category	General description
91 – 100	A	**Unmodified**, or approximates natural condition; the natural abiotic template should not be modified. The characteristics of the resource should be determined by unmodified natural disturbance regimes. There should be no human-induced risks to the abiotic and biotic maintenance of the resource. The supply capacity of the resource will not be used.
76 – 90	B	**Largely natural with few modifications.** A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged. Only a small amount of modifying the natural abiotic template and exceeding the resource base should not be allowed. Although the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a very limited number of localities may be slightly higher than expected under natural conditions, the resilience and adaptability of biota must not be compromised. The impact of acute disturbances must be totally mitigated by the presence of sufficient refuge areas.
61 – 75	C	**Moderately modified.** A loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. A moderate risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the wellbeing and survival of intolerant biota (depending on the nature of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities. However, the impact of local and acute disturbances must at least be partly mitigated by the presence of sufficient refuge areas.

EHI score	Category	General description
41 – 60	D	**Largely modified**. A large loss of natural habitat, biota and basic ecosystem functions has occurred. Large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risk to the well-being and survival of intolerant biota (depending on the nature of the disturbance) may be allowed to generally increase substantially with resulting low abundances and frequency of occurrence, and a reduction of resilience and adaptability at a large number of localities. However, the associated increase in the abundance of tolerant species must not be allowed to assume pest proportions. The impact of local and acute disturbances must at least to some extent be mitigated by refuge areas.
21 – 40	E	**Seriously modified.** The loss of natural habitat, biota and basic ecosystem functions is extensive.
0 – 20	F	**Critically modified.** Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

Step 3b: Determine the **Ecological Importance** that takes into account the size, the rarity of the estuary type within its biogeographical zone, habitat, biodiversity and functional importance of the estuary. An **Estuarine Ecological Importance Rating Index** is used (see **Section 4**).

Step 3c: Set the **Recommended Ecological Category (REC)** which is derived from the PES and Ecological Importance (or the protection status allocated to a specific estuary) (see **Section 7**).

Step 4: **Quantify the Ecological Consequences of various runoff scenarios** (including proposed operational scenarios) where the predicted future condition of the estuary is assessed under each scenario. As with the determination of the PES, the EHI is used to assess the predicted condition in terms of the degree of similarity to the reference condition (**Section 6**).

Step 5: Quantify the (recommended) **Ecological Water Requirements** which represent the lowest flow scenario that will maintain the resource in the REC (**Section 7**).

Step 6: **EcoSpecs** for the recommended REC, as well as **additional baseline and long-term monitoring requirements** to improve the confidence of the EWR and to test compliance with EcoSpecs (**Section 7** and subsequent reports).

The level of available historical data in combination with the level of fieldwork executed during the assessment determines the level of confidence of the study. Criteria for the confidence limits attached to statements in this study are:

Confidence level	Situation	Expressed as percentage
Very low	No data available for the estuary or similar estuaries	(i.e. < 40% certain)
Low	Limited data available	40 – 60% certainty
Medium	Reasonable data available	60 – 80% certainty
High	Good data available	> 80% certainty

1.4 SPECIALIST TEAM

The following specialists comprised the study team:

Specialist	Affiliation	Area of responsibility
Dr S Taljaard	CSIR, Stellenbosch	Coordinator/Water quality
Ms L van Niekerk	CSIR, Stellenbosch	Physical dynamics
Dr G Snow	University of Witwatersrand	Microalgae
Prof J Adams	Nelson Mandela University (NMU)	Macrophytes
Ms N Forbes	Marine and Estuarine Research (MER)	Invertebrates
Mr S Weerts	CSIR, Durban	Fish
Dr J Turpie	Anchor Environmental Consultants	Birds

1.5 STRUCTURE OF THIS REPORT

The report is structured as follows:

Section 1 provides an overview of EWR methods, confidence of the study and study team.

Section 2 provides background information on the catchment, as well as human activities (pressures) potentially impacting on the estuary.

Section 3 defines the geographical boundaries of the study area, as well as the zoning and typical abiotic states adopted for this estuary.

Section 4 addresses the ecological importance of the estuary.

Section 5 provides an assessment of the PES. It also summarises the overall confidence of the study and the degree to which non-flow factors have contributed to any degradation of the system.

Section 6 describes the ecological consequences of various future flow scenarios, and determines the ecological category for each of these using the EHI.

Section 7 concludes with recommendations on the REC, the ecological water requirements for the REC and recommended Ecological Specifications (EcoSpecs). Finally, additional baseline studies to improve the confidence of the EWR assessment are provided.

Appendices include:

Appendix A Detailed simulated runoff scenarios.

Appendix B Summary of hydrodynamic and water quality characteristics for abiotic states (extracted from DWS, 2014a).

2 BACKGROUND INFORMATION

2.1 CATCHMENT CHARACTERISTICS AND LAND USE

The Mzimvubu River system rises in the Drakensberg and has a catchment area of about 19 925 km^2 which is located in a summer rainfall area. Much of the catchment lies in communal land areas of the former Transkei, and has been historically overgrazed, such that summer floods carry heavy loads of silt **(Figure 2.1)**. The lower part of the catchment runs through a gorge of Table Mountain sandstone which is vegetated with indigenous forest (DWS, 2014a).

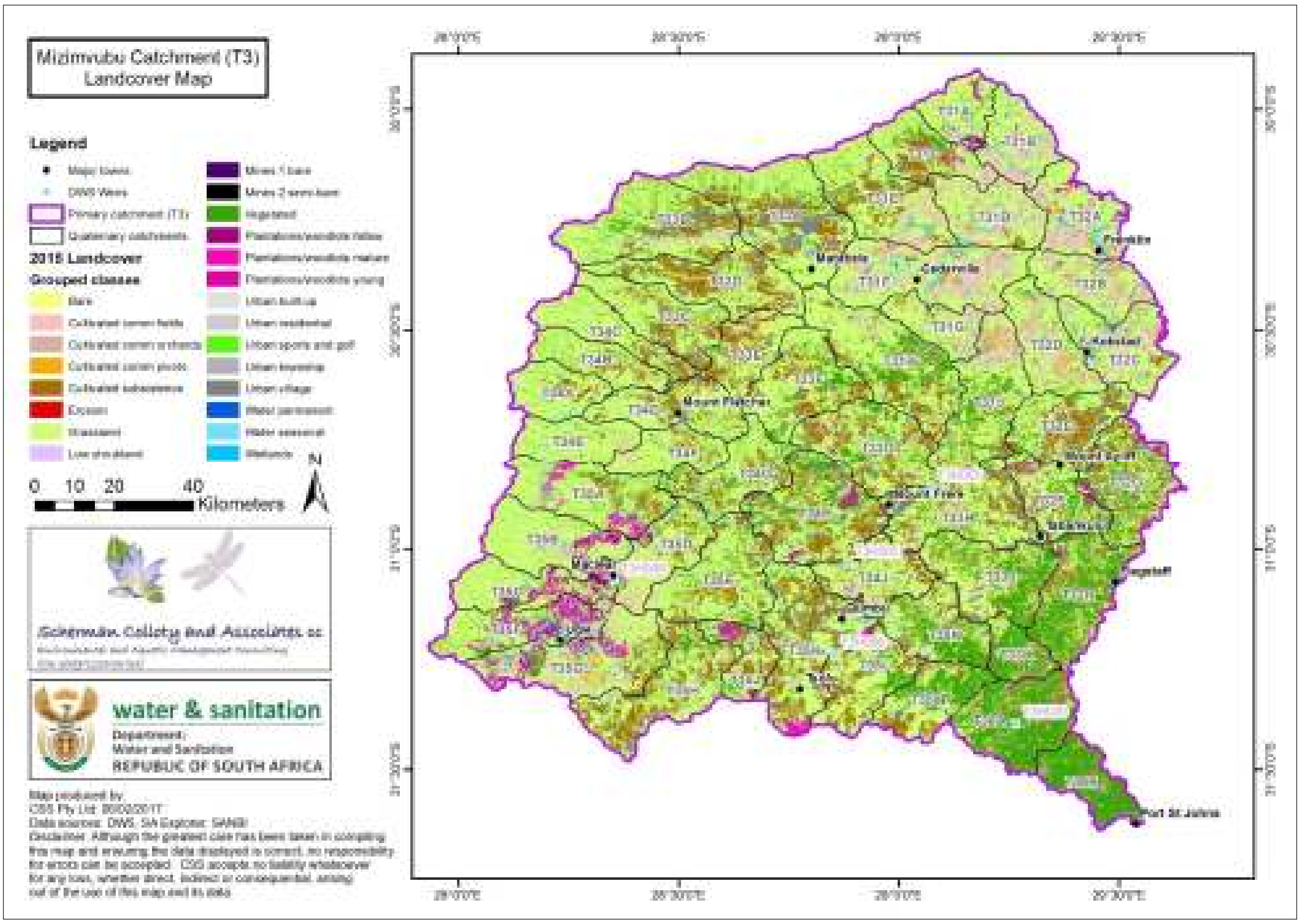


Figure 2.1 Catchment of the Mzimvubu River, as well as dominant land-use distribution

2.2 HUMAN ACTIVITIES (PRESSURES) AFFECTING THE ESTUARY

Human activities affecting the estuary relating to flow modification and non-flow related pressures are briefly summarised in **Tables 2.1** and **2.2**, respectively.

Table 2.1 Pressures related to flow modification

Activity	Presence	Description of impact
Water abstraction and dams (including farm dams)	✓	Limited water abstraction, but no large dams.
Augmentation/Inter-basin transfer schemes	–	
Infestation by invasive alien plants	✓	Invasive alien plants located within catchment and EFZ increase water demand and reduce water volumes to the estuary.

Table 2.2 Pressures, other than modification of river inflow presently affecting estuary

Activity	Presence	Description of impact
Agricultural and pastoral runoff containing silt, fertilisers, pesticides and herbicides	✓	Communal land areas of the former Transkei historically overgrazed.
Municipal waste (including sewage disposal and infrastructure problems)	✓	Pollution risks from canalised creek flowing in from Port St Johns.
Bridge(s) and roads	✓	Access road behind area formerly known as 'First Beach', effectively entrained estuary mouth.
Artificial breaching	–	
Bank stabilisation and destabilisation	–	
Low-lying developments	–	
Migration barrier in river	–	
Recreational fishing	✓	High fishing pressure on system (Source: Lamberth, Department of Agriculture, Forestry and Fisheries (DAFF)).
Commercial/subsistence fishing (e.g. gill-net fishery)	✓	High subsistence fishing pressure on system (Source: Lamberth, DAFF).
Illegal fishing (poaching)	✓	(Source: DAFF)
Bait collection	–	
Grazing and trampling of salt marshes	–	
Translocated and alien fauna and flora	✓	Invasive alien plants located within EFZ (floodplain) reduce water volume as they have lower water use efficiencies than indigenous vegetation.
Recreational disturbance of water birds	✓	

3 DELINEATION OF ESTUARY

3.1 GEOGRAPHICAL BOUNDARIES

The Mzimvubu Estuary (31°37'52” S, 29°32'59” E) falls within the subtropical biogeographical coastal region of South Africa and enters the Indian Ocean at Port St Johns. The boundaries of South Africa’s estuaries incorporate an area known as the estuarine functional zone (EFZ) (Van Niekerk and Turpie, 2012). The estuarine functional zone is defined by the 5 m topographical contour (indicative of 5 m above mean sea level). The estuarine functional zone includes:

- open water area;
- estuarine habitat (sand and mudflats, rock and plant communities); and
- floodplain area.

The 5 m contour boundary has been set to allow the inclusion of estuarine-linked areas and biodiversity components dependent on estuarine processes and has a number of urban and development planning advantages. It allows dynamic areas to be protected as these are important areas responsible for the key physical processes that drive biodiversity in estuaries and along South Africa’s coastline. In most cases, the 5 m contour also allows for the inclusion of a buffer zone of terrestrial vegetation that represents the transition between terrestrial and coastal ecosystems. The official EFZ boundary of the Mzimvubu Estuary as per the national requirement is indicated in **Figure 3.1** (blue), defined by:

Downstream boundary:	31°37'52” S, 29°32'59” E (Estuary mouth)
Upstream boundary:	31°29'7.15" S, 29°22'59.66" E
Lateral boundaries:	5 m contour above mean sea level (MSL) along each bank

Historical references (Day, 1981) suggest an upper boundary of the estuary about 14.5 km upstream from the mouth. It should be noted that the Mzimvubu Estuary mouth may be prone to closure if the river inflow decreases below ~ 1.0 m^3/s.

However, given the nature of the estuary (freshwater-dominated and minimal saline intrusion), the upper limit 5 m contour was not applied. Instead, a modified boundary of the system was applied for the purposes of this assessment which encompasses the major estuarine habitats and estuarine support habitats which are found within the EFZ (**Figure 3.1**, green) which is closely aligned with the historical references.

NOTE: The official EFZ should be adhered to in terms of development under the EIA Regulations

Figure 3.1 Geographical boundaries of the Mzimvubu Estuary based on the official EFZ (blue) and boundaries used in this EWR study (lower part in green)

3.2 ZONING OF MZIMVUBU ESTUARY

For the purposes of this study, the Mzimvubu Estuary was sub-divided into three distinct zones primarily based on bathymetry (**Figure 3.2**):

- Lower Zone: From mouth to 4 km upstream (34% of volume)
- Middle Zone: From 4–10 km upstream (33% of volume)
- Upper Zone: From 10–14 km upstream (33 % of volume)

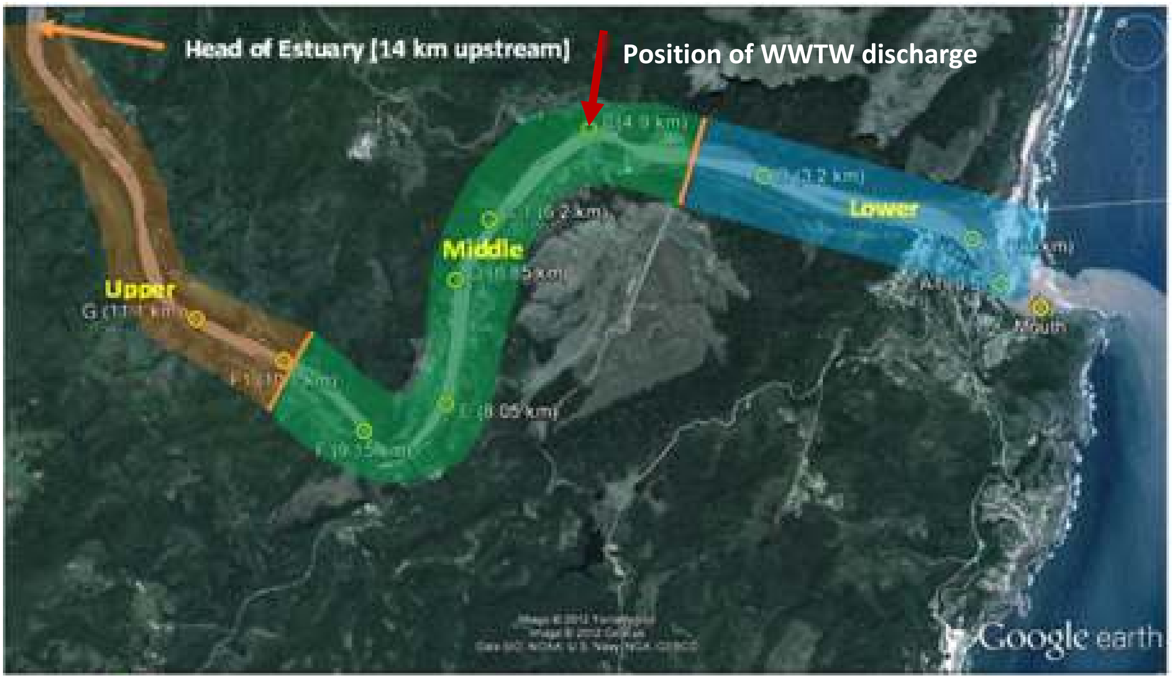


Figure 3.2 Zones identified in the Mzimvubu Estuary

3.3 TYPICAL ABIOTIC STATES ZONING OF MZIMVUBU ESTUARY

As for the 2014 EWR sudy, four typical abiotic states were considered for the Mzimvubu Estuary (**Table 3.1**).

Table 3.1 Typical abiotic states in the Mzimvubu Estuary (DWS, 2014)

Abiotic state	Flow range (m^3/s)
State 1: Significant saline penetration into Lower, Middle and Upper Zones	1–3[1]
State 2: Intermediate saline penetration, into Lower and Middles Zones	3–10
State 3: Limited saline penetration, only in Lower Zone	10–30
State 4: Freshwater dominates, all zones fresh	> 30

The transition between the different states will not be instantaneous, but will take place gradually. To assess the occurrence and duration of the different abiotic states selected for the estuary during the different scenarios, a number of techniques were used:

- Colour coding (indicated above) was used to visually highlight the occurrence of the various abiotic states in the different scenarios.
- Summary tables of the occurrence of different flows at increments of the 10%ile are listed separately to provide a rapid comprehensive overview.

[1] This estuary is classified as a permanently open system, but can close following extended periods of very low base flow. The actual cut-off flows for closure are unknown due to a lack of data, but for the purposes of this study it is assumed to be base flows less than 1 m^3/s. Based on the scenarios provided such a severe reduction in base flows are not expected in future and for this reason the closed state has not been included as a typical abiotic state for this estuary, at least not at this stage.

4 ECOLOGICAL IMPORTANCE

The Ecological Importance takes size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account. Biodiversity importance, in turn is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. These importance scores ideally refer to the system in its **present state**. The scores have been determined for all South African estuaries (Turpie and Clark, 2007), apart from functional importance, which was scored by the specialists in the workshop in the previous EWR study (DWS, 2014a) (refer to **Table 4.1**). The ecological importance rating is presented in **Table 4.2**.

Table 4.1 Estimation of the functional importance score of the Mzimvubu Estuary (DWS, 2014a)

Functionality	Score
a. Estuary: Input of detritus and nutrients generated in estuary	40
b. Nursery function for marine-living fish and crustaceans	100
c. Movement corridor for river invertebrates and fish breeding in sea	80
d. Roosting area for marine or coastal birds	60
e. Catchment detritus, nutrients and sediments to sea	100
Functional importance score – Max (a to e)	**100**

Table 4.2 Ecological importance score for the Mzimvubu Estuary (DWS, 2014a)

Criterion	Weight	Score
Estuary size	15	90
Zonal rarity type	10	30
Habitat diversity	25	90
Biodiversity importance	25	73
Functional importance	25	100
Weighted estuary ecological importance score		**82**

Referring to the estuarine ecological importance rating system (DWAF, 2008), the score of **82** for the Mzimvubu Estuary translates into a rating of **'Highly Important'**.

A number of features contributed to the high importance score of the estuary include (DWS, 2014a):

- Significantly, this is the only WMA not linked to another WMA through cross-catchment transfers and is largely unregulated.
- This catchment has been identified as supplying high levels of ecological services nationally, and SANBI is currently undertaking an assessment of the economic importance of the system. There is confirmed use of the estuary by Zambezi sharks (*Carcharhinus leucas*) as a pupping/nursery ground, and as a nursery for white steenbras (*Lithognathus lithognathus*) and dusky kob (*Argyrosomus japonicus*). The latter two species are of conservation and fisheries concern and there is highly limited available nursery habitat for these species in South Africa.
- The estuary plays a significant role in the delivery of sediments and nutrients/detritus to the marine environment, elevating its importance in geological terms to the local beaches and marine environments.

The system is also designated as a priority estuary in need of protection to meet South Africa's biodiversity targets in the National Estuaries Biodiversity Plan (National Biodiversity Assessment (NBA) 2011) (Turpie et al., 2012).

5 PRESENT ECOLOGICAL STATUS

The PES of an estuary is assessed in terms of the degree of similarity to reference conditions. The Estuarine Health Index is used to determine the PES and corresponds to an ecological category that describes the health using six categories, ranging from natural (A) to critically modified (F) (**Table 1.1**). As per the EHI the different components assessed are:

- Abiotic components: Hydrology, physical habitat, hydrodynamics and water quality.
- Biotic components: Microalgae, macrophytes, invertebrates, fish and birds.

Specialist studies that provide important background information on the various components were conducted and documented as part of the 2014 Estuary Reserve/EWR study of the Feasibility Study (DWS, 2014b). In the following sections the criteria leading to the PES for the Mzimvubu Estuary are summarised, based primarily, unless otherwise stated, on the 2014 EWR Study (DWS, 2014b).

5.1 HYDROLOGY

According to the hydrological data provided for this study, the present Mean Annual Runoff (MAR) into the Mzimvubu Estuary is 2 613.5 million m^3 or MCM. This is a decrease of 4.5% compared to the natural MAR of 2 737.0 MCM. The flow distributions (expressed as mean monthly flows in m^3/s) for the reference condition and present state, as derived from a 85-year simulated data set, are provided in **Tables 5.1** and 5.**2**, respectively. The full 85-year simulated monthly runoff data for the reference condition and present state is provided in **Appendix A**.

Table 5.1 Summary of the monthly flow distribution (in m^3/s) for the reference condition

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
100	335	480	504	621	676	971	556	401	305	336	165	815
99	295	441	436	607	633	719	392	244	303	257	154	304
95	162	319	362	504	549	531	273	87	90	112	76	96
90	102	205	263	340	513	401	181	71	53	43	57	74
85	87	145	226	237	410	291	137	66	43	37	36	41
80	63	110	195	198	301	281	124	56	35	31	28	36
70	48	78	147	157	246	226	112	39	25	25	22	25
60	37	62	82	127	174	176	85	30	21	19	17	21
50	26	49	63	95	135	151	69	27	18	15	15	17
40	23	40	41	73	104	120	56	22	15	13	13	15
30	20	31	36	65	84	89	44	19	13	12	11	12
20	16	22	27	48	60	66	39	16	12	11	10	10
15	14	20	22	42	55	63	33	15	11	10	9	10
10	13	18	20	32	49	54	28	14	10	9	9	9
5	10	15	13	19	38	46	18	13	9	9	8	8
1	8	13	7	12	18	19	10	10	9	7	7	7

Table 5.2 Summary of the monthly flow distribution (in m^3/s) for the present state

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	328	466	488	609	667	964	548	393	298	327	159	801
99	286	427	423	597	621	708	386	238	295	250	148	296
95	156	310	349	492	540	524	266	84	87	107	71	90
90	97	197	256	330	504	393	176	68	50	40	54	70
85	83	139	218	229	403	283	132	63	40	34	32	37
80	59	105	187	192	291	278	121	53	32	28	25	32
70	44	74	141	151	239	221	107	36	22	22	19	21
60	34	58	78	121	168	170	81	27	19	17	15	18
50	24	46	60	89	130	146	66	24	15	12	12	14
40	20	37	37	68	100	116	53	20	12	11	10	13
30	17	28	34	61	80	87	41	16	10	9	9	9
20	13	20	25	45	56	63	36	14	10	8	7	7
15	12	18	20	39	52	60	30	13	9	7	7	7
10	10	16	17	29	46	52	26	12	8	7	6	6
5	8	13	10	17	36	44	16	11	7	6	6	5
1	6	11	6	11	16	18	9	8	7	5	5	4

A graphic representation of the occurrence of the various abiotic states for the reference condition and present state is presented in **Figures 5.1** and **5.2**.

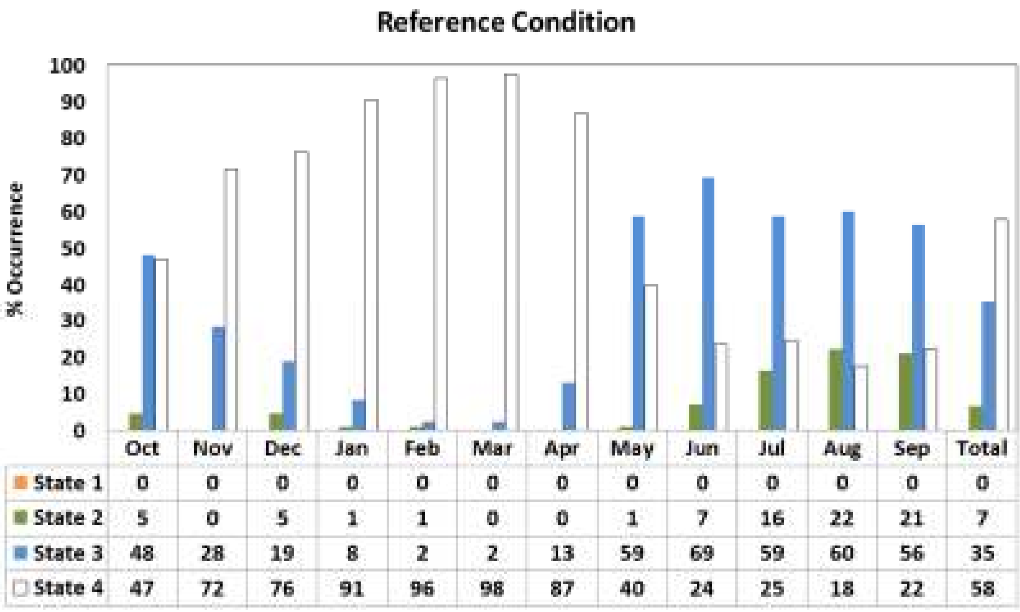
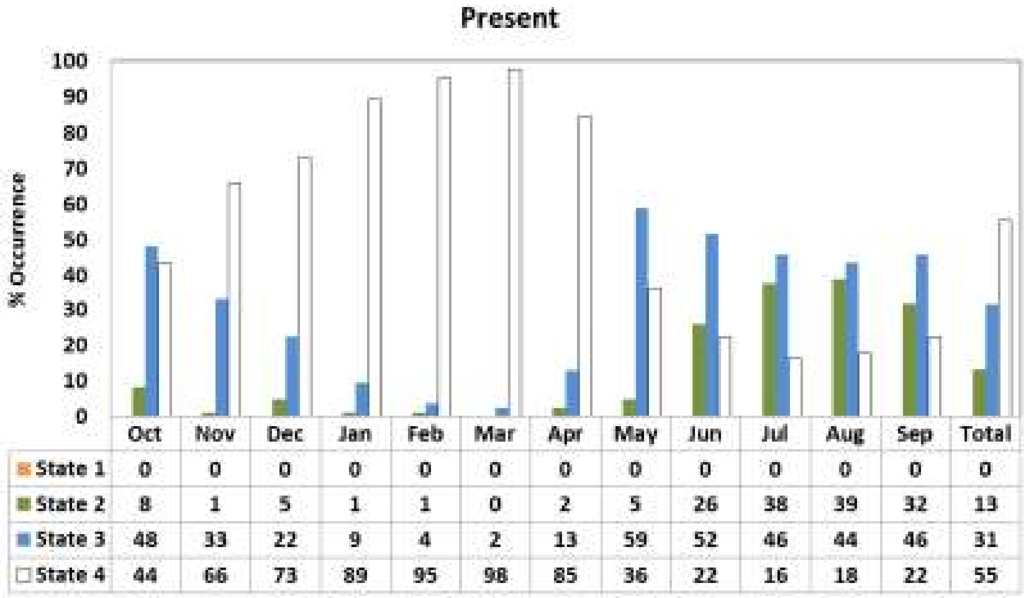


Figure 5.1 Occurrence of abiotic states under the reference condition



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	8	1	5	1	1	0	2	5	26	38	39	32	13
State 3	48	33	22	9	4	2	13	59	52	46	44	46	31
State 4	44	66	73	89	95	98	85	36	22	16	18	22	55

Figure 5.2 Occurrence of abiotic states under the present state

Table 5.3 provides present hydrological health scores of the Mzimvubu Estuary (detailed reference condition and present health assessment is documented in DWS, 2014a and 2014b). Low flows (also called base flows) were taken as the flow range that is exceeded for 70% or more of the time. The average change in the 10, 20 and 30 percentile was taken as change in the low flows to the estuary.

Table 5.3 Present hydrological health scores

Variable		Summary of change	Weight	Score	Conf.
a	% Similarity in period of low flows	Average change in low flows (derived from the 30, 20 and 10 percentile) from present to present.	60	83	M
b	% Similarity in mean annual frequency of floods	Very little water resource development has occurred in this catchment. Most change due to land use and small dam development.	40	98	M
Score: weighted mean (a,b)				**89**	**M**

Conf.: Confidence

5.2 PHYSICAL DYNAMICS

Details on the reference condition and present state change in physical habitat are documented in DWS (2014a). **Table 5.4** provides the present physical habitat health scores of the Mzimvubu Estuary (detailed reference condition and present health assessment is documented in DWS, 2014a and 2014b).

Table 5.4 Present physical habitat scores, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow related effects

Variable		Summary of change	Score	Conf.
a	Supratidal area and sediments	Similar to reference, some loss of supratidal area due to road and infilling around bridge.	95	M
b	Intertidal areas and sediments	Similar to reference, maybe very slightly more muddy and slight loss of intertidal area due to road and infilling around bridge.	95	M
c	Subtidal area and sediments	Similar to reference, maybe slightly more muddy.	90	M
d	Estuary bathymetry/water volume	Similar to reference, some changes due to infilling around bridge.	95	M
Score: mean (a to d)			**94**	**M**

5.3 HYDRODYNAMICS AND MOUTH CONDITION

A summary of the hydrodynamic characteristics of the Mzimvubu Estuary under various abiotic states (**Table 3.1**) is provided in **Appendix B** (detailed present health assessment is documented in DWS, 2014a and 2014b). Percentage occurrence of various abiotic states under reference condition and present state is summarised in **Table 5.5**.

Table 5.5 Summary of occurrence of abiotic states under the reference condition and present state

Abiotic state	Reference	Present
State 1: Significant saline penetration	0	0
State 2: Intermediate saline penetration	7	13
State 3: Limited saline penetration	35	32
State 4: Freshwater dominates	58	55

Table 5.6 provides the hydrodynamic and mouth condition health score for the estuary (detailed reference condition and present health assessment is documented in DWS, 2014a).

Table 5.6 Present hydrodynamic and mouth state health scores, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow-related effects

Variable		Summary of change	Score	Conf.
a	% similarity in mouth condition	Remains permanently open estuary.	100	H
b	% similarity in water retention time	Slight increase in retention due to decrease in base flows.	95	L
Score: mean (a, b)			**98**	**M**

5.4 WATER QUALITY

A summary of the water quality conditions in the Mzimvubu Estuary under various abiotic states (**Table 3.1**) is provided in **Appendix B**. The similarity in each water quality parameter to reference conditions was scored as follows:

- Define zones along the length of the estuary (Z) (i.e. zones A, B, C and D).
- Volume fraction of each zone (V) (i.e. A = 0.25, B = 0.35; C= 0.30; D = 0.10).

- Different abiotic states (S) (i.e. states 1 to 5).
- Define the flow scenarios (i.e. reference, present, future scenarios).
- Determine the % occurrence of abiotic states for each scenario.
- Define WQ concentration range (C) (e.g. 6 mg/ℓ; 4 mg/ℓ; 2 mg/ℓ).

Similarity between reference condition and present state was calculated as follows:

- Calculate average concentration for each zone for reference condition and present state, respectively.
- Average Conc = [({∑% occurrence of states in C1}*C1)+ ({∑% occurrence of states in C2}*C2)+({∑% occurrence of states in Cn}*Cn)] divided by 100.
- Calculate similarity between average concentrations for reference condition and present state for each zone using the adapted Czekanowski's similarity index: min(ref,pres)/mean(ref,pres).
- Calculate overall similarity score for water quality parameter using volume fraction weighted means of all zones.

For the present day health scores, a weighted average of the similarity scores of changes in the different zones is presented in **Table 5.7** (detailed reference condition and present health assessment is documented in DWS (2014a; 2014b)).

Table 5.7 Present water quality health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow-related effects

Variable		Summary of change	Weight	Score	Conf.
1	**Salinity**	Increased salinity due to decrease in base flow	40	88	L/M
2	**Other water quality**				
a	DIN/DIP concentrations	Increased nutrient input from diffuse sources in the catchment, mainly settlements and cattle herds	60	67	L/M
b	Turbidity	Limited erosion as a result of catchment practices. However, this catchment naturally introduced turbid waters to the estuary		98	L/M
c	Dissolved oxygen	No marked changes		100	L/M
d	Toxic substances	Some accumulation (e.g. trace metals) associated with urban development along banks of estuary		90	L
Score: weighted mean (1 and 2 [min a-d])				**75**	**L/M**

Conf.: Confidence; L: Low; M: Medium

5.5 MICROALGAE

Details on the reference condition and present state changes in microalgae in the Mzimvubu Estuary are documented in DWS (2014a). The microalgae health scores for the present state are summarised in **Table 5.8** (detailed reference condition and present health assessment is documented in DWS, 2014a and 2014b).

Table 5.8 Present microalgae health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow-related effects

Variable		Summary of change	Score	Conf.
Phytoplankton				
a	Species richness	It is likely that the reduction in river flow and increase in nutrients has increased the chlorophytes and flagellates to similar density as the diatoms. Conditions also favour some dinoflagellates becoming established. As a result, there has been an estimated **30%** increase in species richness (based on evenness of phytoplankton groups).	70	M
b	Abundance	Based on the water quality, it was calculated there would have been a **28%** increase in biomass from the reference state. The intrusion of nutrient-rich seawater would have supported a medium level of biomass in the deeper waters in the lower reaches of the estuary.	72	M
c	Community composition	The phytoplankton at present was dominated by flagellates, diatoms and chlorophytes with few dinoflagellates at normal flow. Cell density would have been much lower during the reference condition and dominated by diatoms with very few cells from the other groups. It is likely that flagellates, diatoms and chlorophytes were present during the reference condition, but conditions favouring the establishment of an REI zone, with associated dinoflagellates would not have occurred as frequently as at present. Expect a **35%** change from reference.	65	M
Benthic microalgae				
a	Species richness	There has been only a slight decrease in river flow and flood events so it is unlikely that there was a change in species richness associated with river flow. The slight increase in muddiness and elevated nutrients favours the growth of epipelic taxa (those growing on fines), particularly those adapted to more eutrophic conditions (15% increase).	85	M
b	Abundance	The muddiness of the estuary has increased slightly (5%) and nutrients – particularly in the lower reaches near Port St Johns – have increased (DIN 54% and DIP 48%) supporting an increase in biomass. However, river flow and the frequency of floods have only decreased slightly from natural (4% and 5% respectively); the benthos is an unstable environment limiting microalgal growth.	83	M
c	Community composition	There has been only a slight decrease in river flow and flood events so it is unlikely that there was a change in species richness associated with river flow. The slight increase in muddiness and elevated nutrients favours the growth of epipelic taxa (those growing on fines), particularly those adapted to more eutrophic conditions (15% increase).	85	M
Score: min (a to c)			**65**	**M**

Conf.: Confidence; M: Medium

5.6 MACROPHYTES

A summary of the macrophyte health scores for the present state is provided in **Table 5.9** (detailed reference condition and present health assessment is documented in DWS, 2014a and 2014b).

Table 5.9 Present macrophyte health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow-related effects

Variable		Summary of change	Score	Conf.
a	Species richness	Invasive species potentially displaced some species. Species have been lost because of the less dynamic environment.	85	M
b	Abundance	There has also been a loss of reed, sedge and floodplain habitat due to development and disturbance. In the reference condition macrophytes would cover 81 ha, now they cover 51 ha which represents a 37% loss of habitat. There has been some increase in nutrients and sediment input resulting in localised increases in reeds and sedges.	63	M
c	Community composition	Invasive species have altered the community composition as well as development in the floodplain.	66	M
Score: min (a to c)			**63**	**M**

Conf.: Confidence; M: Medium

5.7 INVERTEBRATES

The invertebrate health scores for the present state are summarised in **Table 5.10** (detailed present health assessment is documented in DWS, 2014a and 2014b).

Table 5.10 Present invertebrate health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow-related effects

Variable		Summary of change	Score	Conf.
Zooplankton				
a	Species richness	Historical descriptions going back 150 years indicate little if any change in the estuarine environment and it is equally unlikely that species richness has been reduced.	95	M
b	Abundance	It is assumed that abundance may have been reduced slightly due to a slight change in subtidal habitat.	95	M
c	Community composition	Based on the comments already made there is no indication and no compelling reason to propose a significant change in the community composition.	95	M
Benthic macro-invertebrates				
a	Species richness	Historical descriptions going back 150 years indicate little if any change in the estuarine environment. While some habitat reduction may have occurred through localised infilling it is highly unlikely that any habitat within the estuary has been totally lost or significantly compromised and consequently it is equally unlikely that species richness has been reduced.	95	M
b	Abundance	It is assumed that abundance may have been reduced slightly due to a slight change in sediments with an increase in fine sediments and some loss of intertidal and subtidal habitat (5%).	95	M
c	Community composition	Based on the comments already made in the boxes above there is no indication and no compelling reason to propose a significant change in the community composition.	95	M
Score: min (a to c)			**95**	**M**

Conf.: Confidence; M: Medium

5.8 FISH

A summary of the fish health scores for the present state is provided in **Table 5.11.** This score deviates very slightly (+2%) from that of the previous present health assessment as documented in the original assessment (DWS 2014a; 2014b). The reason for this is that the present assessment was based on a method of determination of health scores within individual estuarine zones (upper, middle, lower, **Figure 3.2**) and subsequent aggregation of these zone scores to a single value reflective of the whole estuary. The nature of the Mzimvubu Estuary, under the delineation used for this study, is such that these zones are quite distinct (under present conditions as well as envisaged scenarios) in many aspects. This is reflected in distinct physico-chemistries, fish communities as well as human usage of estuarine resources. The upper reaches of the estuary are freshwater and the fish community here is expected to be dominated by euryhaline species, notably a few estuarine resident fishes (such as *Gilchristella aestuaria*) and hardy freshwater species (*Oreochromis mossambicus*). The lower and (with some temporal variability) the middle reaches are used by a much more diverse fish community. Fishes here occur in higher abundance and there is a much higher number of species. Notably these zones (under states of some salinity penetration) are used by *Pomadasys commersonnii* and *Argyrosomus japonicus* (as well as other Category IIa fishes (sensu Whitfield, 1998). Fishing pressure in the lower reaches is far greater than in the upper zone. For the purposes of this assessment then, scores and non-flow related impacts (most notably fishing pressure) were weighted and aggregated to attain an overall fish health score for the system (under present and future scenarios).

Table 5.11 Present fish health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow-related effects

Variable		Summary of change	Score	Conf.
a	Species richness	The hydrophysical and ecological processes that drive this system are still largely intact. As a consequence it is unlikely that any fish species have been permanently lost from the estuary and there is unlikely to have been any change in species richness relative to reference conditions.	100	M
b	Abundance	Abundance/biomass will have decreased as a direct result of fishing pressure. Species targeted in recreational, commercial and subsistence fisheries will have declined in abundance (regionally and within the estuary). Species significantly impacted will include most notably *Pomadasys commersonnii* and *Argyrosomus japonicus*. There are also declines in the abundance of the Zambezi shark, *Carcharhinus leucas.*	77	M
c	Community composition	Reductions in abundance of fisheries species will result in a direct change in community composition due to changes in relative abundance of the constituent fishes. Indirect effects could also be expected due to changes in predation pressure on smaller species as a result of piscivores (such as *Argyrosomus japonicus*, *Lichia amia* and *Carcharhinus leucas*) being reduced in the estuary.	78	M
	Score: min (a to c)		**77**	**M**

Conf.: Confidence; M: Medium

5.9 BIRDS

A summary of the bird health scores for the present state is provided in **Table 5.12** (detailed present health assessment is documented in DWS, 2014a and 2014b).

Table 5.12 Present bird health score, as well as an estimate of the change associated with non-flow related factors and an adjusted score only reflecting flow-related effects

Variable		Summary of change	Score	Conf.
a	Species richness	Average instantaneous species richness is likely to have declined.	90	M
b	Abundance	Some reduction in abundance of original species, due to some loss of marginal habitat, increase siltiness and turbidity, human disturbance, hunting, feral dogs.	61	M
c	Community composition	Suitability for waterfowl and piscivores may have declined more than for waders, but no major changes in dominance and composition.	76	M
Score: min (a to c)			**61**	**M**

Conf.: Confidence; M: Medium

5.10 OVERALL PRESENT ECOLOGICAL STATUS

The individual present health scores for the various abiotic and biotic components are used to determine the PES of the Mzimvubu Estuary in accordance with the EHI and are presented in **Table 5.13**. The Estuarine Health Score for the Mzimvubu Estuary is **81**, corresponding to a **PES** of **Category B.**

Table 5.13 Present Ecological Status of the Mzimvubu Estuary

Variable	Weight	Score
Hydrology	25	89
Physical habitat alteration	25	98
Hydrodynamics and mouth condition	25	75
Water quality	25	94
Habitat health score		**89**
Microalgae	20	65
Macrophytes	20	63
Invertebrates	20	95
Fish	20	77
Birds	20	61
Biotic health score		**72**
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		**81**
PRESENT ECOLOGICAL STATUS (PES)		**B**

5.11 RELATIVE CONTRIBUTION OF NON-FLOW RELATED PRESSURES

In scoring the various abiotic and biotic components, specialists were also asked to estimate the extent to which the shift from reference condition to present state was attributed to flow-related or non-flow related effects. Flow-related effects specifically relate to changes caused by a modification in river (volume) inflow (i.e. either base flows, seasonal distribution of flows or flood characteristics). Non-flow related effects include, for example, pollution from land-based activities such as agriculture, urban runoff and wastewater discharges, fishing, human disturbance of birds, habitat destruction associated with development and over-harvesting of estuarine vegetation.

Specialists concluded that non-flow related factors (e.g. habitat destruction and exploitation) contributed to most of the ecological modifications in the Mzimvubu Estuary from reference to the present state (see earlier present health score tables) as summarised in **Table 5.14**.

Table 5.14 Estimated effect of non-flow related factors on the present health of the Mzimvubu Estuary

Component	% of modification resulting from non-flow related pressures	Key contributing non-flow related pressure
Hydrology	N/A	N/A
Physical habitat alteration	90	Road and infilling around the bridge.
Hydrodynamics and mouth condition	0	All flow related.
Water quality	60	Catchment activities, e.g. settlements and cattle herds and erosion.
Microalgae	90	Elevated turbidity through erosion.
Macrophytes	30	Invasive species and some loss of supratidal habitat.
Invertebrates	90	Loss of intertidal habitat.
Fish	89	Fishing pressure, affecting the different zones (and fish categories) differently. Highest impacts are on the estuarine-dependant marine species which occur (and are fished) predominantly in the lower and middle zones of the estuary.
Birds	90	Human disturbance.

Thus, most of the ecological modification in the Mzimvubu Estuary has been a result of non-flow related pressures such as habitat destruction, alien invasive plants, nutrient enrichment (pollution), over-fishing and global/human disturbances to birds, rather than flow modification. In fact, specialists estimated that by removing all non-flow related factors the PES of the Mzimvubu Estuary (Category B) can be improved to a Category A. However, some of the non-flow related impacts would be difficult to remove, such as the global impacts on migratory birds (if any in this system), and the status of marine fish stocks, making improvement to a Category A unlikely.

6 ECOLOGICAL CONSEQUENCES OF SCENARIOS

6.1 DESCRIPTION OF SCENARIOS

The future scenarios that were assessed for the Mzimvubu Estuary are described in **Table 6.1.** More detailed information regarding operational scenarios can be found in the Scenario Description Report, Report no. WE/WMA7/00/CON/CLA/0517.

Table 6.1 Description of Mzimvubu present and future scenarios

Scenario	Update water demands (2040)		EWRs			Development options		MAR (MCM)	% of nMAR
	Realistic projection (a)	Ultimate development projection (b)	EWR4	EWR1	Lalini EWR (scaled)	MWP (Ntabelanga and Lalini dams with hydropower)	Port St Johns proposed WWTW		
Reference								2 737.0	100.0
Present								2 613.5	95.5
2a	Yes	No	No	No	No	Yes	No	2 577.3	94.2
2b	No	Yes	No	No	No	Yes	No	2 536.8	92.7
32	No	Yes	REC tot	No	REC tot	Yes	No	2 537.4	92.7
33	No	Yes	REC low	No	REC low	Yes	No	2 537.2	92.7
41	No	Yes	REC low	REC low	No	Yes	No	2 536.7	92.7
42	No	Yes	REC low	REC low	REC low	Yes	No	2 537.2	92.7
51	No	Yes	REC low	REC low	No	Yes – Reduced Hydro in dry months	No	2 536.6	92.7
52	No	Yes	REC low	REC low	REC low	Yes – Reduced Hydro in dry months	No	2 537.0	92.7
53	Yes	No	REC low	REC low	To be confirmed	Yes – Reduced Hydro in dry months	No	2 536.1	92.7
PresW1	Present river inflow, including 3.5Mℓ per day WWTW inflow						Yes	2614.77	95.5
PresW2	Present inflow, including 4.5Mℓ per day WWTW inflow						Yes	2615.13	95.5
Dam (1.5MAR)	Large dam 1.5 MAR (Ntabelanga) (previous study's scenario 3 – DWS, 2014a)						No	2427.86	88.7

MWP: Mzimvubu Water Project.

The **ultimate development projection (b)** are the demands imposed to fully utilise the available yield of the new proposed dams.

The **realistic projection (a)** refers to an alternative projection which is felt to be more realistic in terms of the expected growth.

Due to the uncertainties linked to the development and location of the proposed new Port St Johns WWTW, a simple approach was followed for this scenario assessment. The EIA for the WWTW was only recently initiated, with one of the four possible sites potentially impacting on the estuary by entering the estuary via a small tributary outside EFZ (see **Figure 3.2**). The estuary team therefore followed a simple approach and assessed the impact of additional flows from the WWTW entering the estuary on top of present day flows. The capacity of the WWTW will be 3.5 Mℓ/day. Over the next 30 years this would increase to 4.5 Mℓ/day. Discharge will be treated to DWS General Standards.

The 1.5 MAR Dam scenario (i.e. a 1.5 MAR capacity dam at Ntabelanga) was adopted as the REC in the 2014 EWR study (DWS, 2014a). It was decided to re-assess this scenario as part of this Classification study to compare with the new development scenarios.

The occurrences of the flow distributions (mean monthly flows in m^3/s) under the future scenarios derived from the 1920 to 2004 simulation period are provided in **Tables 6.2** to **6.13** and in **Figures 6.1** to **6.12**. The full sets of 85-year series of simulated monthly runoff data for the future scenarios are provided in **Appendix A**.

Table 6.2 Summary of the monthly flow (in m^3/s) under Scenario 2a

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
100	325	444	402	613	673	972	508	393	297	308	154	750
99	271	396	383	600	626	692	378	237	294	229	144	259
95	129	266	303	449	542	528	266	82	83	104	58	85
90	92	183	251	315	510	369	175	67	46	39	40	56
85	75	118	197	227	390	279	131	60	38	34	30	33
80	55	89	178	180	284	239	115	50	32	30	28	27
70	40	65	130	146	186	200	105	38	26	25	22	23
60	30	55	70	104	153	161	80	30	24	23	19	20
50	25	44	50	80	120	140	67	28	21	19	18	18
40	23	36	40	68	85	112	55	25	20	18	17	17
30	21	34	36	56	68	84	49	23	19	17	16	15
20	20	31	31	50	58	65	45	22	18	16	15	14
15	18	29	30	40	54	63	41	21	17	16	15	14
10	17	28	28	34	44	54	36	21	17	16	15	14
5	16	27	24	31	37	44	32	20	16	15	14	13
1	15	25	23	27	28	33	27	18	16	15	13	12

Table 6.3 Summary of the monthly flow (in m^3/s) under Scenario 2b

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
100	323	440	399	611	672	970	507	391	294	305	153	746
99	268	392	379	599	623	691	377	235	292	227	142	257
95	128	263	301	445	541	526	264	81	82	103	57	83
90	91	181	248	313	508	367	174	66	45	38	40	55
85	74	116	195	224	389	278	129	59	37	33	29	32
80	54	87	176	178	282	238	113	49	31	29	28	26
70	38	63	129	145	184	198	104	37	25	24	22	23
60	29	54	68	103	151	158	79	29	23	22	19	19
50	24	43	49	79	118	139	65	27	20	19	17	17
40	22	35	39	67	84	111	53	25	19	17	16	16
30	20	32	35	54	66	83	47	23	18	17	16	15
20	19	30	30	48	56	63	43	21	17	15	15	14
15	17	28	29	39	53	62	39	20	16	15	14	13
10	16	27	26	32	42	52	35	20	16	15	14	13
5	15	26	23	30	36	42	30	19	16	14	13	12
1	14	24	22	25	26	32	26	17	15	14	13	11

Table 6.4 Summary of the monthly flow (in m³/s) under Scenario 32

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
100	323	411	396	581	671	970	496	380	290	305	150	741
99	265	382	367	579	614	691	375	233	287	224	142	253
95	131	269	298	432	528	526	264	81	83	103	58	83
90	93	173	240	307	484	377	169	68	49	40	41	57
85	77	116	188	220	369	278	131	60	38	35	32	35
80	59	93	174	167	279	251	115	51	34	32	29	28
70	42	67	129	144	198	210	102	41	27	26	22	24
60	33	55	72	102	155	162	81	32	25	22	19	20
50	26	45	52	80	123	143	66	30	21	19	18	18
40	22	37	39	67	83	113	54	26	19	18	16	16
30	21	32	36	56	70	80	47	23	17	16	15	14
20	18	29	29	48	55	63	44	21	16	15	14	13
15	16	26	27	41	53	58	39	20	16	14	14	12
10	15	25	24	33	43	53	34	19	15	14	13	12
5	14	23	20	28	37	43	28	19	14	13	13	11
1	13	22	19	22	24	29	23	16	14	13	12	11

Table 6.5 Summary of the monthly flow (in m³/s) under Scenario 33

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
100	323	421	385	596	672	970	500	391	289	304	149	744
99	265	384	370	593	620	691	376	235	287	224	142	253
95	129	255	299	423	530	526	264	81	83	103	58	83
90	93	174	246	308	495	372	174	68	49	40	42	56
85	76	113	191	224	382	278	131	59	39	35	32	34
80	57	91	162	169	280	238	114	52	35	32	29	27
70	41	65	129	147	189	206	102	42	27	26	23	24
60	32	54	72	101	155	163	81	32	25	23	20	20
50	26	44	52	81	121	140	67	31	22	19	18	18
40	22	37	39	66	85	112	54	27	19	18	17	16
30	21	32	35	55	69	80	47	23	18	16	15	15
20	18	29	29	47	56	62	44	21	17	16	14	13
15	17	27	28	40	52	59	39	20	16	15	14	13
10	16	25	25	34	42	52	34	20	15	14	13	12
5	15	24	21	28	37	42	28	19	15	14	13	11
1	13	22	19	23	25	29	23	16	14	13	12	11

Table 6.6 Summary of the monthly flow (in m³/s) under Scenario 41

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	323	440	399	611	672	970	507	391	294	305	153	746
99	268	392	379	599	623	691	377	235	292	227	142	257
95	128	263	301	445	541	526	264	81	82	103	57	83
90	91	181	248	313	508	367	174	66	45	38	40	55
85	74	116	195	224	389	278	129	59	37	33	29	32
80	54	87	176	178	282	242	113	49	31	29	28	26
70	38	63	129	145	184	198	102	37	25	24	22	23
60	29	54	68	103	151	158	79	29	23	22	19	19
50	24	43	49	79	118	139	65	27	20	19	18	17
40	22	35	39	67	84	111	53	25	19	17	16	16
30	20	32	35	54	66	83	47	23	18	17	16	15
20	19	30	30	48	56	63	43	21	17	15	15	14
15	17	28	29	39	53	62	39	20	16	15	14	13
10	16	27	26	32	42	52	35	20	16	15	14	13
5	15	26	23	30	36	42	30	19	16	14	13	12
1	14	24	22	25	26	32	26	17	15	14	13	11

Table 6.7 Summary of the monthly flow (in m³/s) under Scenario 42

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	323	421	385	596	672	970	500	391	289	304	149	744
99	265	384	370	593	620	691	376	235	287	224	142	253
95	129	255	299	423	530	526	264	81	83	103	58	83
90	93	174	246	308	495	372	174	68	49	40	42	56
85	76	113	191	224	382	278	131	59	39	35	32	34
80	57	91	162	169	280	238	114	52	35	32	29	27
70	41	65	129	147	189	206	102	42	27	26	23	24
60	32	54	72	101	155	163	81	32	25	23	20	20
50	26	44	52	81	121	140	67	31	22	19	18	18
40	22	37	39	66	85	112	54	27	19	18	17	16
30	21	32	35	55	69	80	47	23	18	16	15	15
20	18	29	29	47	56	62	44	21	17	16	14	13
15	17	27	28	40	52	59	39	20	16	15	14	13
10	16	25	25	34	42	52	34	20	15	14	13	12
5	15	24	21	28	37	42	28	19	15	14	13	11
1	13	22	19	23	25	29	23	16	14	13	12	11

Table 6.8 Summary of the monthly flow (in m³/s) under Scenario 51

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	323	441	399	611	672	970	506	391	294	306	153	746
99	269	393	381	599	623	691	377	235	292	228	143	259
95	128	264	302	445	541	526	264	81	82	103	57	84
90	91	182	249	313	508	367	174	66	44	37	39	55
85	74	117	195	224	388	278	129	59	37	33	29	32
80	55	88	176	178	281	242	113	49	30	28	27	26
70	39	63	129	145	184	198	102	37	24	23	21	23
60	29	54	68	103	151	159	79	29	22	21	18	19
50	25	43	49	79	118	138	66	27	19	18	17	18
40	22	35	39	67	84	111	54	24	18	16	16	16
30	21	33	35	55	67	82	47	22	17	16	15	15
20	19	31	30	48	56	63	44	21	16	14	14	14
15	17	28	29	39	53	62	40	20	15	14	14	14
10	16	28	27	33	43	53	35	19	15	14	14	13
5	16	26	23	30	36	42	31	19	15	14	13	12
1	14	24	22	26	27	32	26	17	14	13	12	12

Table 6.9 Summary of the monthly flow (in m³/s) under Scenario 52

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	323	420	387	595	671	970	496	391	292	308	152	747
99	267	386	372	587	616	691	375	235	289	227	142	258
95	129	258	298	425	529	526	264	81	83	103	57	83
90	93	176	248	309	490	372	171	66	47	38	41	56
85	77	117	193	223	378	278	131	59	37	34	31	35
80	58	92	163	167	276	240	115	50	33	30	28	28
70	41	66	130	148	190	207	102	39	25	24	22	25
60	33	55	73	101	155	164	81	29	23	21	19	20
50	27	45	53	82	122	139	68	28	20	17	17	19
40	23	38	40	67	85	113	55	24	17	16	16	17
30	22	34	36	57	70	80	49	20	16	15	14	15
20	19	30	30	48	57	63	45	19	15	14	13	14
15	18	28	29	41	53	60	41	18	14	13	13	13
10	17	27	26	35	43	54	36	17	14	13	12	13
5	15	25	22	30	38	43	30	17	13	12	12	12
1	14	24	21	24	26	31	25	14	12	11	11	12

Table 6.10 Summary of the monthly flow (in m^3/s) under Scenario 53

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	324	449	401	611	672	970	487	391	297	314	155	747
99	279	406	392	599	619	691	374	235	295	232	143	272
95	129	275	300	446	541	526	264	81	81	103	56	83
90	92	189	254	310	508	369	174	65	47	34	37	51
85	80	129	201	222	381	278	131	55	34	29	27	29
80	58	92	176	178	272	237	111	45	28	25	23	23
70	41	67	130	147	188	201	102	33	21	20	17	19
60	32	57	71	107	153	162	81	25	18	17	14	15
50	27	47	53	82	121	133	70	23	16	14	13	14
40	24	39	43	70	86	113	58	20	14	12	12	12
30	23	37	39	58	70	80	52	18	13	12	11	11
20	21	35	34	52	58	68	48	17	12	10	10	10
15	20	32	33	43	54	63	44	16	11	10	10	10
10	19	31	31	37	46	57	40	15	11	10	10	9
5	18	30	27	35	40	47	35	15	11	10	9	8
1	16	28	26	30	31	37	31	13	10	9	8	8

Table 6.11 Summary of the monthly flow (in m^3/s) under Scenario PresW1

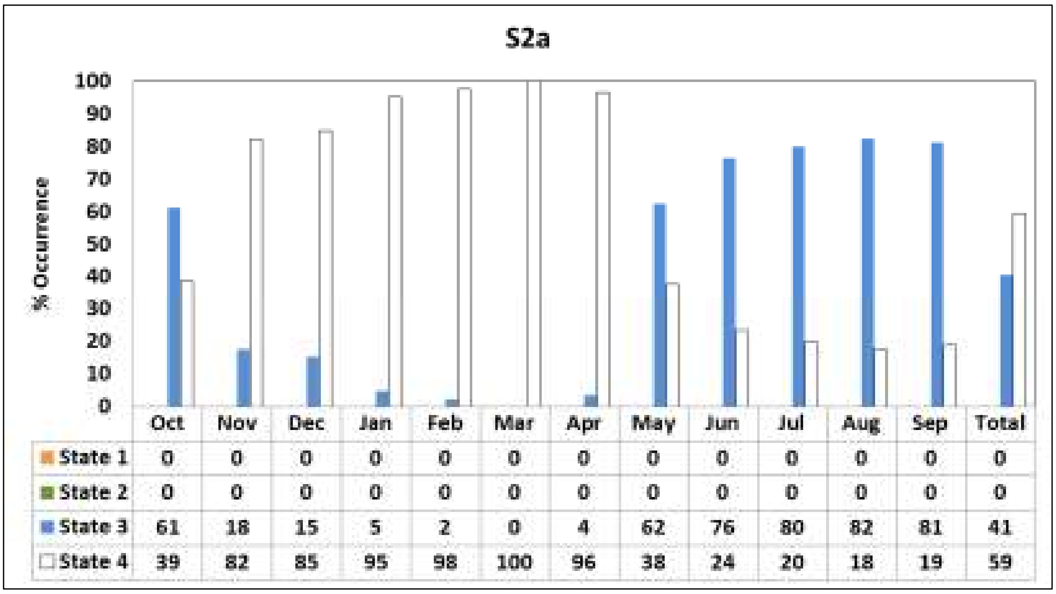
%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
100	328	466	488	609	667	964	548	393	298	327	159	801
99	286	427	423	597	621	708	386	238	295	250	148	296
95	156	310	349	492	540	524	266	84	87	107	71	90
90	97	197	256	330	504	393	176	68	50	40	54	70
85	83	139	218	229	403	284	132	63	40	34	32	37
80	59	105	187	192	291	278	121	53	32	28	25	32
70	44	74	141	151	239	221	107	36	22	22	19	21
60	34	58	78	121	168	170	81	27	19	17	15	18
50	24	46	60	89	131	146	66	24	15	12	12	14
40	20	37	37	68	100	116	53	20	12	11	10	13
30	17	28	34	61	80	87	41	16	10	9	9	9
20	13	20	25	45	56	63	36	14	10	9	7	7
15	12	18	20	40	52	60	31	13	9	8	7	7
10	11	16	17	29	46	52	26	12	8	7	6	6
5	8	13	10	17	36	44	16	11	7	6	6	6
1	6	11	6	11	16	18	9	8	7	5	5	4

Table 6.12 Summary of the monthly flow (in m³/s) under Scenario PresW2

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
100	328	466	488	609	667	964	548	393	298	327	159	801
99	286	427	423	597	621	708	386	238	295	250	148	296
95	156	310	349	492	540	524	266	84	87	107	71	90
90	97	197	256	330	504	393	176	68	50	40	54	70
85	83	139	218	229	403	284	132	63	40	34	32	37
80	59	105	187	192	291	278	121	53	32	28	25	32
70	44	74	141	151	239	221	107	36	22	22	19	21
60	34	58	78	121	168	170	81	27	19	17	15	18
50	24	46	60	89	131	146	66	24	15	12	12	14
40	20	37	37	68	100	116	53	20	12	11	10	13
30	17	28	34	61	80	87	41	16	10	9	9	9
20	13	20	25	45	56	63	36	14	10	9	7	7
15	12	18	20	40	52	60	31	13	9	8	7	7
10	11	16	17	29	46	52	26	12	8	7	6	6
5	8	13	10	17	36	44	16	11	7	6	6	6
1	6	11	6	11	16	18	9	8	7	5	5	4

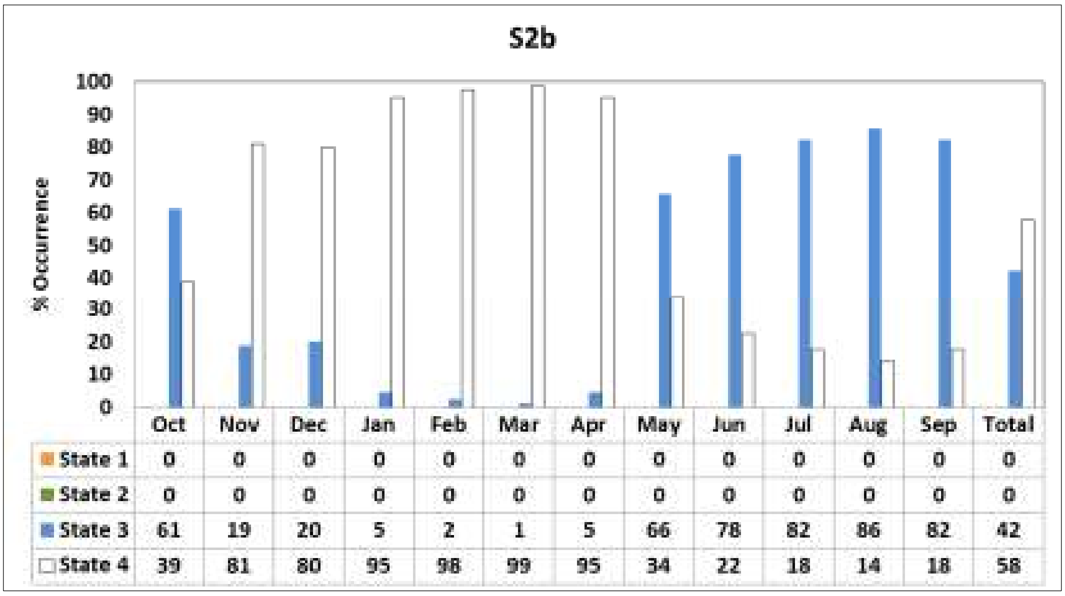
Table 6.13 Summary of the monthly flow (in m³/s) under Scenario Dam (1.5 MAR)

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
100	318.7	501.6	430.7	621.2	705.9	986.3	468.9	389.0	318.2	352.5	162.4	811.7
99	302.3	446.2	399.4	604.0	674.3	703.0	365.7	204.0	306.3	253.5	140.5	289.1
95	153.8	320.5	335.1	468.9	543.5	526.5	252.1	75.8	79.0	91.8	59.1	92.3
90	96.5	197.3	246.7	307.3	499.0	372.9	151.5	61.4	45.8	35.4	38.9	67.5
85	76.5	114.0	215.1	228.2	403.7	285.0	126.1	54.2	31.9	29.8	26.8	33.1
80	65.8	97.4	172.9	178.4	272.9	251.8	106.4	45.2	27.3	25.5	23.1	26.8
70	39.3	72.6	142.1	135.7	200.1	209.6	94.7	33.1	19.7	19.8	16.1	20.0
60	28.5	51.1	74.5	101.6	150.8	159.1	67.4	22.0	17.0	16.5	12.7	16.3
50	21.1	37.1	45.6	85.2	120.0	133.3	57.6	20.1	14.1	11.9	11.1	14.1
40	17.7	31.4	30.9	63.4	84.4	103.8	41.0	18.1	11.8	10.0	9.6	11.6
30	14.9	21.4	24.0	47.9	62.9	75.9	34.4	14.7	10.6	9.3	8.5	8.2
20	12.0	16.6	18.2	37.6	47.2	50.9	31.4	12.2	9.8	8.2	7.2	7.5
15	10.8	14.9	14.6	29.2	38.6	47.7	25.7	11.7	8.5	7.5	6.8	7.0
10	9.8	13.2	11.3	20.0	34.8	41.8	19.1	10.6	7.9	7.0	6.3	6.4
5	7.4	11.3	7.0	11.9	27.3	33.8	12.7	9.8	7.3	6.4	5.6	5.2
1	5.7	9.3	5.1	6.9	15.2	13.0	9.3	6.4	5.6	4.1	2.8	3.1



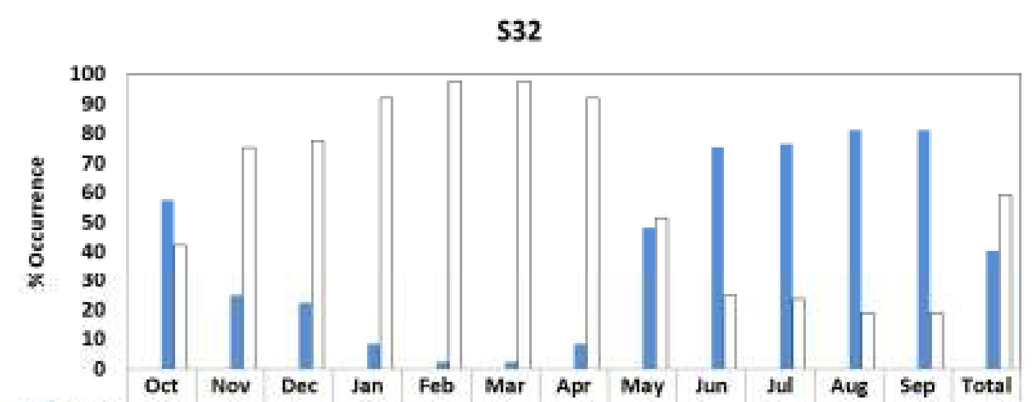
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	0	0	0	0	0	0	0	0	0	0	0	0	0
State 3	61	18	15	5	2	0	4	62	76	80	82	81	41
State 4	39	82	85	95	98	100	96	38	24	20	18	19	59

Figure 6.1 Occurrence of the various abiotic states under Scenario 2a



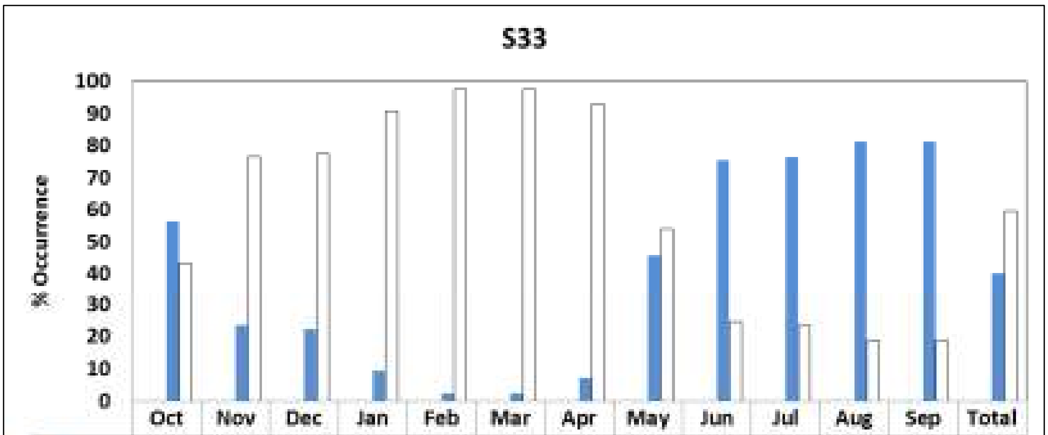
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	0	0	0	0	0	0	0	0	0	0	0	0	0
State 3	61	19	20	5	2	1	5	66	78	82	86	82	42
State 4	39	81	80	95	98	99	95	34	22	18	14	18	58

Figure 6.2 Occurrence of the various abiotic states under Scenario 2b



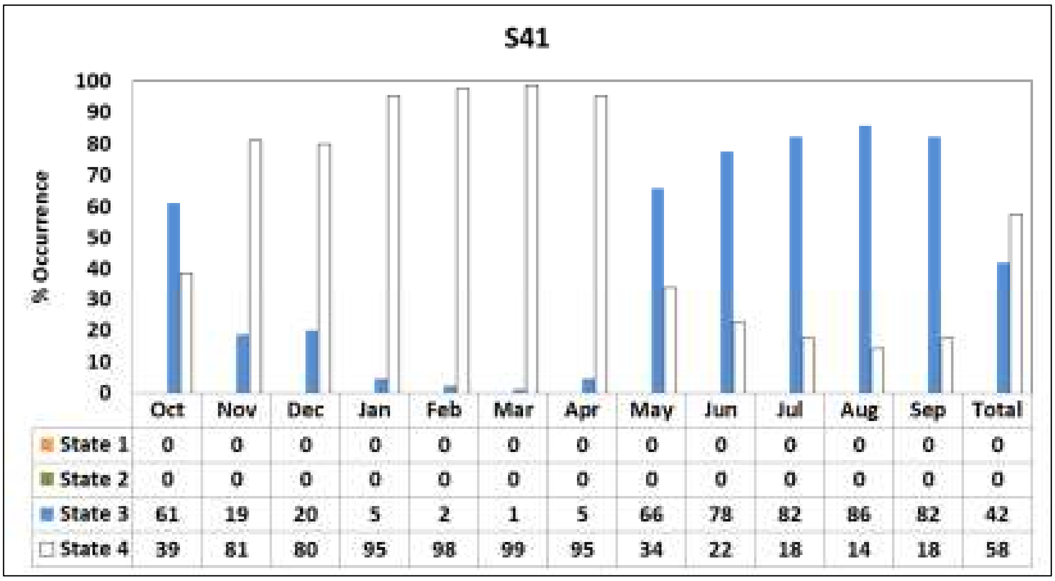
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	0	0	0	0	0	0	0	0	0	0	0	0	0
State 3	58	25	22	8	2	2	8	48	75	76	81	81	41
State 4	42	75	78	92	98	98	92	52	25	24	19	19	59

Figure 6.3 Occurrence of the various abiotic states under Scenario 32



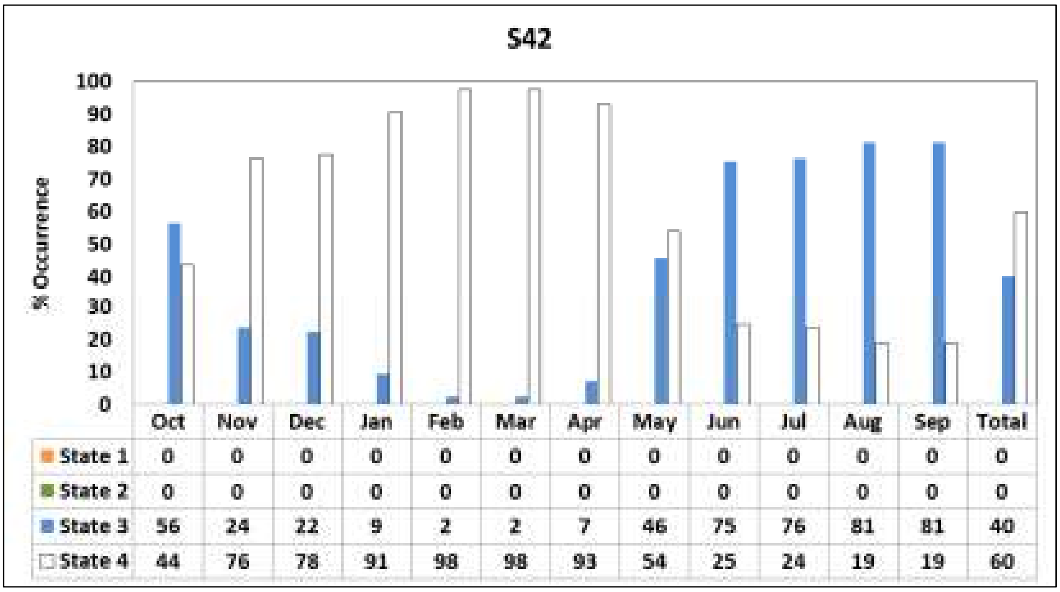
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	0	0	0	0	0	0	0	0	0	0	0	0	0
State 3	56	24	22	9	2	2	7	46	75	76	81	81	40
State 4	44	76	78	91	98	98	93	54	25	24	19	19	60

Figure 6.4 Occurrence of the various abiotic states under Scenario 33



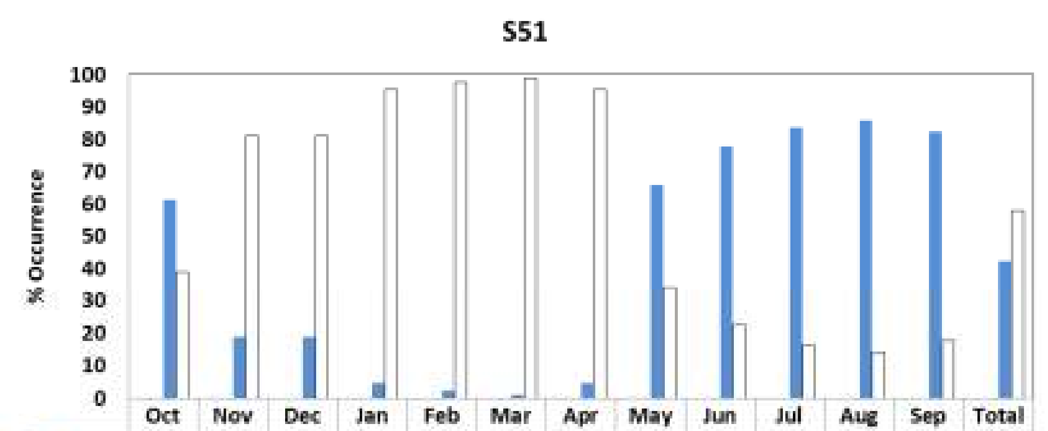
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	0	0	0	0	0	0	0	0	0	0	0	0	0
State 3	61	19	20	5	2	1	5	66	78	82	86	82	42
State 4	39	81	80	95	98	99	95	34	22	18	14	18	58

Figure 6.5 Occurrence of the various abiotic states under Scenario 41



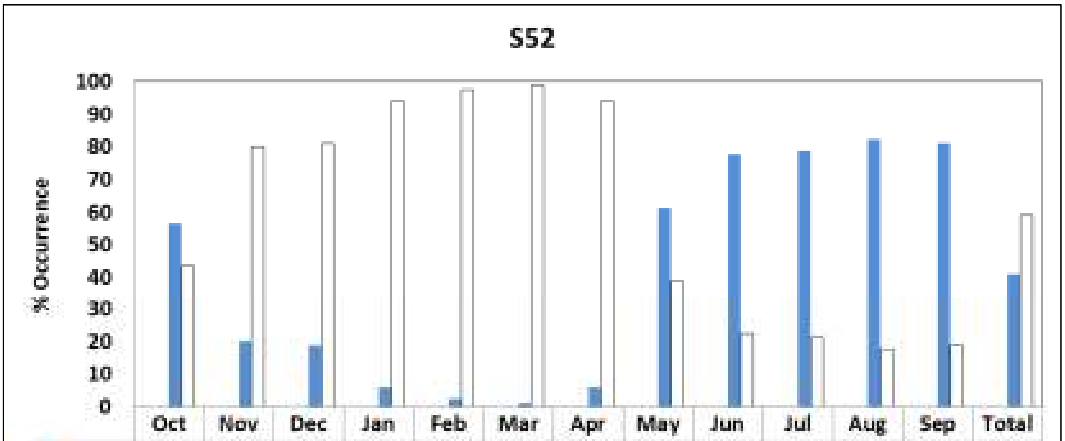
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	0	0	0	0	0	0	0	0	0	0	0	0	0
State 3	56	24	22	9	2	2	7	46	75	76	81	81	40
State 4	44	76	78	91	98	98	93	54	25	24	19	19	60

Figure 6.6 Occurrence of the various abiotic states under Scenario 42



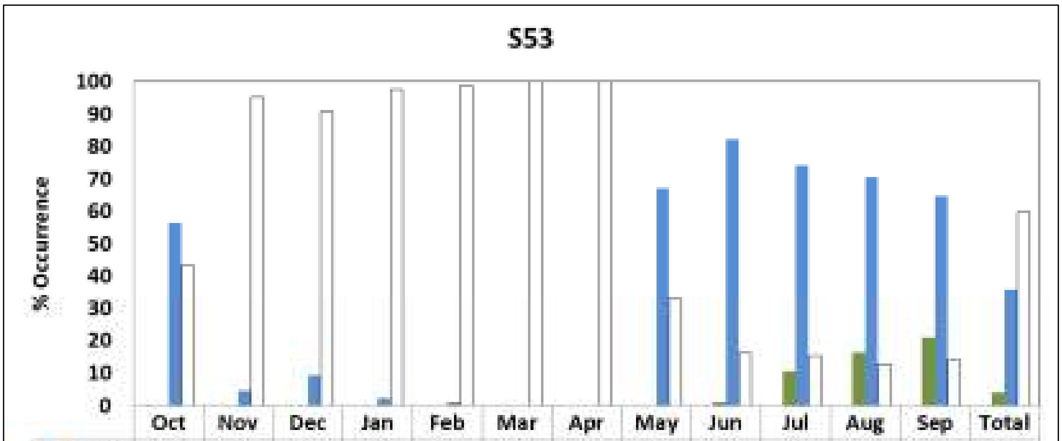
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	0	0	0	0	0	0	0	0	0	0	0	0	0
State 3	61	19	19	5	2	1	5	66	78	84	86	82	42
State 4	39	81	81	95	98	99	95	34	22	16	14	18	58

Figure 6.7 Occurrence of the various abiotic states under Scenario 51



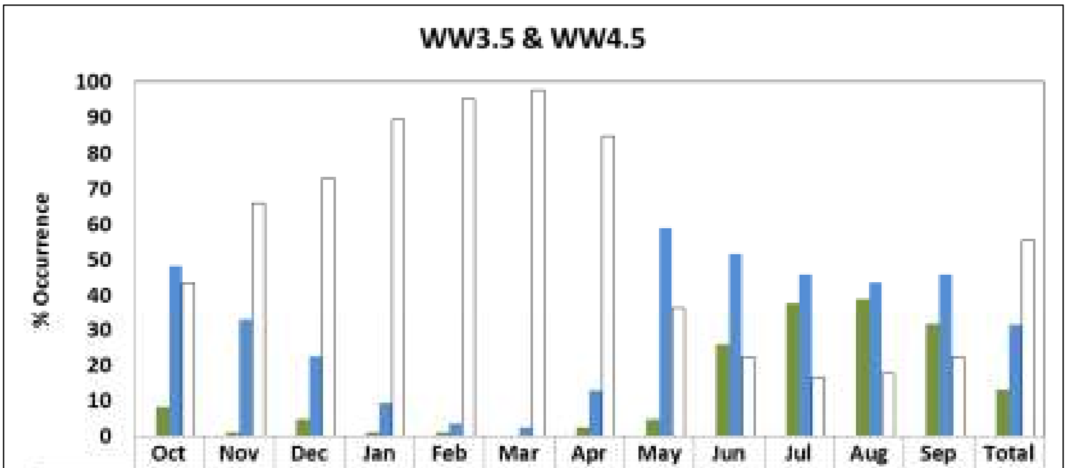
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	0	0	0	0	0	0	0	0	0	0	0	0	0
State 3	56	20	19	6	2	1	6	61	78	79	82	81	41
State 4	44	80	81	94	98	99	94	39	22	21	18	19	59

Figure 6.8 Occurrence of the various abiotic states under Scenario 52



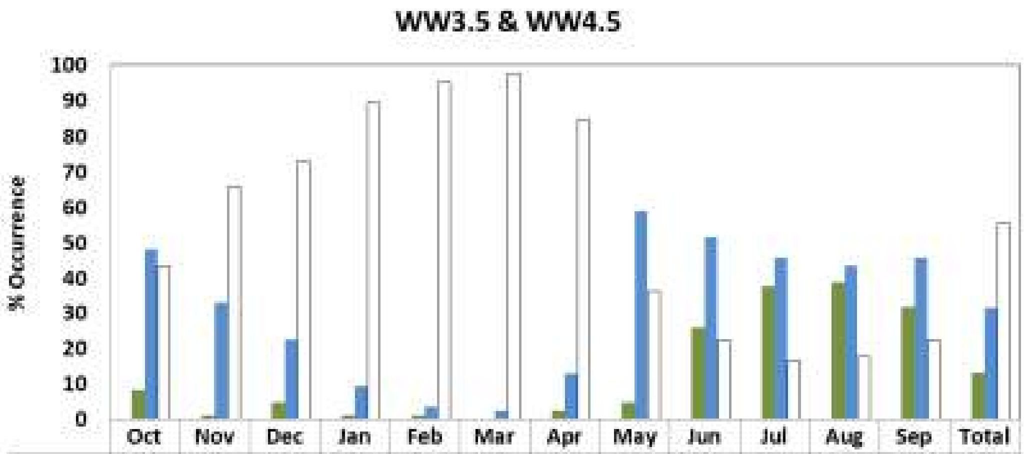
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	0	0	0	0	0	0	0	0	1	11	16	21	4
State 3	56	5	9	2	1	0	0	67	82	74	71	65	36
State 4	44	95	91	98	99	100	100	33	16	15	13	14	60

Figure 6.9 Occurrence of the various abiotic states under Scenario 53



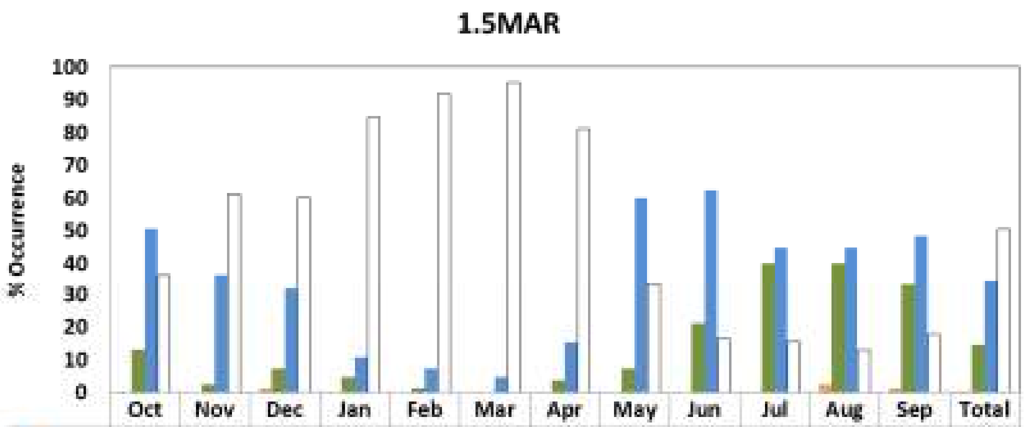
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	8	1	5	1	1	0	2	5	26	38	39	32	13
State 3	48	33	22	9	4	2	13	59	52	46	44	46	31
State 4	44	66	73	89	95	98	85	36	22	16	18	22	55

Figure 6.10 Occurrence of the various abiotic states under Scenario PresW1



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	8	1	5	1	1	0	2	5	26	38	39	32	13
State 3	48	33	22	9	4	2	13	59	52	46	44	46	31
State 4	44	66	73	89	95	98	85	36	22	16	18	22	55

Figure 6.11 Occurrence of the various abiotic states under Scenario PresW2



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	1	0	0	0	0	0	0	0	2	1	0
State 2	13	2	7	5	1	0	4	7	21	40	40	33	14
State 3	51	36	32	11	7	5	15	60	62	45	45	48	35
State 4	36	61	60	85	92	95	81	33	16	15	13	18	50

Figure 6.12 Occurrence of the various abiotic states under Scenario Dam (1.5 MAR)

6.2 HYDROLOGY

Tables 6.14 and **6.15** provide a summary of the changes in low flows and flood regime under the various scenarios (Sc). Low flows (also called base flows) were taken as the flow range that is exceeded for 70% or more of the time. The average change in the 10, 20 and 30 percentile was taken as change in the low flows to the estuary.

Table 6.14 Summary of change in low flow conditions under reference, present and future scenarios

Percentile	Monthly flow (m^3/s)													
	Ref	Pres	Sc 2a	Sc 2b	Sc 32	Sc 33	Sc 41	Sc 42	Sc 51	Sc 52	Sc 53	Pres W1	Pres W2	Sc Dam (1.5 MAR)
10	20.6	18.2	23.9	23.0	23.2	23.7	23.0	23.7	22.9	23.6	20.9	18.2	18.2	15.6
20	14.9	12.5	19.7	18.9	18.9	19.3	18.9	19.3	18.5	18.5	15.2	12.6	12.6	11.5
30	11.4	8.9	16.7	15.9	15.5	15.9	15.9	15.9	15.5	15.0	11.6	8.9	8.9	8.4
% Similarity in low flows		**83**	**77**	**80**	**80**	**79**	**80**	**79**	**81**	**81**	**98**	**84**	**84**	**74**

Table 6.15 Summary of 20 highest simulated monthly volumes under reference, present and future scenarios

Date	Monthly volume (10^6 m^3/month)													
	Ref	Pres	Sc 2a	Sc 2b	Sc 32	Sc 33	Sc 41	Sc 42	Sc 51	Sc 52	Sc 53	Pres W1	Pres W2	Sc Dam (1.5 MAR)
Mar-76	2 675	2 658	2 686	2 680	2 680	2 680	2 680	2 680	2 680	2 680	2 680	2658	2658	2726
Sep-87	2 260	2 221	2 085	2 074	2 062	2 071	2 073	2 071	2 075	2 076	2 074	2221	2221	2254
Mar-27	1 782	1 751	1 627	1 623	1 535	1 557	1 623	1 557	1 621	1 546	1 597	1751	1751	1696
Mar-00	1 694	1 677	1 696	1 693	1 693	1 693	1 693	1 693	1 693	1 693	1 693	1677	1677	1722
Jan-96	1 669	1 636	1 644	1 641	1 420	1 588	1 641	1 588	1 641	1 568	1 641	1636	1636	1669
Feb-39	1 660	1 640	1 657	1 654	1 654	1 654	1 654	1 654	1 654	1 654	1 654	1641	1641	1731
Jan-76	1 618	1 591	1 600	1 597	1 557	1 597	1 597	1 597	1 597	1 597	1 597	1591	1591	1464
Mar-25	1 601	1 580	1 580	1 577	1 581	1 579	1 576	1 579	1 575	1 576	1 566	1580	1580	1569
Jan-34	1 571	1 544	1 553	1 550	1 550	1 550	1 550	1 550	1 550	1 550	1 550	1544	1544	1608
Jan-00	1 556	1 528	1 432	1 424	1 399	1 405	1 424	1 406	1 425	1 410	1 440	1528	1528	1584
Feb-98	1 523	1 491	1 503	1 495	1 470	1 485	1 495	1 485	1 495	1 474	1 483	1491	1491	1629
Apr-78	1 488	1 466	1 355	1 351	1 319	1 331	1 351	1 331	1 349	1 321	1 296	1466	1466	1245
Feb-85	1 468	1 434	1 429	1 420	1 195	1 183	1 420	1 183	1 417	1 156	1 385	1434	1434	1370
Mar-94	1 429	1 408	1 420	1 417	1 417	1 417	1 417	1 417	1 417	1 417	1 417	1408	1408	1320
Mar-63	1 398	1 380	1 392	1 384	1 384	1 384	1 384	1 384	1 384	1 384	1 384	1380	1380	1433
Jan-55	1 397	1 365	1 254	1 245	1 207	1 177	1 245	1 177	1 244	1 181	1 242	1366	1366	1327
Dec-76	1 369	1 327	1 081	1 073	1 068	1 036	1 073	1 037	1 074	1 042	1 076	1327	1328	1163
Feb-88	1 359	1 333	1 347	1 342	1 342	1 342	1 342	1 342	1 342	1 342	1 342	1333	1333	1389
Feb-96	1 345	1 325	1 329	1 326	1 326	1 326	1 326	1 326	1 326	1 326	1 326	1325	1325	1322
Mar-67	1 325	1 303	1 276	1 273	1 212	1 227	1 273	1 227	1 271	1 221	1 253	1303	1303	1198
% Similarity in floods		**98**	**96**	**95**	**93**	**94**	**95**	**94**	**95**	**93**	**95**	**98**	**98**	**95**

Summaries of the hydrological changes under each of the scenarios and the hydrology health scores for various scenarios are provided in **Tables 6.16** and **6.17**, respectively.

Table 6.16 Summary of hydrological changes under present and future scenarios

Scenario	Summary of change
Present PresW1 and PresW2	There is a 17% <u>decrease</u> in base flows from reference. Floods are very similar to reference with only a 2% decline in magnitude.
2a	There is a 23% <u>increase</u> in base flows from reference. Floods are similar to reference with a 4 % decline in magnitude.
2b	There is a 20% <u>increase</u> in base flows from reference. Floods are similar to reference with a 5% decline in magnitude.
32	There is a 20% <u>increase</u> in base flows from reference. Floods decline by 7% in magnitude from reference conditions.
33	There is a 21% <u>increase</u> in base flows from reference. Floods are similar to reference with a 6% decline in magnitude.
41	There is between a 20 and 21 % <u>increase</u> in base flows from reference. Floods are similar to reference with a 5% decline in magnitude.
42	There is a 21% <u>increase</u> in base flows from reference. Floods decline by 6% in magnitude from reference conditions.
51	There is a 19% <u>increase</u> in base flows from reference. Floods are similar to reference with a 5% decline in magnitude.
52	There is a 19% <u>increase</u> in base flows from reference. Floods decline by 7% in magnitude from reference conditions.
53	There is a 2% <u>increase</u> in base flows from reference. Floods decline by 5% in magnitude from reference conditions.
Dam (1.5MAR)	There is a 26% <u>decrease</u> in base flows from reference. Floods are very similar to reference with only a 5% decline in magnitude.

Table 6.17 Hydrology health scores for present and future scenarios

Variable	Weight	Scenario												
		Pres	**2a**	**2b**	**32**	**33**	**41**	**42**	**51**	**52**	**53**	**Pres W1**	**Pres W2**	**Dam (1.5 MAR)**
a. % Similarity in low flows	60	83	77	80	80	79	80	79	81	81	98	84	84	74
b. % Similarity in flood volumes	40	98	96	95	93	94	95	94	95	93	95	98	98	95
Score: weighted mean (a, b)		**89**	**85**	**86**	**85**	**85**	**86**	**85**	**87**	**86**	**97**	**90**	**90**	**84**

6.3 PHYSICAL HABITAT

Summaries of the physical habitat changes under each of the scenarios and the physical habitat scores for various scenarios are provided in **Tables 6.18** and **6.19**, respectively. No numerical modelling was done to assess the changes in the sediment processes under the various scenarios.

Table 6.18 Summary of physical habitat changes under present and future scenarios

Scenario	Summary of change
Present PresW1 and PresW2	Similar to reference, some loss of supratidal area due to road and infilling around bridge. Intertidal areas similar to reference, maybe very slightly more muddy and slight loss of intertidal area due to road and infilling around bridge. Subtidal areas similar to reference, but slightly more muddy. Estuary bathymetry similar to reference, some changes due to infilling around bridge.
2a – S2b	Some infilling of the supratidal, intertidal and subtidal areas are expected. It is also assumed that the subtidal will be subjected to the most change and expected to be more muddy.
32 and 52	Represents the worst case scenario from a sediment perspective as a result in the decline in floods.
33 – 52 and Dam (1.5 MAR)	Some infilling of the supratidal, intertidal and subtidal areas are expected (scores varying between 90 and 80). It is also assumed that the subtidal will be subjected to the most change and is expected to be more muddy.

Table 6.19 Physical habitat health scores for present and future scenarios

Variable		Scenario												
		Pres	2a	2b	32	33	41	42	51	52	53	Pres W1	Pres W2	Dam (1.5 MAR)
a	Supratidal area and sediments	95	93	90	80	85	90	85	90	80	90	95	95	90
b	Intertidal areas and sediments	95	93	90	80	85	90	85	90	80	90	95	95	90
c	Subtidal area and sediments	90	87	85	75	80	85	80	85	75	85	90	90	85
d	Estuary bathymetry/ water volume	95	93	90	80	85	90	85	90	80	90	95	95	90
Score: mean (a to d)		**94**	**92**	**89**	**79**	**84**	**89**	**84**	**89**	**79**	**89**	**93**	**94**	**89**

6.4 HYDRODYNAMICS AND MOUTH CONDITION

A summary of the hydrodynamic characteristics of the Mzimvubu Estuary under various abiotic states (**Table 3.1**) is provided in **Appendix B** (detailed present health assessment is documented in DWS, 2014a). The percentage occurrence of various abiotic states under reference, present and future scenarios is summarised in **Table 6.20**.

Table 6.20 Summary of occurrence of abiotic states under the reference, present and future scenarios

Abiotic state	Scenario													
	Ref	Pres	2a	2b	32	33	41	42	51	52	53	Pres W1	Pres W2	Dam (1.5 MAR)
State 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	0.0	0.4
State 2	6.7	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	13.1	13.0	14.4
State 3	35.4	31.5	40.6	42.3	40.7	40.3	42.3	40.3	42.3	41.0	36.1	31.4	31.5	34.7
State 4	57.9	55.4	59.4	57.7	59.3	59.7	57.7	59.7	57.7	59.0	59.8	55.5	55.5	50.5

A summary of the hydrodynamic changes under each of the scenarios and the hydrodynamic scores for various scenarios are provided in **Tables 6.21** and **6.22**, respectively.

Table 6.21 Summary of hydrodynamic changes under present and future scenarios

Scenario	Summary of change
Present, PresW1 and PresW2	Mouth conditions will be similar to present, i.e. 100% open. Retention increases slightly as a result of a decrease in base flows.
2a – 52	Mouth conditions will be similar to present, i.e. 100% open. Retention decreases slightly as a result of elevated base flows from reference conditions, i.e. 7% loss of State 2: Intermediate saline penetration.
53	Mouth conditions will be similar to present, i.e. 100% open. Retention decreases slightly as a result of elevated base flows from reference conditions, i.e. 3% loss of State 2: Intermediate saline penetration.
Dam (1.5 MAR)	Mouth conditions will similar to present, i.e. 100% open. Retention decreases slightly as a result of elevated base flows from reference conditions, i.e. 1% loss of State 2: Intermediate saline penetration.

Table 6.22 Hydrodynamic health scores for present and future scenarios

Variable		Scenario												
		Pres	**2a**	**2b**	**32**	**33**	**41**	**42**	**51**	**52**	**53**	**Pres W1**	**Pres W2**	**Dam (1.5 MAR)**
a	% similarity in mouth condition	100	100	100	100	100	100	100	100	100	100	100	100	100
b	% similarity in water retention time	95	93	93	93	93	93	93	93	93	97	95	95	95
Score: mean (a, b)		**98**	**97**	**97**	**97**	**97**	**97**	**97**	**97**	**97**	**99**	**98**	**98**	**98**

6.5 WATER QUALITY

A summary of the water quality conditions in the Mzimvubu Estuary under various abiotic states (**Table 3.1**) is provided in **Appendix B**. The chemical composition of the WWTW discharge in PresW1 and PresW2 (see **Figure 3.2** for proposed position entering the estuary via a small tributary outside the EFZ) is expected to comply with general standards (DWA, 2013) as shown in **Table 6.23**.

Table 6.23 Expected quality of discharge from the Port St Johns WWTW

Parameter	DWS general standards
Total NH_4-N (µg/ℓ)	6 000
NO_x-N (µg/ℓ)	15 000
Dissolved inorganic nitrogen (DIN) (µg/ℓ)	**21 000**
Dissolved inorganic phosphate (DIP) (µg/ℓ)	**10 000**
Suspended solids (mg/ℓ)	**25**

Given the proposed location where effluent from the proposed WWTW will enter the estuary, it is expected to have its major affect in Zone B (see **Figure 3.2**). Taking into account expected effluent volumes (i.e. 3.5Mℓ/day and 4.5Mℓ/day for PresW1 and W2, repectively), estimated composition of the effluent (see above), residence times in water of Zone B, as well as the estimated volume of estuarine water body (Zone B) into which the effluent will discharge (i.e. into which it will 'dilute'), water quality characteristics under different states is estimated in **Table 6.24** for scenarios PresW1 and PresW2, respectively:

Table 6.24 Expected water quality characteristics under different states for scenarios PresW1 and PresW2

PARAMETER		STATE 1: Significant saline			STATE 2: Intermediate saline			STATE 3: Limited saline			STATE 4: Freshwater		
Residence (day)		5	13	30	2	7	14	1	3	5	1	1	1
Salinity	PresW1	30	20	10	25	15	0	20	0	0	5	0	0
	PresW2	30	19	10	25	15	0	20	0	0	5	0	0
DO (mg/ℓ)	PresW1	8	4	7	8	5	7	8	7	8	8	8	8
	PresW2	8	3	7	8	4	7	8	6	8	8	8	8
Turbidity (NTU)	PresW1	40	40	60	40	50	70	90	160	160	250	250	250
	PresW2	40	40	60	40	50	70	90	160	160	250	250	250
DIN (µg/ℓ)	PresW1	100	650	150	120	380	180	130	280	180	180	210	180
	PresW2	100	800	150	120	450	180	130	310	180	180	220	180
DIP (µg/ℓ)	PresW1	10	260	25	15	135	30	15	80	30	30	45	30
	PresW2	10	330	25	15	165	30	15	95	30	30	50	30

Expected change in water quality characteristics under each of the scenarios and the water quality health scores are provided in **Tables 6.25** and **6.26**, respectively.

Table 6.25 Summary of changes in average water quality concentrations under various scenarios (see Figure 3.2 for zones)

Parameter	Scenarios	Summary of change	Zone		
			Lower	Middle	Upper
Salinity	Reference		12	1	0
	Present	Slight increase in salinity penetration.	12	2	0
	2a	Decrease in salinity penetration.	11	0	0
	2b		11	0	0
	32		11	0	0
	33		11	0	0
	41		11	0	0
	42		11	0	0
	51		11	0	0
	52		11	0	0
	53		11	1	0
	PresW1 and PresW2	During low flow states (1, 2 and 3) there will be a plug of freshwater moving up and down in section of estuary with salinity 15-20 (lower and middle reaches).	12	2	0
	Dam (1.5 MAR)	Increase in salinity due to an decrease in base flows.	18	6	0

Parameter	Scenarios	Summary of change	Zone		
			Lower	Middle	Upper
DIN (µg/ℓ)	Reference		93	92	92
	Present	Increased nutrient input from diffuse sources in the catchment, mainly settlements and cattle herds.	156	175	180
	2a		160	180	180
	2b		159	180	180
	32		160	180	180
	33		160	180	180
	41		159	180	180
	42		160	180	180
	51		159	180	180
	52		160	180	180
	53		160	178	180
	PresW1	Marked increase in Zone B (middle) as a result of WWTW effluent input.	156	225	180
	PresW2		156	279	180
	Dam (1.5 MAR)	Similar effect to present and future scenarios 2a-53.	154	174	180
DIP (µg/ℓ)	Reference		13	13	13
	Present	Increased nutrient input from diffuse sources in the catchment, mainly settlements and cattle herds.	23	29	30
	2a		24	30	30
	2b		24	30	30
	32		24	30	30
	33		24	30	30
	41		24	30	30
	42		24	30	30
	51		24	30	30
	52		24	30	30
	53		24	30	30
	PresW1	Marked increase in Zone B (middle) as a result of WWTW effluent input.	23	68	30
	PresW2		23	79	30
	Dam (1.5 MAR)	Similar effect to present and future scenarios 2a-53.	23	29	30
Dissolved oxygen (mg/ℓ)	Reference		8	8	8
	Present	No marked change from reference.	8	8	8
	2a		8	8	8
	2b		8	8	8
	32		8	8	8
	33		8	8	8
	41		8	8	8
	42		8	8	8
	51		8	8	8
	52		8	8	8
	53		8	8	8
	PresW1	Slight decrease expected due to influence for WWTW effluent in Zone B (middle) (organic enrichment).	8	7	8
	PresW2		8	7	8
	Dam (1.5 MAR)	No marked change from reference.	8	8	8

Parameter	Scenarios	Summary of change	Zone		
			Lower	Middle	Upper
Turbidity (NTU)	Reference		164	189	170
	Present	Limited erosion as a result of catchment practices. However, this catchment naturally introduced turbid waters to the estuary. Slight increase in future scenarios relates to increase in high flow states (States 3 and 4).	172	195	198
	2a		184	213	213
	2b		183	212	212
	32		184	213	213
	33		186	214	214
	41		183	212	212
	42		186	214	214
	51		183	212	212
	52		184	213	213
	53		184	210	210
	PresW1		172	195	198
	PresW2		172	195	198
	Dam (1.5 MAR)	Closer to reference compared with above Scenarios, due to redictino in higer flows.	165	191	193
Toxic substances	2a-S53 and Dam (1.5 MAR)	Some accumulation (e.g. trace metals) associated with urban development along banks of estuary (90).			
	PresW1 and PresW2	Some increase accumulation (e.g. trace metals) associated with urban development along banks of estuary and WWTW discharge (80).			

Table 6.26 Water quality health scores for present and future scenarios

Variable		Weight	Scenario												
			Pres	2a	2b	32	33	41	42	51	52	53	Pres W1	Pres W2	Dam (1.5 MAR)
1	**Salinity**	40	88	66	67	65	66	67	66	67	65	92	70*	65*	73
2	**General water quality**														
a	DIN/DIP concentrations	60	67	67	67	67	66	67	66	67	67	67	60	59	68
b	Turbidity		98	94	94	94	94	94	94	94	94	95	98	98	99
c	Dissolved oxygen		100	100	100	100	100	100	100	100	100	100	98	97	100
d	Toxic substances		90	90	90	90	90	90	90	90	90	90	80	80	90
Score: weighted mean (1,2 [min a-d]))			**75**	**67**	**67**	**66**	**66**	**67**	**66**	**67**	**66**	**77**	**64**	**61**	**70**

*Reflect loss of salinity structure

6.6 MICROALGAE

A summary of the changes in microalgae under each of the scenarios and the microalgae health scores for various scenarios are provided in **Tables 6.27** and **6.28**, respectively.

Table 6.27 Summary of changes in microalgae under present and future scenarios

Scenario	Summary of change
Present	Refer to **Table 5.8** for details.
2a	A change in flow (loss of State 2) results in a loss of residence time for phytoplankton; development of an REI requires > 2 weeks of residence time. As a result, phytoplankton biomass is likely to remain low (< 5 µg/ℓ) throughout the estuary (the average biomass flowing in river water is elevated as a result of elevated nutrients but the estuary acts as a conduit). The phytoplankton community composition shifted from a diatom-dominated community (reference; high diatom:flagellate ratio) to a community where flagellate, chlorophyte and dinoflagellate abundances were higher (reduced diatom:flagellate ratio); this is lower than present due to loss of State 2 (loss of dinoflagellates from upper zone). The dam is likely to trap coarser sediments and there should be a shift in sediment composition to fines (muddier). The benthic microalgal scores were determined based on changes to 'muddiness' of inter- and subtidal zones alone; assuming half of the present state change was related to nutrients (8% for richness and composition, and 10% for abundance), then the average change in physical characteristics of the inter- and subtidal zones for S2a (10%) was used to determine benthic microalgal scores.
2b	A change in flow (loss of State 2) results in a loss of residence time for phytoplankton; development of an REI requires > 2 weeks of residence time. As a result, phytoplankton biomass is likely to remain low (< 5 µg/ℓ) throughout the estuary (the average biomass flowing in river water is elevated as a result of elevated nutrients but the estuary acts as a conduit). The phytoplankton community composition shifted from a diatom-dominated community (reference; high diatom:flagellate ratio) to a community where flagellate, chlorophyte and dinoflagellate abundances were higher (reduced diatom:flagellate ratio); this is lower than present due to loss of State 2 (loss of dinoflagellates from upper zone). The dam is likely to trap coarser sediments and there should be a shift in sediment composition to fines (muddier). The benthic microalgal scores were determined based on changes to 'muddiness' of inter- and subtidal zones alone; assuming half of the present state change was related to nutrients (8% for richness and composition, and 10% for abundance), then the average change in physical characteristics of the inter- and subtidal zones for S2a (12%) was used to determine benthic microalgal scores.
32	A change in flow (loss of State 2) results in a loss of residence time for phytoplankton; development of an REI requires > 2 weeks of residence time. As a result, phytoplankton biomass is likely to remain low (< 5 µg/ℓ) throughout the estuary (the average biomass flowing in river water is elevated as a result of elevated nutrients but the estuary acts as a conduit). The phytoplankton community composition shifted from a diatom-dominated community (reference; high diatom:flagellate ratio) to a community where flagellate, chlorophyte and dinoflagellate abundances were higher (reduced diatom:flagellate ratio); this is lower than present due to loss of State 2 (loss of dinoflagellates from upper zone). The dam is likely to trap coarser sediments and there should be a shift in sediment composition to fines (muddier). The benthic microalgal scores were determined based on changes to 'muddiness' of inter- and subtidal zones alone; assuming half of the present state change was related to nutrients (8% for richness and composition, and 10% for abundance), then the average change in physical characteristics of the inter- and subtidal zones for S2a (22%) was used to determine benthic microalgal scores.
33	A change in flow (loss of State 2) results in a loss of residence time for phytoplankton; development of an REI requires > 2 weeks of residence time. As a result, phytoplankton biomass is likely to remain low (< 5 µg/ℓ) throughout the estuary (the average biomass flowing in river water is elevated as a result of elevated nutrients but the estuary acts as a conduit). The phytoplankton community composition shifted from a diatom dominated community (reference; high diatom:flagellate ratio) to a community where flagellate, chlorophyte and dinoflagellate abundances were higher (reduced diatom:flagellate ratio); this is lower than present due to loss of State 2 (loss of dinoflagellates from upper zone). The dam is likely to trap coarser sediments and there should be a shift in sediment composition to fines (muddier). The benthic microalgal scores were determined based on changes to 'muddiness' of inter- and subtidal zones alone; assuming half of the present state change was related to nutrients (8% for richness and composition, and 10% for abundance), then the average change in physical characteristics of the inter- and subtidal

Scenario	Summary of change
	zones for S2a (17%) was used to determine benthic microalgal scores.
41	A change in flow (loss of State 2) results in a loss of residence time for phytoplankton; development of an REI requires > 2 weeks of residence time. As a result, phytoplankton biomass is likely to remain low (< 5 µg/ℓ) throughout the estuary (the average biomass flowing in river water is elevated as a result of elevated nutrients but the estuary acts as a conduit). The phytoplankton community composition shifted from a diatom-dominated community (reference; high diatom:flagellate ratio) to a community where flagellate, chlorophyte and dinoflagellate abundances were higher (reduced diatom:flagellate ratio); this is lower than present due to loss of State 2 (loss of dinoflagellates from upper zone). The dam is likely to trap coarser sediments and there should be a shift in sediment composition to fines (muddier). The benthic microalgal scores were determined based on changes to 'muddiness' of inter- and subtidal zones alone; assuming half of the present state change was related to nutrients (8% for richness and composition, and 10% for abundance), then the average change in physical characteristics of the inter- and subtidal zones for S2a (12%) was used to determine benthic microalgal scores.
42	A change in flow (loss of State 2) results in a loss of residence time for phytoplankton; development of an REI requires > 2 weeks of residence time. As a result, phytoplankton biomass is likely to remain low (< 5 µg/ℓ) throughout the estuary (the average biomass flowing in river water is elevated as a result of elevated nutrients but the estuary acts as a conduit). The phytoplankton community composition shifted from a diatom dominated community (reference; high diatom:flagellate ratio) to a community where flagellate, chlorophyte and dinoflagellate abundances were higher (reduced diatom:flagellate ratio); this is lower than present due to loss of State 2 (loss of dinoflagellates from upper zone). The dam is likely to trap coarser sediments and there should be a shift in sediment composition to fines (muddier). The benthic microalgal scores were determined based on changes to 'muddiness' of inter- and subtidal zones alone; assuming half of the present state change was related to nutrients (8% for richness and composition, and 10% for abundance), then the average change in physical characteristics of the inter- and subtidal zones for S2a (17%) was used to determine benthic microalgal scores.
51	A change in flow (loss of State 2) results in a loss of residence time for phytoplankton; development of an REI requires > 2 weeks of residence time. As a result, phytoplankton biomass is likely to remain low (< 5 µg/ℓ) throughout the estuary (the average biomass flowing in river water is elevated as a result of elevated nutrients but the estuary acts as a conduit). The phytoplankton community composition shifted from a diatom dominated community (reference; high diatom:flagellate ratio) to a community where flagellate, chlorophyte and dinoflagellate abundances were higher (reduced diatom:flagellate ratio); this is lower than present due to loss of State 2 (loss of dinoflagellates from upper zone). The dam is likely to trap coarser sediments and there should be a shift in sediment composition to fines (muddier). The benthic microalgal scores were determined based on changes to 'muddiness' of inter- and subtidal zones alone; assuming half of the present state change was related to nutrients (8% for richness and composition, and 10% for abundance), then the average change in physical characteristics of the inter- and subtidal zones for S2a (12%) was used to determine benthic microalgal scores.
52	A change in flow (loss of State 2) results in a loss of residence time for phytoplankton; development of an REI requires >2 weeks of residence time. As a result, phytoplankton biomass is likely to remain low (<5 µg/ℓ) throughout the estuary (the average biomass flowing in river water is elevated as a result of elevated nutrients but the estuary acts as a conduit). The phytoplankton community composition shifted from a diatom dominated community (reference; high diatom:flagellate ratio) to a community where flagellate, chlorophyte and dinoflagellate abundances were higher (reduced diatom:flagellate ratio); this is lower than present due loss of State 2 (loss of dinoflagellates from upper zone). The dam is likely to trap coarser sediments and there should be a shift in sediment composition to fines (muddier). The benthic microalgal scores were determined based on changes to 'muddiness' of inter- and subtidal zones alone; assuming half of the present state change was related to nutrients (8% for richness and composition, and 10% for abundance), then the average change in physical characteristics of the inter- and subtidal zones for S2a (22%) was used to determine benthic microalgal scores.

Scenario	Summary of change
53	The 4% State 3 flow (elevated residence time) is likely to increase microalgal abundance but not as severely as the 13% State 3 flows at present; 25% increase from reference. A 5% change in muddiness of intertidal and subtidal sediments is likely to support an increase in microphytobenthos (MPB) biomass. Changes in phytoplankton richness (27% change from natural) and community composition (32%) are related to the shift from a diatom-dominated reference state as described in the scenarios S2a-S52 above. Changes in the MPB community composition and richness (20% change from natural) are related to a shift to epipelic microalgal taxa.
PresW1	3.5 Mℓ/d of nutrient-rich wastewater discharge is likely to support an increase in microalgal biomass (phytoplankton and MPB) in the middle reaches of the estuary. The particularly high orthophosphate and organic loads are likely to provide a suitable environment for cyanobacteria (a group capable of fixing atmospheric nitrogen). The change has been estimated to be a 5% increase in richness, abundance and community composition relative to the present state for both phytoplankton and benthic microalgae.
PresW2	4.5 Mℓ/d of nutrient-rich wastewater discharge is likely to support an increase in microalgal biomass (phytoplankton and MPB) in the middle reaches of the estuary. The particularly high orthophosphate and organic loads are likely to provide a suitable environment for cyanobacteria (a group capable of fixing atmospheric nitrogen). The change has been estimated to be a 7% increase in richness, abundance and community composition relative to the present state for both phytoplankton and benthic microalgae.
Dam (1.5 MAR)	A 1.5 MAR dam is likely to result in a slight decrease in river flow, increasing the residence time in the estuary by 1% compared to present, which is likely to result in an estimated 2% increase (abundance) or change (richness and composition) of phytoplankton. The intertidal and subtidal sediment composition are likely to become muddier by ~5%, which is likely to produce a proportional change in richness, abundance and composition of benthic microalgae (20%, 22% and 20% change from natural, respectively).

Table 6.28 Microalgae health scores for present and future scenarios

Variable		Scenario												
		Pres	**2a**	**2b**	**32**	**33**	**41**	**42**	**51**	**52**	**53**	**Pres W1**	**Pres W2**	**Dam (1.5 MAR)**
Phytoplankton														
a	Species richness	70	79	80	79	78	80	78	80	79	73	65	63	68
b	Abundance	72	81	82	81	80	82	80	82	81	75	67	65	70
c	Community composition	65	74	73	74	73	75	73	75	74	68	60	58	63
Benthic microalgae														
a	Species richness	85	82	80	70	75	80	75	80	70	80	80	78	80
b	Abundance	83	80	78	68	73	78	73	78	68	78	78	76	78
c	Community composition	85	82	80	70	75	80	75	80	70	80	80	78	80
Score: min (a-c)		**65**	**74**	**73**	**68**	**73**	**75**	**73**	**75**	**68**	**68**	**60**	**58**	**63**

6.7 MACROPHYTES

A summary of the changes in macrophytes under each of the scenarios and the macrophyte health scores for various scenarios are provided in **Tables 6.29** and **6.30**, respectively.

Table 6.29 Summary of changes in macrophytes under present and future scenarios

Scenario	Summary of change
2a – 2b	Small infilling of the supratidal, intertidal and subtidal areas will lead to an increase in the area occupied by reeds and sedges. This is due to the 4 and 5% decline in the magnitude of floods and increase in stability leading to macrophyte encroachment. The change in State 2 does not influence the macrophytes as salinity is within the tolerance range of the plants.
32	This is the worst case scenario as there will be a decline in floods (7%). The increase in nutrients, silt input and shallowing of the estuary will encourage reed encroachment into the main water channel. Although there are some salinity changes this is within the tolerance and optimum growth range of the dominant species. Invasive species and the loss of floodplain habitat remains.
33	Reed and sedge encroachment but not as severe as S32, 6 % decline in floods.
41	Similar to Scenario 2b, 5% decline in floods.
42	Similar to Scenario 33, 6 % decline in floods.
51	Reduced hydropower in dry months to introduce low flow to the estuary (State 2). However, this does not influence abiotic characteristics and therefore has no effect on the macrophytes. In terms of floods this scenario is similar to Scenario 2b and 41 as there is a 5% decline in floods which causes an increase in reeds growing into the main channel.
52	Reduced hydropower in dry months to introduce low flow to the estuary (State 2). Similar to worst case Scenario 32, 7% decline in floods leading to sediment stability and an increase in macrophyte growth.
53	Salinity moves closer to reference conditions, as State 2 is re-instated. Floods are reduced which causes a change in habitat. Floods are similar to Scenarios 41 and 51, a 5% reduction which causes infilling and sediment stability. This results in an increase in the encroachment of reeds and sedges.
PresW1	This scenario is the present condition plus wastewater input near the bridge. Nutrient input will have a localised influence on the macrophytes increasing growth and abundance with some possible spread of reeds onto open sand and mudbanks and into the main channel. In calmer sheltered areas on hard substrates, some macroalgal growth can be expected.
PresW2	The wastewater input volume is greater than the previous scenario. Nutrient input will have a localised influence on the macrophytes increasing growth and abundance with some possible spread of reeds into the main channel. Greater macroalgal growth than the previous scenario expected.
Dam (1.5 MAR)	Water abstraction results in an increase in salinity by approximately 3 ppt in the lower and middle reaches. Some possible decrease in species richness in response to higher salinity. Floods are reduced by 5% and there is an increase in reeds and sedges as conditions are more stable.

Table 6.30 Macrophytes health scores for present and future scenarios

Variable		Scenarios												
		Pres	**2a**	**2b**	**32**	**33**	**41**	**42**	**51**	**52**	**53**	**Pres W1**	**Pres W2**	**Dam (1.5 MAR)**
a	Species richness	85	85	84	80	81	84	81	84	80	84	83	83	80
b	Abundance	63	63	62	58	59	62	59	62	58	62	60	58	62
c	Community composition	66	66	65	61	62	65	62	65	61	65	63	63	66
Score: min (a to c)		**63**	**63**	**62**	**58**	**59**	**62**	**59**	**62**	**58**	**62**	**60**	**58**	**62**

6.8 INVERTEBRATES

A summary of the changes in invertebrates under each of the scenarios and the invertebrate health scores for various scenarios are provided for **Tables 6.31** and **6.33**.

Table 6.31 Summary of changes in invertebrates under present and future scenarios

Scenario	Summary of change
Present	This a system with a natural low diversity and abundance. This is driven by the very dominant physical processes such as high volume of strong outflows, low retention and mobile sediments. All of these drive a zooplankton and benthic community comprised of the tougher, opportunistic species and development of more diverse communities and higher biomass occurs during times of lower flow and greater marine penetration extending estuarine conditions beyond Zone 1 and into Zone 2. Studies on other large dyanamic systems show that the response of the invertebrate community under low flow conditions can occur over short time periods (two weeks). Under present conditions, the similar flow volumes, mouth behaviour and physical habitats suggests that the invertebrate community is very similar to reference from a species richness, biomass and community composition point of view.
2a	The increases in flow for these scenarios and the resultant loss of State 2 is considered to have no effect on species richness as the small number of freshwater-tolerant and opportunistic species which are found within the estuary would still occur in the lower zone. However, the increase in base flows over the critical low flow periods resulting in a loss of the productive middle zone as an estuary habitat means that overall abundance will be reduced and species composition is slightly altered by the fresher conditions.
2b	
32	
33	
41	
42	
51	
52	Increase in base flows further reduces species richness and productivity as a result of the change in salinity and to a small extent the increase in flood magnitude.
53	Small loss of estuarine species as the system gets more fresh than present, with more of an effect on abundance as the middle zone of the estuary feels most of this effect.
PresW1	Changes in the salinity regime, slight changes in nutrient retention and in turn microalgal and microphytobenthic food resources for invertebrates, result in an increased loss of species diversity (7%), with a greater effect on abundance and community composition.
PresW2	Changes in the salinity regime, slight changes in nutrient retention, and in turn microalgal and microphytobenthic food resources for invertebrates, result in an increased loss of species diversity (15%), with a greater effect on abundance and community composition.
Dam (1.5 MAR)	Under this scenario there would be a major reduction in the flood regime resulting in much shorter periods of strong outflow and greater tidall- driven salinity penetration as long as the mouth remains open. This results in reduction in base flow, less sediment mobility, possible sediment consolidation, more salinity penetration as the mouth remains open, greater water clarity and the development of a community with increased estuary species. The typical estuarine mero- and holoplankton would be forced upstream while areas nearer the mouth and under greater tidal influence would show a change towards a more neritic type community, especially after flood tide periods.

Table 6.32 Invertebrate health scores for present and future scenarios

Variable		Scenario												
		Pres	2a	2b	32	33	41	42	51	52	S53	PresW 1	PresW 2	Dam (1.5 MAR)
Zooplankton														
a	Species richness	95	95	95	95	95	95	95	95	95	93	93	85	92
b	Abundance	95	85	85	85	85	85	85	85	85	90	90	85	92
c	Community composition	95	87	87	87	87	87	87	87	87	90	93	90	92
Benthic macro-invertebrates														
a	Species richness	95	95	95	95	95	95	95	95	95	93	90	85	92
b	Abundance	95	75	75	75	75	75	75	75	70	75	85	80	95
c	Community composition	95	85	85	85	85	85	85	85	80	93	90	85	95
Score: min (a to c)		**95**	**75**	**75**	**75**	**75**	**75**	**75**	**75**	**70**	**75**	**85**	**80**	**92**

6.9 FISH

A summary of the changes in fish under each of the scenarios and the invertebrate health scores for various scenarios are provided in **Tables 6.33** and **6.34**, respectively.

Table 6.33 Summary of changes in fish under present and future scenarios

Scenario	Summary of change
Present	The hydrophysical and ecological processes that drive this system are still largely intact. There is some increase in the frequency of penetration of saline waters into the middle zones of the estuary, which favours use of this zone by a higher abundance of estuarine-dependent marine spawning fishes. There may be some loss of freshwater fish abundance in these conditions, but this is likely to be minimal, because freshwater fishes in the lower river are strongly dominated by hardy *Oreochromis mossambicus* and *Clarias gariepinus*. The former especially is highly tolerant of salinity. As a consequence it is unlikely that any fish species will have been permanently lost from the estuary. Abundance and biomass of estuarine-dependent marine spawning will have decreased, however, as a direct result of fishing pressure. Species targeted in recreational, commercial and subsistence fisheries will have declined in abundance (regionally and within the estuary). Species significantly impacted will include most notably *Pomadasys commersonnii* and *Argyrosomus japonicus*. There are also declines in the abundance of the Zambezi shark, *Carcharhinus leucas*. These reductions in abundance of fisheries species will result in a direct change in community composition due to changes in relative abundance of the constituent fishes. Indirect effects could also be expected due to changes in predation pressure on smaller species as a result of piscivores (such as *Argyrosomus japonicus*, *Lichia amia* and *Carcharhinus leucas*) being reduced in the estuary.
2a 2b 32 33 41 42 51 52	The most important aspect of all of these scenarios is that they all involve base flows higher than reference (and present) conditions. Under these scenarios, hydrodynamic and associated water quality State 2 will no longer occur in the system during the low flow period, as it did under reference conditions or as it does in the present day. Significant impacts can be expected with changes in salinity regime. Fish in this estuary are sensitive to changes in salinity distribution (in time and space) in the range of freshwater to oligohaline, and much less so in the mesohaline and polyhaline ranges. The loss of salinity penetration into the middle zones of the system therefore affects the estuary's nursery function and fisheries value, especially for estuarine-dependent fishes (fish category IIa, Whitfield 1998). Some estuarine migrant fishes (particularly some mullet species, most notably *Myxus capensis* and *Mugil cephalus*) and estuarine resident

Scenario	Summary of change
	species (such as *Gilchristella aestuaria*) will remain in the middle zone of the estuary under fresh conditions but the abundance of many others will decline markedly. This is important when considering that only two of the three estuarine zones (under the estuarine delineation considered, i.e. the lower and middle zones) experience salinity intrusion under the hydrodynamic states considered (reference, present and scenarios). Therefore at least 50% of the present estuarine influence by salinity, and the entire middle reach, will be affected in the low flow months because of elevated base flows under these scenarios. The estuarine nature of the system will be lost during these low flow periods. This is the critical nursery period that coincides with estuarine-dependant marine fishes breeding and recruitment cycles. Complete loss of estuarine-dependant marine species under these freshwater conditions is unlikely. Even species which generally show a preference for saline water will include a small percentage of individuals which will comfortably inhabit the middle zone under freshwater conditions. The full species complement will remain in the estuary as a whole, as the saline states generally persist in the lower reaches of the system over most of the low flow period. Indeed, while the system as a whole will see reduced abundance of fishes because of reduced habitat for estuarine-dependent marine species, the concentrations of these fishes in the lower reaches may increase under conditions of the middle reaches not being favourable (assuming that the lower reaches are not presently used to full capacity, which is unlikely given fishing pressure). This may make these populations susceptible to increased exploitation by fishing in the lower reaches. Under conditions of increased freshwater state in the middle reaches of the estuary it is unlikely that loss of abundance of estuarine-dependent marine fishes will be offset by an increase in freshwater fish abundance. The latter are largely restricted by daytime habitat availability (reed beds along the estuary banks). Impacts from turbidity (and other water quality changes) are probably negligible in the light of the changes in salinity. There is some decrease in floods which may affect the offshore estuary and result in changes in recruitment-cueing signals. This might affect recruitment of Anguillid eels, Zambezi sharks, and (to a lesser degree) estuarine fish. These impacts are probably not significant over the short term, but in the long-term population changes in the estuary, and the river upstream may result. In this regard it is also important that the 'offshore estuary' be considered. This is the area offshore of the Mzimvubu that is seasonally affected by the summer outflows. This is a critical area that is used by the estuarine fish assemblage under high flow conditions. During these periods these fishes are dependent on the turbid, low salinity conditions that are created offshore. Floods are therefore important for the fish assemblage of the Mzimvubu Estuary. Sediment budgets might be an issue at the the Mzimvubu depocentre, which is likely to be a feeding ground for some estuarine species. Scenarios that involve relative reductions in high flow floods (S32, S42 and S52) are therefore likely to result in some degree of loss of fish health score in the estuary, over the long term.
53	Flows under this scenario are very similar to those under the reference condition. Indeed, the distribution of abiotic states is closer to reference conditions than it is under recent conditions. An important difference however, is that base flows are slightly higher than under reference conditions (rather than slightly lower as is presently the case). This results in a reduced frequency of State 2 compared to reference conditions with impacts similar to those described above, and losses in abundance of estuarine-dependent marine species. These fishes are more susceptible to the complete loss of salinity than they are to slight gains in the mesohaline and polyhaline ranges. Impacts to the fish health score can be anticipated, and although not as significant as those associated with flow scenarios involving a hydroelectric scheme, these changes are expected to result in a loss in fish health score to below those experienced under present day conditions.
PresW1	Flows under this scenario are very similar to those under present conditions. Shifts in salinity are minor on average, but there might be localised impacts of low salinity water in the lower and middle reaches of the estuary under State 2. Although some oxygen reductions might be expected, over the wider area of the estuary these are slight and also localised, and salinity impacts are likely to be more of an issue (but see below). High nutrient inflows might result in an increase in benthic algae and over the longer term and increase in macrophytes (reed banks). The former could arguably favour some species, such as mullet (increase in food) but the latter will result in a loss of shallow tidal sandbank habitat which would be to the detriment of many estuarine fishes (including

Scenario	Summary of change
	mullet). A small tidal inlet point on the north bank is likely to be the recipient of WWTW outflow. This small inlet point is quite unique in the Mzimvubu Estuary in forming a backwater bay. Although small this habitat is likely to harbour species not found abundantly elsewhere in the system, which is otherwise quite linear and affected by ever-present flows. Species unique to this habitat are likely to include estuarine resident Eleortids and Gobiids. A few freshwater species might also use this habitat as a refuge. Discharge of wastewater to this backwater inlet might significantly affect its water quality and reduced dissolved oxygen concentrations could result in the loss of populations of these fishes from the estuary. Species richness might therefore be affected. The most significant impact (after fishing pressure) nevertheless remains flow-related impacts affecting fish abundances in the estuary.
PresW2	Impacts identical in nature, but slightly more severe than those described above (Scenario PresW1) can be expected.
Dam (1.5 MAR)	This scenario, involving reductions in base flows, results in increased penetration of salinity into the estuary, and higher frequency of States 1, 2 and 3. This will result in an increased area of saline habitat for estuarine-resident and estuarine-dependent marine fishes, and increases in abundance in these fishes. This will offset losses in populations of species that are heavily targeted by the various fisheries (*Pomadasys commersonnii* and *Argyrosomus japonicus*) and (assuming that fishing pressure remained constant) actually improve abundances of these fishes to more similar levels as those expected under reference conditions. Overall, however, and considering the full species array of estuarine fishes, increased extent and frequency of saline habitat will result in system abundances above reference conditions. Although reduced flows are beneficial for the estuarine function for most species, patterns of fish use in the estuary will deviate from the reference condition to a greater extent than is presently the case, and a slightly lower fish health score can be expected, with both fish abundance and community composition being affected. It is unlikely the any freshwater fishes will be lost because of the elevated salinity regime, and species richness in the system will remain the same as under reference conditions.

Table 6.34 Fish health scores for present and future scenarios

Variable		Scenario												
		Pres	**2a**	**2b**	**32**	**33**	**41**	**42**	**51**	**52**	**53**	**Pres W1**	**Pres W2**	**Dam (1.5 MAR)**
a	Species richness	100	100	100	100	100	100	100	100	100	100	90	85	100
b	Abundance	77	64	64	62	64	64	62	64	62	72	72	68	73
c	Community composition	78	70	70	65	70	70	65	70	65	73	73	70	73
Score: min (a to c)		**77**	**64**	**64**	**62**	**64**	**64**	**62**	**64**	**62**	**72**	**72**	**68**	**73**

6.10 BIRDS

A summary of the changes in birds under each of the scenarios and the invertebrate health scores for various scenarios are provided in **Tables 6.35** and **6.36**, respectively.

Table 6.35 Summary of changes in birds under present and future scenarios

Scenario	Summary of change
Present	There has been an overall decrease in bird numbers. Waterfowl have decreased due to a variety of anthropogenic pressures as well as increased salinity and have shifted in composition to increased species. Terns have decreased due to disturbance and changes in the mouth area. Waders have decreased slightly due to general population declines and habitat loss.
2a, 2b, 33, S41, 42, 51, 52	Waterfowl increase from present as a result of the system being fresher; waders decrease as a result of decreased habitat and benthic invertebrate abundance; piscivores decrease as a result of decreased fish abundance.
32, 53	Effects are very similar to the above but less pronounced.
PresW1 and PresW2	Waterfowl increase very slightly relative to present because the salinity is slightly lower; Piscivores do not change measurably because there is only a slight change in fish abundance; waders decrease slightly as there is a slight decrease in habitat and invertebrate abundance. The effects are slightly more pronounced under WW4.5 than WW3.5.
Dam (1.5 MAR)	Waterfowl increase very slightly relative to present because the salinity is slightly lower; Piscivores do not change measurably because there is only a slight change in fish abundance; waders decrease slightly as there is a slight decrease in habitat and invertebrate abundance.

Table 6.36 Bird health scores for present and future scenarios

Variable		Scenario												
		Pres	2a	2b	32	33	41	42	51	52	53	Pres W1	Pres W2	Dam (1.5 MAR)
a	Species richness	90	90	90	90	90	90	90	90	90	90	90	90	90
b	Abundance	61	62	62	62	62	62	62	62	62	62	62	62	62
c	Community composition	76	77	77	77	77	77	77	77	77	76	75	75	73
Score: min (a to c)		**61**	**62**	**62**	**62**	**62**	**62**	**62**	**62**	**62**	**62**	**62**	**62**	**62**

6.11 ECOLOGICAL CATEGORIES ASSOCIATED WITH FUTURE SCENARIOS

The individual health scores for the various abiotic and biotic components are used to determine the ecological status or ecological category for the Mzimvubu Estuary under various future scenarios (**Table 6.37**), again using the EHI.

Table 6.37 EHI score and corresponding ecological categories under present and future scenarios

Variable	Wght	Scenario												
		Pres	2a	2b	32	33	41	42	51	52	53	Pres W1	Pres W2	Dam (1.5 MAR)
Hydrology	25	89	85	86	85	85	86	85	87	86	97	90	90	84
Physical habitat	25	98	97	97	97	97	97	97	97	97	99	98	98	98
Hydrodynamics/ mouth condition	25	75	67	67	66	66	67	66	67	66	77	64	61	70
Water quality	25	94	92	89	79	84	89	84	89	79	89	93	94	89
Habitat health	**50**	**89**	**85**	**85**	**82**	**83**	**85**	**83**	**85**	**82**	**90**	**86**	**86**	**85**

Variable	Wght	Scenario												
		Pres	2a	2b	32	33	41	42	51	52	53	Pres W1	Pres W2	Dam (1.5 MAR)
score														
Microalgae	20	65	74	73	68	73	75	73	75	68	68	60	58	63
Macrophytes	20	63	63	62	58	59	62	59	62	58	62	60	58	62
Invertebrates	20	95	75	75	75	75	75	75	75	70	75	85	80	92
Fish	20	77	64	64	62	64	64	62	64	62	72	72	68	73
Birds	20	61	62	62	62	62	62	62	62	62	62	62	62	62
Biotic health score	**50**	**72**	**68**	**67**	**65**	**67**	**68**	**66**	**68**	**64**	**68**	**68**	**65**	**70**
ESTUARY HEALTH SCORE		**81**	**76**	**76**	**73**	**75**	**76**	**75**	**76**	**73**	**79**	**77**	**75**	**78**
ECOLOGICAL CATEGORY		**B**	**B/C**	**B/C**	**B/C**	**B/C**	**B/C**	**B/C**	**B/C**	**B/C**	**B**	**B/C**	**B/C**	**B/C**

6.12 OVERALL CONFIDENCE LEVELS IN THE STUDY

Confidence of this study is **medium**. Confidence levels of the various components, as well as an indication of data availability, are summarised in **Table 6.38.**

Table 6.38 Mzimvubu Estuary EWR study: Data availability and confidence levels

Component	Data availability (derived from DWS, 2014b)	Confidence in ecological category	
		PES	Future scenarios
Hydrology	M	M	M
Hydrodynamics	M	M	M
Physical habitat	L/M	M	M
Water quality	L/M	L/M	L
Microalgae	M	M	M
Macrophytes	M	M	M
Invertebrates	M	M	M
Fish	L/M	M	L
Birds	M	M	M
Overall confidence		**Medium**	**Medium**

M: Medium; L: Low

7 RECOMMENDATIONS

7.1 RECOMMENDED ECOLOGICAL CATEGORY

Applying the guidelines for the determination of the REC (refer to **Table 7.1**), based on an estuary's PES and importance, the Recommended Ecological Category for the Mzimvubu Estuary should be a **Category A** or at least **Best Attainable State**.

Table 7.1 Guidelines to assign REC based on protection status and importance, as well as PES of an estuary (DWAF, 2008)

Protection status and importance	REC	Policy basis
Protected area	A or BAS*	Protected and desired protected areas should be restored to and maintained in the best possible state of health.
Desired Protected Area (based on complementarity)		
Highly important	**PES + 1, min B**	**Highly important estuaries should be in an A or B category.**
Important	PES + 1, min C	Important estuaries should be in an A, B or C category.
Of low to average importance	PES, min D	The remaining estuaries can be allowed to remain in a D category.

* BAS = Best Attainable State

Consideration of the Mzimvubu Estuary's present state and related issues, led to the BAS being set at a **Category B**, i.e. within the PES category. Most of the changes in this estuary have not been a result of flow modification, but rather non-flow related pressures such as habitat destruction, alien invasive plants, nutrient enrichment (pollution), over-fishing and human disturbances to birds. As some of these anthropogenic impacts would be difficult to remove or improve, e.g. status of marine fish stocks, the REC was set as a **Category B**.

The following anthrpogenic pressures should however be addressed to ensure that the system stays in a Category B:

- Return some variability to the mouth dynamics through removal of the access road behind the area formerly known as 'First Beach', which has effectively entrained the estuary mouth.
- Reinstating local sediment dynamics (also through the removal of the abovementioned access road). The realistic possibility of reversing the loss of 'First Beach' could potentially re-establish this once-popular recreational beach for the town of Port St Johns.
- Institute land-use management regulation within the EFZ zone that focuses on restricting the loss of further habitat within this zone and the estuary floodplain up to the 10 m contour (or 10 m above mean sea level).
- Rehabilitate disturbed areas of the estuary EFZ where impacts are reversible; rehabilitation would significantly enhance the functional integrity and importance of the estuary as a whole.
- Establish a programme for invasive alien plant management within the estuary floodplain, which would make a significant contribution towards addressing this and enhancing the functional importance of the floodplain as a feature of the estuary.
- Manage fishing pressure in the estuary through the possible partial closure of the estuary to fishing in order to protect important fish stocks and sensitive habitats.
- Address possible point-source pollution risks from the canalised creek that flows from the town of Port St Johns, as the study has suggested that this canal may be compromising water quality.

7.2 RECOMMENDED ECOLOGICAL FLOW SCENARIO

The EWR methods for estuaries (DWAF, 2008) set the following as a guideline for the Ecological Flow Requirement Scenario: *"The recommended Ecological Flow Requirement scenario is defined as the flow scenario (or a slight modification thereof) that represents the highest change in river inflow that will maintain the estuary in the Recommended Ecological Category".*

In the case of the Mzimvubu Estuary a **Category B** was proposed as the REC, which is similar to the PES. The recommended ecological flow scenario was set as that equivalent to scenario 53, with a flow distribution as presented in **Table 7.2**.

Table 7.2 Recommended Ecological Flow scenario for the Mzimvubu Estuary (REC – Category B)

%iles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	324	449	401	611	672	970	487	391	297	314	155	747
99	279	406	392	599	619	691	374	235	295	232	143	272
95	129	275	300	446	541	526	264	81	81	103	56	83
90	92	189	254	310	508	369	174	65	47	34	37	51
85	80	129	201	222	381	278	131	55	34	29	27	29
80	58	92	176	178	272	237	111	45	28	25	23	23
70	41	67	130	147	188	201	102	33	21	20	17	19
60	32	57	71	107	153	162	81	25	18	17	14	15
50	27	47	53	82	121	133	70	23	16	14	13	14
40	24	39	43	70	86	113	58	20	14	12	12	12
30	23	37	39	58	70	80	52	18	13	12	11	11
20	21	35	34	52	58	68	48	17	12	10	10	10
15	20	32	33	43	54	63	44	16	11	10	10	10
10	19	31	31	37	46	57	40	15	11	10	10	9
5	18	30	27	35	40	47	35	15	11	10	9	8
1	16	28	26	30	31	37	31	13	10	9	8	8

7.3 ECOLOGICAL SPECIFICATIONS

EcoSpecs define the Ecological Category (EC). Thresholds of Potential Concern (TPCs) are upper and lower levels along a continuum of change in selected environmental indicators and are used and interpreted according to the guidelines set out in Rogers and Bestbier (1997). A monitoring programme must be designed according to the principles of adaptive management to provide guidance on how to address issues if the EcoSpecs and TPCs (Rogers and Bestbier, 1997) are exceeded. A monitoring programme for the Mzimvubu Estuary will be included in the Monitoring Report for the Mzimvubu Classification study.

The EcoSpecs, as well as the TPCs, representative of a Category B (PES/REC) for the Mzimvubu Estuary, are presented in **Table 7.3**.

Table 7.3 EcoSpecs and TPCs for the Mzumvubu Estuary (PES/REC: Category B)

Component	EcoSpecs	TPCs
Hydrology	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	River inflow distribution patterns differ by more than 5% from that of scenario 53 (i.e. the recommended flow scenario).
Hydrodynamics	Maintain mouth condition and hydrodynamics to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ The mouth of the estuary becomes very constricted or closed. ▪ Changes in tidal amplitude at the tidal gauge of more than 20% from the PES (2017).
Sediment dynamics	Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as to not exceed TPCs for biota (see above).	▪ River inflow distribution patterns (flood components) differ by more than 20% (in terms of magnitude, timing and variability) from that of the PES (2017). ▪ Suspended sediment concentration from river inflow deviates by more than 20% of the sediment load-discharge relationship to be determined as part of baseline studies (PES 2017). ▪ Findings from the bathymetric surveys undertaken as part of a monitoring programme indicate changes in the sedimentation and erosion patterns in the estuary have occurred (± 0.5 m).
	Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates (see above).	▪ The median bed sediment diameter deviates by more than a factor of two from levels to be determined as part of baseline studies (PES 2017). ▪ Sand/mud distribution in middle and upper reaches changes by more than 20% from PES (2017). ▪ Changes in tidal amplitude at the tidal gauge of more than 20% from PES (2017).
Water quality	Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae.	▪ Salinity in the winter months remains low for more than 50% of the time (4 to 6 months): – Lower reaches: < 20 ▪ Salinity in winter months remains low for more than 80% of the time (1 to 2 months): – Lower reaches: < 25 – Middle reaches: < 15
	System variables (pH, dissolved oxygen and transparency) not to exceed TPCs for biota.	▪ River inflow and estuary: – 7.0 < pH > 8.5 – Dissolved Oxygen (DO) less than 6 mg/ℓ – Turbidity (naturally turbid)
	Inorganic nutrient concentrations not to cause exceedance of TPCs for macrophytes and microalgae.	▪ River inflow: – Average Dissolved Inorganic Nitrogen (DIN) > 200 µg/ℓ; Dissolved Inorganic Phosphate (DIP) > 30 µg/ℓ ▪ Estuary: – Average DIN > 150 µg/ℓ; DIP > 20 µg/ℓ
	Presence of toxic substances not to cause exceedance of TPCs for biota.	▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995).

Component	EcoSpecs	TPCs
		▪ Substance concentrations in estuarine sediment not to exceed targets as per Western Indian Ocean (WIO) Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Microalgae	Maintain low phytoplankton biomass (average chlorophyll *a* < 20 µg/ℓ or median chlorophyll *a* < 3.5 µg/ℓ) and a diversity of phytoplankton groups (cyanobacteria excluded). Maintain medium intertidal benthic microalgal biomass (median chlorophyll a < 23 mg/m^2).	▪ Observable blooms and scums in the estuary. Consistent high phytoplankton biomass (average chlorophyll a > 20 µg/ℓ or median chlorophyll a > 3.5 µg/ℓ) as a result of high nutrient inputs and increase in water retention. ▪ Presence of cyanobacteria.
Macrophytes	Maintain the diversity of macrophyte habitats in the estuary. Reeds and sedges covering approximately 16 ha. Prevent further disturbance and development of the floodplain habitat	▪ Sedimentation in main channel and colonisation by vegetation. 50% loss of reed and sedge habitats in non-flood year due to salinity changes. No increase in invasive species in riparian zone.
Invertebrates	The low-diversity invertebrate community should have representatives of the original freshwater, opportunistic taxa.	▪ The invertebrate community is structured by the physico-chemical drivers of the system, more specifically the periodic high flow levels which result in periods of low salinities and sediment instability that are inimical to the expansion of a benthic community. ▪ The channel-like nature of the estuary results in very few intertidal areas while the edges, especially amongst the reed beds, are characterised by soft sediments that support only suitably specialised species.
Fish	▪ The lower reaches (zone) in its entirety acts as a nursery to a diversity of estuarine dependence category IIa (Whitfield, 1998) species. ▪ The middle reaches of the estuary are used as a nursery to the same species during the low flow period and over the months June – October, for 4 out of 5 years on average. ▪ A good trophic basis exists for predatory estuarine dependant marine species (most notably *Agyrosomus japonicus* and *Pomadasys commersonnii*) ▪ Estuarine resident species represented by core group (*Glossogobius* spp., *Oligolepis* spp. *Ambassis* spp. and *Gilchistella aestuaria*). The upper reaches of the estuary are used by these species as well. ▪ *Oreochromis mossambicus* limited to the lower reaches	▪ An abundance (to be defined as an average with prediction limits) of estuarine dependence category IIa species as young juveniles in winter and spring and early summer (*Solea bleekeri*, *Acanthopagrus vagus*, *Pomadasys commersonnii*, *Agyrosomus japonicus*, *Rhabdosargus holubi*) ▪ Mullet occur throughout the system, throughout the year, represented by a full array of size classes. ▪ Any one of these species does not occur in the estuary in two consecutive years. ▪ *Oreochromis mossambicus* distribution extends into the lower reaches of the estuary for more than two consecutive years. ▪ Alien fish species occur. ▪ A decline in catches (*Agyrosomus japonicus* or *Pomadasys commersonnii*) (not related to gear changes or bag limit restrictions). Estuarine-dependent marine species occurring abundantly in the upper reaches.

Component	EcoSpecs	TPCs
	of middle zone in the low flow period for most of the time. ▪ Species assemblage comprises indigenous species only. ▪ Connectivity to healthy transitional marine-estuarine waters (the offshore estuary) is maintained. Connectivity down the full length of the estuary and into the marine environment is maintained.	
Birds	The estuary should contain an avifaunal community that includes representatives of all the original groups. Tern roosts should be seen from time to time.	▪ Number of waterbird species recorded per count drops below 10 for 3 consecutive seasons. ▪ Summer numbers of waterbirds other than gulls and terns drop below 50 for 3 consecutive seasons. ▪ Once enough winter counts have been made, an appropriate winter threshold will need to be identified.

7.4 ADDITIONAL BASELINE SURVEYS

Additional baseline studies that are important to the improvement of the confidence of the EWR study are provided in **Table 7.4.** These components are all important to improve the confidence overall, but the sediment dynamics and invertebrate components, especially, are of a high priority.

Table 7.4 Additional baseline surveys to improve confidence of EWR study on the Mzimvubu Estuary (highest priorities are highlighted)

Component	Action	Temporal scale (frequency and when)	Spatial scale (stations)
Hydrology	Freshwater inflow	Continuous	Station added to DWS water quality (WQ) monitoring network closer to head of estuary, 15 km from mouth.
Hydrodynamics	Record water levels in estuary	Continuous	As close to estuary mouth as possible to capture tidal rise and fall – currently on road bridge and sufficient for needs.
	Aerial photographs of estuary (spring low tide)	Bi-annual	Low spring tide during winter and summer.
Sediment dynamics	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but more detailed in the mouth (every 100 m). The vertical accuracy should be about 5 cm.	Every 3 years	Entire estuary.
	Set sediment grab samples (at cross-section profiles) for analysis of particle-size distribution and origin (i.e. using microscopic observations).	Every 3 years	Entire estuary.

Component	Action	Temporal scale (frequency and when)	Spatial scale (stations)
Water quality	Electrical conductivity, pH, inorganic nutrients and organic content (e.g. TP and Kjeldahl N) in river inflow *(preferably also suspended solids and temperature).*	Monthly	Station added to DWS WQ monitoring network closer to head of estuary, 15 km from mouth.
	2 in situ salinity and temperature recoders	Continuous	Lower and middle reaches.
	Salinity and temperature profiles (<u>surface to bottom</u>) (and any other in situ measurements possible, e.g. pH, DO, turbidity).	Once during high flow and low flow season	At selected stations.
	Total suspended solids and inorganic nutrient concentrations in <u>surface and bottom waters</u> (together with above).	Once during high flow and low flow season	Along entire length of estuary in deepest areas (6–10 stations).
	Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – see Newman and Watling, 2007).	Once-off	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae	Phytoplankton biomass (using chlorophyll *a* as an index). Determine phytoplankton group structure; diatoms, dinoflagellates, flagellates, chlorophytes and cyanobacteria using Utermohl method. Determine benthic chlorophyll *a* and diatom community structure in the intertidal and subtidal zones.	Once-off during low flow conditions; < 3 m^3/s.	At least 5 sites along the full salinity gradient (estuary mouth to fresh upper reaches (< 1 PSU).
Macrophytes	No additional baseline surveys required		
Invertebrates	Record benthic invertebrate species and abundance, based on subtidal grab and intertidal core samples at a series of stations along the entire length of the estuary. Include observations of macrocrustacean fauna such as sesarmid crabs and sandprawns (hole counts).	At least three low flow samples	Entire estuary.
Fish	Record species and abundance of fish, based on seine-net and gill-net sampling. The data will establish baselines and provide a measure of natural variability. They should be based on replicate sampling of stations and wet and dry seasons. Sampling during floods and freshettes should be avoided (and discounted in the baseline data set). In situ physico-chemical measurements should be made of temperature, salinity, turbidity, dissolved oxygen and pH throughout the water column concurrent with fish sampling. Some focus should be given to sampling habitats for freshwater fish species using dip-nets (and possibly electroshocking) in vegetated (or elsewise structured) habitats.	Early winter, late winter, spring (i.e. 3 surveys annually) every year for 3 years	Entire estuary (minimum 12 stations, replicate hauls and sets at each).
Birds	Count all the waterbirds on the estuary.	Every summer and winter	Counts should be divided into upper, middle and lower estuary.

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APPENDIX A: DETAILED SIMULATED RUNOFF SCENARIOS

Reference condition (m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	26.9	21.6	28.8	35.9	104.1	205.2	123.3	45.2	18.8	11.5	8.3	13.7
1921	23.7	276.1	248.2	76.6	30.9	19.3	10.1	87.1	86.9	60.2	59.2	34.5
1922	51.0	178.2	81.1	199.0	519.0	281.0	70.5	13.2	12.7	240.5	109.1	17.0
1923	10.8	10.8	24.8	94.6	148.0	125.3	48.3	14.2	14.4	11.0	11.0	18.0
1924	18.9	30.1	377.8	162.2	55.7	597.8	318.0	66.2	18.0	11.6	8.7	14.2
1925	14.2	33.4	27.1	66.2	49.3	290.4	121.3	22.1	36.7	26.3	12.2	27.7
1926	43.1	40.1	63.1	43.6	54.0	665.4	265.6	18.5	10.6	11.3	13.8	12.5
1927	30.7	25.2	115.8	319.3	185.1	89.7	35.7	14.0	12.5	10.2	17.6	15.3
1928	18.7	36.4	82.4	54.4	51.4	257.9	109.0	20.8	55.5	61.5	33.7	91.7
1929	101.7	87.3	147.3	158.3	66.2	114.3	85.6	28.2	21.4	19.3	53.3	42.3
1930	25.6	15.4	38.6	348.5	343.1	291.1	123.4	26.1	12.2	344.9	152.2	15.9
1931	21.3	30.7	75.3	46.4	299.0	137.1	28.7	17.4	19.1	25.6	18.4	53.4
1932	52.9	210.1	184.5	51.6	19.6	54.2	40.2	14.9	9.4	9.9	8.9	7.6
1933	6.9	337.8	352.9	586.4	247.1	155.1	78.8	18.8	13.8	32.3	24.1	10.4
1934	37.3	77.4	186.4	89.0	36.9	77.1	136.3	106.1	91.0	40.0	35.4	24.7
1935	13.9	13.6	7.4	12.7	292.0	173.7	44.0	71.6	47.5	24.3	15.1	10.6
1936	29.1	484.1	189.1	70.9	516.3	227.3	44.4	12.0	10.2	9.3	8.0	9.5
1937	13.1	13.6	37.7	119.0	257.6	98.5	110.3	56.1	25.5	29.1	27.1	17.4
1938	23.4	49.5	242.5	243.7	680.3	225.6	27.3	22.7	19.3	25.5	22.6	127.9
1939	89.7	59.0	36.0	31.1	402.3	226.1	69.1	130.0	69.6	18.8	11.1	27.6
1940	26.5	31.9	79.7	114.1	134.9	68.8	50.6	25.8	12.7	12.7	12.2	9.5
1941	20.9	19.3	8.6	66.3	349.0	255.0	102.6	45.4	21.4	11.3	15.9	21.1
1942	49.1	274.2	382.5	197.3	57.3	159.5	210.5	87.5	44.4	31.1	165.8	93.0
1943	83.2	320.3	307.9	162.9	117.4	148.3	65.5	14.3	23.9	22.9	12.8	196.2
1944	100.8	21.9	6.7	40.8	226.2	250.6	84.1	15.6	12.2	9.7	7.8	6.7
1945	38.0	23.3	12.8	131.0	111.3	133.2	71.3	34.3	21.4	13.0	9.4	7.8
1946	12.8	35.5	41.9	105.2	167.6	199.1	100.6	27.1	50.1	36.6	15.4	17.0
1947	22.6	315.4	225.7	183.8	311.1	282.7	107.1	26.0	13.3	10.1	7.9	6.7
1948	18.8	18.1	14.3	48.8	83.6	69.0	43.0	22.6	12.9	11.4	10.1	9.8
1949	10.8	20.1	30.4	40.2	258.6	424.8	155.3	54.3	33.3	20.7	62.5	40.8
1950	32.6	24.9	226.8	126.9	147.9	81.1	30.9	15.0	11.8	9.5	15.8	28.3
1951	58.1	29.1	9.6	45.7	221.9	106.7	38.8	23.9	17.2	15.7	11.9	25.4
1952	23.2	41.0	90.0	68.5	97.8	62.7	49.0	27.4	11.9	8.8	10.9	36.8
1953	61.0	62.1	65.1	59.5	77.7	111.2	59.4	70.4	63.2	31.0	13.7	14.5
1954	51.2	46.6	30.8	521.6	540.8	157.4	61.7	33.4	25.2	18.0	9.7	11.9
1955	20.3	42.2	38.6	22.8	174.6	290.8	112.2	23.2	21.2	14.7	9.7	16.0
1956	21.8	106.9	422.3	350.2	167.2	239.8	127.6	33.9	17.0	14.4	24.3	96.5
1957	86.0	41.2	35.3	203.0	135.9	45.2	64.7	42.0	17.8	12.2	9.6	9.1
1958	9.1	131.4	232.5	86.3	84.1	66.4	67.5	418.6	166.5	43.1	37.2	23.3
1959	19.1	39.7	41.1	65.1	76.5	51.9	41.6	27.6	15.2	11.0	14.6	24.5
1960	22.8	55.6	153.6	85.9	56.0	144.2	158.4	64.2	22.5	12.3	11.8	10.6
1961	7.8	61.4	67.7	58.2	222.8	199.8	79.8	24.0	13.7	9.5	10.8	9.1
1962	14.5	90.7	79.9	398.6	240.0	522.1	218.9	31.8	14.5	43.5	28.2	9.8
1963	95.7	176.9	83.2	140.9	74.3	147.0	115.4	39.5	302.0	127.5	20.2	20.0
1964	101.5	49.4	28.1	50.6	105.0	48.3	20.6	17.6	208.8	124.5	64.3	35.3
1965	71.0	104.5	40.6	242.6	160.1	34.4	12.0	57.4	39.1	14.5	17.2	21.2
1966	16.4	15.6	38.3	174.7	194.8	494.7	274.3	69.6	34.8	37.9	23.0	9.9
1967	14.3	25.8	21.2	18.3	28.1	54.6	38.7	16.7	9.3	9.1	12.9	20.8
1968	18.2	19.8	19.3	13.6	59.0	245.8	116.4	38.3	22.5	14.0	11.8	9.9
1969	40.6	31.2	36.3	28.1	62.0	32.9	10.3	11.7	20.0	15.4	78.6	68.1
1970	136.1	70.8	26.3	115.0	102.9	53.4	37.9	57.3	37.4	32.3	66.3	38.0
1971	168.6	89.8	45.2	153.2	491.5	303.6	83.8	19.4	15.0	11.8	9.0	8.7
1972	12.7	96.9	49.2	21.8	281.4	196.2	83.0	26.9	12.3	12.1	14.9	17.6
1973	20.1	65.9	46.1	432.0	478.5	533.7	196.2	70.3	43.5	22.2	14.4	8.9
1974	9.5	67.4	67.0	44.5	52.7	63.5	43.7	17.4	10.0	8.9	8.4	68.1
1975	36.9	30.6	511.2	604.1	536.2	998.8	357.7	77.0	43.1	18.1	12.0	29.5
1976	286.3	122.9	21.0	69.6	126.9	89.0	47.6	20.6	12.8	13.9	13.1	24.4
1977	55.8	51.8	67.5	75.2	66.5	168.4	573.9	211.2	24.7	12.4	15.4	36.7
1978	74.1	70.8	171.9	74.7	97.5	61.6	35.9	20.6	14.4	40.4	37.2	22.2
1979	22.0	17.7	20.2	96.1	128.5	67.7	28.9	13.0	10.1	9.3	7.6	107.9
1980	57.9	53.7	39.2	124.6	258.7	102.7	23.8	31.5	27.9	14.6	25.3	23.4
1981	14.1	20.3	36.5	66.4	74.4	271.6	129.3	26.8	22.5	27.8	17.6	15.2
1982	45.6	51.5	20.4	9.4	9.8	16.6	23.4	16.3	10.8	23.9	15.0	14.6
1983	24.4	87.3	197.2	130.5	103.9	149.5	110.5	38.7	22.8	31.4	20.8	11.5
1984	35.4	49.0	23.2	147.8	601.5	195.7	17.5	10.3	8.8	8.1	6.6	8.0
1985	241.5	148.2	136.2	233.3	131.5	63.5	34.0	13.8	11.6	11.4	22.2	28.6
1986	119.6	143.2	59.0	32.7	49.0	78.9	44.1	14.3	14.2	12.1	29.9	872.0
1987	339.8	65.8	44.7	64.3	556.8	392.6	113.5	44.3	28.1	22.1	19.0	19.7
1988	22.6	60.1	195.1	128.2	508.9	189.7	137.6	66.8	20.0	19.7	13.2	7.2
1989	41.2	433.2	195.8	85.1	42.3	283.3	138.0	27.2	16.3	14.0	21.8	16.5
1990	22.2	16.4	41.1	140.9	173.1	62.6	16.3	9.0	9.5	8.4	6.9	13.3
1991	223.4	123.6	145.4	72.3	92.2	56.0	31.0	16.0	9.2	7.6	9.3	11.8
1992	12.7	21.7	13.3	13.6	59.7	121.3	59.3	17.0	8.8	6.7	9.0	17.5
1993	137.2	85.9	153.3	195.5	255.0	318.7	116.6	13.5	11.2	19.0	20.3	11.0
1994	10.1	21.6	31.2	72.7	44.7	179.2	127.2	39.6	29.7	22.5	11.3	12.8
1995	25.3	29.0	364.8	623.0	551.0	170.6	45.4	18.7	14.3	30.7	21.5	11.7
1996	17.2	197.7	221.1	327.3	184.8	117.6	109.1	47.9	305.7	144.0	35.7	16.4
1997	24.5	42.6	26.7	99.5	623.8	407.3	112.5	30.5	17.4	13.8	16.5	13.3
1998	12.9	75.4	173.1	154.0	270.5	150.8	46.6	16.1	11.8	10.7	8.4	6.8
1999	37.1	37.2	290.6	580.9	422.6	632.5	299.3	82.8	34.2	15.8	10.3	20.5
2000	33.6	46.7	85.1	171.7	143.8	105.9	64.0	27.4	14.9	14.2	14.0	18.0
2001	41.9	357.4	272.3	160.1	102.2	151.1	65.6	28.8	25.8	42.9	93.8	78.4
2002	31.4	14.9	38.5	62.0	45.9	62.8	40.9	21.5	16.6	11.3	10.7	21.5
2003	16.0	14.5	12.5	65.8	100.7	173.2	83.5	18.0	12.5	31.9	29.4	89.5
2004	52.2	78.6	138.7	203.8	124.4	82.0	43.1	16.5	11.3	8.8	9.9	7.9
Average	50.4	85.5	110.6	144.9	199.9	194.3	95.3	40.8	33.5	29.9	24.7	38.0
Min	6.9	10.8	6.7	9.4	9.8	16.6	10.1	9.0	8.8	6.7	6.6	6.7
Max	339.8	484.1	511.2	623.0	680.3	998.8	573.9	418.6	305.7	344.9	165.8	872.0

Present state, PresW1 and PresW2 (m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	24.3	19.5	26.7	32.2	100.4	198.4	120.3	42.2	16.3	9.1	6.1	11.0
1921	21.1	268.6	243.0	73.4	29.9	18.2	8.4	84.2	83.3	56.8	56.3	31.1
1922	48.8	173.7	78.5	194.1	512.4	278.0	67.5	11.1	10.3	234.1	103.9	14.1
1923	8.5	8.9	23.5	88.8	143.9	122.3	43.7	12.1	11.8	8.6	8.7	15.3
1924	16.2	27.7	364.7	155.8	54.4	589.8	310.2	62.4	15.1	9.0	6.3	11.3
1925	11.6	31.4	25.0	62.5	45.2	281.6	116.3	19.7	33.3	23.2	9.8	24.7
1926	39.9	37.3	59.9	40.1	50.9	653.8	259.0	16.2	8.0	8.9	11.0	9.4
1927	27.4	22.1	110.2	307.3	179.2	88.8	33.2	11.7	9.9	7.8	14.8	12.5
1928	16.3	33.3	77.2	49.7	48.0	249.0	103.6	18.7	51.6	57.8	30.3	87.2
1929	96.9	83.5	141.4	151.1	62.4	109.2	81.5	25.6	18.8	16.4	49.6	38.3
1930	22.9	13.4	36.4	337.1	334.5	285.1	119.8	23.5	9.6	335.2	145.3	13.1
1931	18.7	28.1	70.8	42.3	288.2	132.1	26.1	15.4	16.3	22.4	15.4	49.0
1932	49.0	202.8	177.8	48.1	17.9	51.3	37.0	12.5	7.1	7.5	6.5	5.5
1933	5.1	322.6	341.9	576.4	241.0	150.4	74.7	16.7	11.0	28.6	20.8	7.9
1934	34.3	73.5	179.3	84.7	34.7	73.2	131.9	102.3	87.5	36.8	32.3	21.4
1935	11.5	11.6	5.8	11.2	279.8	168.2	41.6	68.8	43.4	21.4	12.5	8.1
1936	26.2	469.9	183.2	68.0	507.1	221.3	41.1	9.8	7.7	6.9	5.7	7.1
1937	10.8	11.7	35.7	112.5	246.6	93.9	106.6	52.3	22.9	25.7	24.1	14.4
1938	20.8	46.6	232.5	235.1	672.1	221.3	25.3	20.0	16.5	22.4	19.7	121.1
1939	84.8	56.2	34.0	28.8	395.0	220.6	66.3	126.7	65.5	16.0	8.5	24.5
1940	23.7	29.7	75.5	109.9	131.9	67.0	48.0	23.0	10.3	10.1	9.7	7.1
1941	18.4	17.0	6.9	62.9	336.5	247.8	99.2	42.6	18.7	8.8	13.2	18.0
1942	44.8	267.1	371.6	191.2	54.8	155.0	205.1	84.1	41.2	28.3	160.2	87.5
1943	79.6	311.5	300.4	158.3	115.1	145.2	61.6	12.2	20.9	20.0	10.3	189.7
1944	96.1	19.9	4.6	38.6	218.4	243.3	80.0	13.4	9.6	7.4	5.5	4.4
1945	35.0	20.8	11.1	123.6	105.5	128.8	67.8	31.4	18.6	10.8	7.2	5.6
1946	10.5	33.1	38.9	98.9	159.8	192.2	96.4	24.5	47.5	33.3	12.7	14.0
1947	19.9	305.2	217.5	176.7	303.7	277.5	103.6	23.6	10.8	7.6	5.6	4.3
1948	16.2	15.7	12.6	45.9	79.5	66.6	40.6	19.9	10.3	8.9	7.6	7.3
1949	8.6	18.2	27.9	36.9	247.8	415.6	150.6	51.5	30.0	18.2	59.0	36.6
1950	29.2	22.7	217.7	120.5	143.3	78.7	28.8	12.7	9.2	7.2	13.1	24.9
1951	54.3	25.6	8.0	42.9	212.4	102.3	36.7	21.5	14.5	13.0	9.5	22.3
1952	20.5	38.0	85.2	63.8	93.4	60.0	46.0	24.5	9.5	6.5	8.4	33.0
1953	57.0	58.7	61.8	55.7	73.9	106.4	55.6	67.3	59.1	27.9	11.2	11.7
1954	48.0	43.8	28.3	509.8	529.9	152.4	58.7	30.6	22.3	15.3	7.3	9.3
1955	17.6	39.2	35.6	20.0	167.9	282.4	107.6	20.9	18.2	12.3	7.4	13.1
1956	19.1	102.1	409.3	342.7	163.2	235.2	123.0	31.1	14.4	11.7	21.0	91.1
1957	81.6	38.8	33.3	195.4	130.5	43.7	62.8	38.8	15.1	9.7	7.3	6.6
1958	6.9	125.4	223.4	81.6	81.3	63.1	63.5	410.3	160.2	39.7	33.8	20.3
1959	16.5	36.7	37.8	60.3	71.9	49.8	39.7	25.0	12.6	8.5	11.9	21.3
1960	19.9	52.5	147.0	81.2	53.3	139.0	152.9	60.6	19.8	9.9	9.3	8.0
1961	5.7	57.2	63.6	54.4	213.9	192.3	75.4	21.5	11.2	7.1	8.4	6.6
1962	12.1	85.5	75.3	386.1	232.6	515.3	213.5	29.0	12.1	40.1	24.9	7.3
1963	90.2	169.0	79.4	136.0	70.6	143.7	111.0	36.3	294.8	121.7	17.4	16.8
1964	96.2	45.2	25.4	47.2	100.1	45.4	18.7	15.3	201.0	118.8	61.0	31.6
1965	67.3	99.2	36.8	234.3	152.7	31.4	10.5	54.2	35.4	11.9	14.3	18.0
1966	13.6	13.5	35.6	167.8	187.7	486.5	267.7	65.9	31.8	34.8	20.0	7.4
1967	11.7	23.4	19.3	16.0	25.7	52.3	36.1	14.3	7.1	6.9	10.5	17.7
1968	15.6	17.5	17.3	11.2	54.7	237.0	111.3	35.9	19.7	11.4	9.2	7.5
1969	37.1	27.9	33.6	25.3	58.8	30.0	8.6	9.7	16.9	12.8	73.5	63.2
1970	129.9	66.7	24.3	109.4	98.5	51.3	35.4	54.1	34.1	29.6	61.8	34.2
1971	162.2	85.6	42.6	146.8	480.1	296.8	80.1	17.3	12.2	9.3	6.6	6.2
1972	10.2	91.7	45.5	19.6	269.8	189.9	79.9	24.3	9.8	9.5	12.2	14.7
1973	17.4	62.6	43.1	418.3	468.1	525.8	191.3	67.4	40.3	19.5	11.7	6.3
1974	7.3	64.0	63.3	41.5	50.7	60.4	40.8	14.9	7.6	6.5	6.1	63.9
1975	33.3	28.2	495.6	594.1	529.3	992.2	352.2	73.2	39.5	15.6	9.4	26.1
1976	277.6	117.0	19.6	65.6	121.7	86.4	44.8	17.9	10.3	11.2	10.5	21.3
1977	52.3	48.7	64.3	71.2	64.0	164.6	565.4	205.6	22.0	9.8	12.8	33.1
1978	69.7	67.4	165.0	69.8	93.6	58.4	34.2	17.9	11.5	36.4	33.3	19.1
1979	19.3	15.6	18.3	91.4	124.1	65.0	26.4	10.9	7.6	7.0	5.4	103.0
1980	53.7	50.7	36.0	118.3	250.0	98.6	21.9	28.6	24.8	12.2	22.3	20.2
1981	11.8	18.5	33.9	62.4	70.4	263.8	124.4	24.2	19.7	24.4	15.0	12.6
1982	42.2	47.5	17.4	7.6	7.7	15.0	20.9	13.8	8.6	21.2	12.8	12.6
1983	21.6	81.4	187.4	124.2	99.8	145.0	106.5	36.1	20.1	28.3	18.1	8.9
1984	32.3	45.6	20.9	141.6	587.4	190.2	15.6	8.2	6.5	5.9	4.5	5.8
1985	229.9	142.1	130.2	225.6	127.5	61.2	31.5	11.7	9.1	8.8	19.1	25.3
1986	114.3	137.2	55.9	30.2	46.2	76.0	41.1	12.1	11.6	9.5	27.0	856.7
1987	332.3	62.9	42.1	61.0	546.0	384.7	110.2	41.7	25.4	19.2	15.9	16.4
1988	19.9	56.7	186.9	122.5	499.7	184.5	132.9	62.9	17.5	16.7	10.6	4.9
1989	38.5	418.8	188.8	80.9	39.4	277.5	133.9	24.6	13.5	11.2	18.7	13.3
1990	19.6	13.9	39.1	135.4	168.5	61.1	14.1	6.9	7.0	6.0	4.7	10.7
1991	214.7	118.3	138.4	67.7	88.5	53.8	28.9	13.5	6.9	5.4	7.0	9.1
1992	10.5	19.6	11.3	11.5	55.8	116.6	56.0	14.5	6.5	4.6	6.8	14.6
1993	130.1	81.1	146.7	187.7	247.8	312.9	112.2	11.3	8.6	16.1	17.3	8.3
1994	7.9	19.3	28.7	68.3	41.2	172.3	122.1	36.9	27.4	19.4	8.6	10.1
1995	22.5	26.8	351.0	610.8	543.0	167.6	43.4	16.2	11.7	28.0	18.4	8.9
1996	14.8	189.2	212.6	320.0	181.0	115.4	106.0	45.3	298.6	138.1	32.5	13.4
1997	21.4	40.1	24.0	94.3	610.9	398.8	108.1	28.1	14.8	11.2	13.7	10.6
1998	10.5	70.4	165.7	148.1	261.9	147.5	44.3	13.8	9.3	8.3	6.2	4.8
1999	33.9	34.0	279.5	570.6	414.1	626.2	293.2	79.4	31.1	13.3	7.9	17.5
2000	30.4	43.8	80.4	164.7	138.3	103.1	61.3	24.7	12.3	11.6	11.4	14.8
2001	38.3	346.0	263.9	154.9	98.2	146.4	62.1	26.6	22.7	39.4	88.6	73.3
2002	28.1	12.7	35.5	58.0	42.9	60.2	38.1	19.0	13.8	8.9	8.1	18.3
2003	13.4	12.7	10.1	61.2	95.7	166.1	78.7	15.7	10.0	28.8	26.0	84.3
2004	48.4	73.6	133.3	196.5	120.4	79.9	39.8	14.2	8.8	6.4	7.3	5.5
Average	46.9	81.3	105.8	139.4	194.1	189.5	91.7	38.1	30.5	27.0	21.8	34.7
Min	5.1	8.9	4.6	7.6	7.7	15.0	8.4	6.9	6.5	4.6	4.5	4.3
Max	332.3	469.9	495.6	610.8	672.1	992.2	565.4	410.3	298.6	335.2	160.2	856.7

Scenario 2a (m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	129.8	28.8	30.4	31.4	82.2	199.9	120.2	40.8	23.5	17.5	14.6	16.6
1921	23.1	227.5	236.0	70.9	34.2	33.9	27.2	71.8	70.6	37.3	51.6	27.6
1922	48.7	173.1	74.6	195.3	516.2	279.3	66.7	20.5	18.0	212.1	100.4	18.2
1923	16.9	23.9	29.0	92.9	118.9	97.2	45.3	21.0	18.0	16.0	15.7	18.2
1924	20.8	34.5	303.8	152.5	59.8	590.0	310.6	60.6	21.9	17.5	14.9	15.6
1925	18.8	35.1	32.5	67.6	43.6	244.4	106.5	24.7	28.2	23.6	16.9	23.6
1926	37.8	43.1	59.1	46.1	48.5	607.5	256.6	23.1	16.9	17.4	17.8	14.9
1927	25.8	31.8	66.1	290.1	178.7	96.9	48.3	20.8	17.9	16.1	19.1	17.2
1928	22.6	32.4	40.1	37.5	36.1	233.4	101.3	24.1	44.4	55.7	30.2	83.2
1929	96.4	83.4	142.2	151.7	58.9	113.3	81.2	27.8	24.7	22.7	38.6	32.7
1930	25.5	28.3	31.9	310.0	336.5	289.2	119.0	29.6	18.2	316.5	141.5	17.5
1931	22.8	34.6	58.0	40.6	282.7	131.1	37.1	23.8	23.1	25.6	20.8	30.4
1932	32.9	190.1	177.3	54.8	28.8	43.8	37.4	20.0	15.9	16.1	14.7	12.7
1933	13.8	239.5	342.5	580.0	240.0	152.3	73.4	24.9	19.0	24.0	20.5	14.5
1934	34.6	65.3	154.8	83.0	39.8	69.0	132.0	101.9	86.4	38.8	32.4	23.5
1935	19.5	26.9	23.5	28.8	212.9	142.7	49.5	59.5	40.9	23.1	17.3	14.4
1936	25.0	449.1	179.4	68.0	513.3	220.8	45.2	19.6	16.4	15.7	14.4	13.4
1937	17.6	27.2	38.1	83.4	182.3	90.9	109.1	50.1	26.6	27.8	25.1	18.5
1938	21.4	36.3	218.9	236.3	678.8	219.9	38.9	25.9	22.1	24.4	23.5	96.0
1939	67.8	55.2	43.4	37.6	372.3	222.9	65.5	126.6	63.0	23.0	16.6	26.8
1940	26.3	36.5	80.6	107.4	125.5	73.1	54.3	28.0	18.5	17.8	16.6	14.3
1941	19.9	28.7	24.5	68.0	290.9	199.5	88.4	45.7	25.3	17.7	18.2	19.8
1942	30.0	200.9	371.8	191.2	54.0	155.5	206.1	83.0	39.9	30.4	155.6	85.6
1943	78.6	311.9	301.4	158.1	116.4	148.9	59.7	21.1	24.8	24.6	17.7	155.2
1944	93.8	32.6	22.6	54.0	175.8	227.4	80.8	22.3	18.0	16.0	14.2	12.5
1945	28.8	29.8	26.0	73.0	71.4	130.8	67.2	30.4	21.1	17.9	15.3	13.3
1946	17.4	39.9	46.9	80.9	115.4	186.9	97.3	27.5	46.9	34.7	19.7	17.8
1947	23.1	272.4	217.6	177.2	307.3	279.6	103.4	28.0	18.6	16.2	14.4	12.3
1948	19.9	28.7	27.0	53.6	68.4	67.1	50.3	26.9	18.2	16.7	15.2	13.8
1949	16.7	29.0	35.8	43.3	187.0	342.4	129.6	40.2	27.1	23.8	53.0	33.8
1950	26.1	31.5	179.7	119.0	143.0	78.8	40.5	21.6	17.3	15.7	18.7	26.3
1951	40.7	32.0	24.3	54.5	152.9	85.5	48.1	28.5	21.6	19.7	16.9	17.9
1952	21.4	33.3	78.1	62.6	55.2	53.0	50.3	28.4	18.2	15.7	15.4	24.8
1953	42.2	55.4	56.7	52.5	61.7	87.0	54.3	67.8	57.6	28.2	18.3	17.3
1954	47.9	49.9	37.9	468.2	532.1	152.7	60.3	28.8	25.1	20.9	15.6	15.4
1955	22.1	42.5	35.6	32.1	141.3	245.3	105.8	28.2	23.7	19.4	15.9	15.4
1956	23.6	80.8	379.2	341.8	161.8	237.9	122.7	30.0	21.2	19.3	22.6	76.3
1957	69.4	45.4	42.9	177.0	131.4	52.8	66.7	39.3	21.4	17.6	15.5	13.7
1958	15.7	87.0	192.5	80.5	78.3	63.0	64.4	409.9	157.0	38.7	32.8	23.6
1959	22.5	36.4	37.4	52.7	59.0	52.4	49.6	30.6	20.1	16.7	17.1	20.7
1960	23.3	44.4	117.4	70.3	55.7	130.8	152.3	59.5	23.1	17.9	16.6	14.4
1961	14.8	40.3	50.2	51.6	195.5	195.3	74.5	24.6	18.6	15.8	16.2	14.0
1962	17.8	66.7	58.7	365.0	233.8	519.5	212.4	31.5	19.8	40.9	28.4	14.6
1963	72.9	148.6	75.8	136.6	73.8	140.2	110.9	37.3	293.0	118.6	22.9	19.2
1964	81.3	49.1	30.1	49.9	79.4	43.5	31.7	22.3	178.8	116.5	59.2	32.6
1965	61.6	99.0	36.6	229.5	153.4	35.5	28.4	50.6	34.8	19.4	19.4	20.1
1966	19.7	26.5	40.4	156.4	134.1	476.5	268.2	64.3	31.9	34.5	24.1	14.8
1967	17.6	30.9	31.8	32.0	33.3	63.0	47.9	22.7	16.5	15.7	16.8	18.5
1968	19.6	29.3	28.5	27.1	57.2	157.2	79.7	40.9	26.3	18.7	16.3	14.1
1969	29.8	33.5	36.9	35.9	54.6	41.0	27.0	19.2	20.8	18.2	41.6	41.6
1970	92.6	59.5	34.0	87.5	78.9	57.5	45.9	50.6	33.4	31.2	43.0	26.1
1971	126.4	73.2	37.1	120.3	485.3	298.7	78.9	24.6	19.4	17.3	15.1	13.7
1972	17.2	74.2	44.5	32.6	213.9	186.8	79.2	28.6	18.0	16.9	18.0	19.6
1973	21.5	58.3	45.7	371.1	469.7	530.1	190.6	66.6	41.4	24.7	18.3	13.9
1974	16.0	57.8	59.9	48.9	58.6	55.2	43.1	22.9	16.7	15.4	14.8	49.9
1975	31.4	32.8	403.7	597.4	533.9	1002.8	351.0	73.7	36.9	21.3	16.9	23.3
1976	259.8	112.5	29.8	73.3	103.5	83.4	49.6	24.3	19.0	17.9	16.6	20.2
1977	50.2	49.8	65.4	70.3	64.1	165.7	522.7	203.7	26.0	18.1	18.7	31.1
1978	53.7	65.9	153.3	67.6	93.5	58.9	45.9	25.9	19.4	28.2	30.1	22.6
1979	21.4	27.3	29.8	100.4	124.5	64.8	35.6	20.7	16.9	15.7	14.2	85.3
1980	48.0	56.4	37.8	89.8	155.2	93.2	34.1	26.3	23.9	18.5	24.5	23.2
1981	19.9	31.4	35.0	55.8	67.5	222.7	113.4	28.7	24.7	25.6	19.4	17.6
1982	40.2	37.5	23.6	25.3	21.3	30.5	32.2	20.4	16.5	27.6	19.9	18.6
1983	23.5	59.1	153.5	102.6	79.7	110.7	92.1	38.1	24.2	30.6	22.7	15.2
1984	26.0	43.9	31.1	108.6	585.3	188.5	30.6	18.1	15.5	14.8	13.5	12.0
1985	179.5	119.0	130.7	224.6	128.4	63.3	40.7	21.3	18.0	16.6	21.3	23.9
1986	84.3	118.1	54.2	39.2	45.7	73.6	47.8	20.9	18.8	17.3	29.8	804.5
1987	331.0	62.7	41.4	60.3	551.9	387.0	109.7	42.9	30.0	25.3	21.3	17.6
1988	20.7	48.7	163.4	121.5	504.5	184.2	136.0	61.0	24.1	20.6	16.6	12.7
1989	35.1	385.3	187.0	80.4	39.8	279.0	133.3	29.8	20.6	18.8	19.4	15.2
1990	21.0	26.5	50.4	138.4	162.3	72.5	31.9	17.5	15.9	15.0	13.5	14.7
1991	174.0	95.8	114.1	64.9	86.7	63.8	42.7	22.7	16.4	14.9	15.7	14.4
1992	16.9	33.4	27.2	26.8	57.8	115.4	61.8	21.8	15.8	14.3	15.1	16.5
1993	90.6	62.2	128.7	149.2	187.9	230.7	109.9	20.4	16.9	20.5	20.9	14.5
1994	15.8	35.8	31.5	60.6	41.1	130.9	94.6	35.8	32.0	25.9	16.8	15.5
1995	24.7	34.8	301.7	614.0	544.4	167.1	55.1	24.5	19.9	34.1	25.3	15.9
1996	20.8	124.4	204.3	318.8	180.7	116.9	106.2	46.9	296.9	136.7	30.4	18.6
1997	21.3	39.8	30.6	72.9	615.7	402.8	107.0	28.8	20.3	18.1	18.9	15.9
1998	17.0	46.0	146.0	146.8	262.5	148.5	52.0	23.3	17.3	15.8	14.1	12.2
1999	24.4	34.7	260.6	534.6	416.0	633.4	294.3	78.3	32.8	20.3	16.0	20.7
2000	33.0	44.7	81.8	144.9	115.9	103.3	62.6	28.9	20.2	19.8	19.5	19.5
2001	35.4	298.9	263.7	155.0	97.7	148.3	66.7	30.6	26.6	38.3	71.2	69.2
2002	29.8	27.1	35.7	56.9	44.2	64.3	46.0	23.4	18.9	16.6	15.2	18.6
2003	18.5	25.5	23.3	31.5	66.7	115.6	74.7	22.2	18.3	30.0	28.6	60.2
2004	40.9	72.2	131.7	199.1	120.3	80.9	44.1	20.4	16.7	15.2	14.4	12.1
Average	45.3	76.6	101.2	134.7	183.2	182.7	93.7	41.8	34.9	31.4	25.7	35.0
Min	13.8	23.9	22.6	25.3	21.3	30.5	27.0	17.5	15.5	14.3	13.5	12.0
Max	331.0	449.1	403.7	614.0	678.8	1002.8	522.7	409.9	296.9	316.5	155.6	804.5

Scenario 2b (m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	128.8	27.5	29.1	30.0	82.0	198.4	118.9	39.8	22.6	16.6	13.8	15.9
1921	22.3	224.5	232.8	69.3	32.9	32.3	25.7	70.8	69.7	36.5	51.1	26.5
1922	47.8	171.4	73.5	193.6	513.7	278.0	65.1	19.5	17.1	210.3	99.1	17.5
1923	16.1	22.5	27.7	90.8	117.2	96.3	43.6	20.1	17.2	15.1	14.9	17.5
1924	20.0	33.2	301.0	151.1	58.0	588.8	309.3	59.4	21.0	16.6	14.1	14.9
1925	18.0	33.7	31.2	65.2	41.9	242.4	104.8	23.7	27.4	22.8	16.1	22.9
1926	36.9	41.6	56.9	44.4	46.7	606.0	255.2	22.2	16.0	16.6	17.0	14.3
1927	25.0	30.4	64.2	286.8	177.4	95.2	46.8	19.9	17.0	15.2	18.3	16.5
1928	21.7	31.1	38.8	36.1	34.9	230.9	99.6	23.1	43.4	54.1	29.4	81.0
1929	95.1	82.3	140.8	150.5	57.7	112.0	79.9	26.8	23.8	21.9	37.8	32.0
1930	24.6	26.9	30.6	307.6	334.6	287.3	117.5	28.7	17.4	313.8	140.2	16.8
1931	22.0	33.3	56.6	39.1	280.7	129.8	35.6	22.9	22.3	24.8	20.0	29.7
1932	32.1	187.7	176.0	53.4	27.5	42.2	35.9	19.1	15.1	15.2	13.9	12.1
1933	13.1	237.0	338.7	578.7	238.8	151.0	72.2	23.9	18.1	23.2	19.6	13.9
1934	33.7	63.2	151.6	81.7	38.4	67.9	130.7	100.7	85.3	37.9	31.5	22.9
1935	18.6	25.6	22.2	27.4	210.6	141.0	48.0	58.1	39.5	22.3	16.5	13.8
1936	24.3	445.3	178.1	66.8	512.0	219.5	43.7	18.6	15.6	14.8	13.6	12.7
1937	16.8	25.8	36.7	81.9	180.7	89.4	107.7	49.0	25.7	26.9	24.3	17.9
1938	20.6	35.0	215.2	233.5	677.5	218.5	37.4	25.0	21.2	23.5	22.7	95.3
1939	65.7	54.1	42.0	36.1	371.1	221.4	64.5	124.0	61.7	22.2	15.7	26.0
1940	25.3	35.1	79.0	105.2	124.0	71.3	52.6	27.1	17.7	17.0	15.8	13.7
1941	19.2	27.3	23.2	66.5	287.8	197.7	86.7	44.7	24.4	16.8	17.4	19.0
1942	29.1	199.3	369.2	189.9	52.6	154.3	204.8	81.7	38.8	29.5	153.7	84.4
1943	77.3	310.1	300.1	156.9	115.1	147.6	58.6	20.1	24.0	23.8	16.9	153.1
1944	92.5	31.3	21.2	52.3	173.4	226.6	79.1	21.4	17.1	15.1	13.4	11.8
1945	27.8	28.5	24.6	71.6	69.9	129.7	65.9	29.5	20.2	17.1	14.5	12.7
1946	16.6	38.6	45.5	79.4	113.4	184.5	96.1	26.6	46.0	33.9	18.9	17.1
1947	22.3	269.4	215.8	174.7	304.0	277.8	102.1	27.1	17.8	15.3	13.5	11.7
1948	19.2	27.3	25.6	52.1	67.0	65.4	48.7	25.9	17.4	15.8	14.4	13.2
1949	15.8	27.6	34.5	41.8	184.5	338.5	128.0	39.2	26.3	23.0	51.5	33.0
1950	25.3	30.2	177.2	117.7	141.5	77.4	39.0	20.6	16.4	14.9	17.9	25.5
1951	39.9	30.6	23.0	52.8	150.0	83.8	46.5	27.5	20.7	18.9	16.0	17.2
1952	20.5	31.9	76.2	60.9	53.5	51.2	48.7	27.4	17.4	14.8	14.6	24.1
1953	41.3	54.1	55.4	51.0	60.0	85.4	53.0	65.9	56.2	27.4	17.4	16.6
1954	47.1	48.6	36.4	464.7	530.8	151.4	59.2	27.7	24.3	20.1	14.8	14.7
1955	21.2	41.2	34.3	30.7	138.0	243.6	104.5	27.3	22.8	18.5	15.1	14.6
1956	22.8	79.5	375.4	340.6	160.5	236.6	121.5	29.1	20.3	18.5	21.8	74.6
1957	68.4	44.0	41.3	174.6	130.1	51.1	65.1	38.3	20.5	16.8	14.7	13.1
1958	15.0	85.6	189.4	78.9	77.4	61.8	63.0	408.7	155.6	37.6	32.0	22.9
1959	21.7	35.0	36.0	51.2	57.6	50.7	48.0	29.6	19.3	15.8	16.4	20.0
1960	22.4	43.1	114.9	68.4	54.2	129.0	150.6	58.3	22.2	17.1	15.8	13.8
1961	14.0	38.9	48.7	50.0	192.6	193.7	73.4	23.6	17.7	15.0	15.3	13.4
1962	17.1	65.3	57.3	361.1	232.5	516.6	210.9	30.6	18.9	40.0	27.6	14.0
1963	72.1	145.6	74.2	134.1	72.4	139.3	109.6	36.4	291.4	117.3	22.1	18.4
1964	78.9	47.5	28.7	48.1	79.1	42.4	30.2	21.3	177.2	115.2	57.9	32.0
1965	60.6	97.3	35.2	227.8	152.1	33.9	26.9	49.6	34.0	18.5	18.6	19.4
1966	18.9	25.1	39.0	153.8	131.9	475.4	266.7	63.2	31.0	33.7	23.3	14.2
1967	16.9	29.6	30.4	30.5	32.0	61.4	46.2	21.8	15.6	14.8	15.9	17.8
1968	18.8	27.9	27.2	25.6	55.9	155.0	77.7	39.9	25.5	17.8	15.5	13.4
1969	29.1	32.2	35.4	34.4	53.3	39.4	25.6	18.2	19.9	17.3	40.8	40.9
1970	91.8	58.2	32.7	85.7	77.0	55.7	44.4	49.6	32.6	30.3	42.1	25.4
1971	125.5	71.8	35.7	118.1	481.3	296.0	77.5	23.6	18.6	16.4	14.3	13.0
1972	16.4	72.9	43.1	31.1	211.5	184.4	78.1	27.7	17.1	16.1	17.2	18.9
1973	20.7	57.0	44.3	366.3	467.1	528.9	189.4	65.4	40.5	23.9	17.5	13.2
1974	15.2	56.2	57.8	47.2	56.9	53.4	41.6	22.0	15.8	14.5	13.9	48.8
1975	30.4	31.4	400.7	596.1	531.7	1000.6	349.7	72.4	35.8	20.5	16.1	22.6
1976	256.9	111.2	28.4	71.5	102.1	82.8	48.0	23.3	18.1	17.1	15.8	19.5
1977	49.4	48.5	64.1	68.5	62.3	163.0	521.4	202.4	25.2	17.3	17.9	30.3
1978	52.8	64.4	150.0	66.3	92.2	57.5	44.4	24.9	18.5	27.3	29.3	21.9
1979	20.6	25.9	28.5	98.0	122.3	63.0	34.2	19.8	16.1	14.9	13.4	83.9
1980	46.7	55.1	36.4	87.8	153.8	92.0	32.6	25.4	23.0	17.7	23.7	22.4
1981	19.0	30.0	33.6	54.3	66.1	220.4	112.3	27.8	23.8	24.7	18.6	16.9
1982	39.3	36.2	22.2	23.9	20.1	28.9	30.7	19.5	15.6	26.7	19.1	17.9
1983	22.7	57.8	152.2	101.0	78.2	108.9	90.6	37.2	23.4	29.8	21.9	14.5
1984	25.2	42.5	29.7	107.1	581.7	186.8	29.1	17.1	14.7	14.0	12.7	11.4
1985	178.3	116.1	129.3	221.5	126.5	62.2	39.3	20.3	17.1	15.7	20.5	23.1
1986	83.4	115.5	53.0	37.7	44.4	71.1	46.1	20.0	17.9	16.4	28.9	800.2
1987	328.9	61.6	40.2	59.1	549.7	385.7	108.4	41.9	29.1	24.4	20.5	17.0
1988	19.9	47.3	160.9	120.4	501.4	182.9	134.7	59.8	23.2	19.7	15.7	12.0
1989	34.2	381.6	185.7	79.1	38.4	277.8	132.0	28.9	19.7	17.9	18.6	14.5
1990	20.3	25.2	48.7	135.6	160.9	70.7	30.4	16.6	15.1	14.2	12.6	13.9
1991	171.9	94.3	112.6	63.2	85.3	62.0	41.2	21.7	15.6	14.0	14.9	13.6
1992	16.0	32.0	25.8	25.4	56.5	113.4	59.8	20.9	15.0	13.5	14.3	15.8
1993	89.6	60.6	126.1	146.7	186.4	229.6	108.6	19.4	16.0	19.6	20.1	13.9
1994	15.1	34.5	30.1	59.0	39.6	128.0	92.6	34.9	31.1	25.0	16.0	14.8
1995	23.9	33.5	298.1	612.7	543.1	165.9	53.6	23.5	19.0	33.2	24.5	15.3
1996	20.0	122.9	202.3	316.1	179.3	115.7	104.9	45.9	294.2	135.6	29.6	18.0
1997	20.6	38.4	29.3	71.3	612.7	401.5	105.9	27.9	19.4	17.2	18.1	15.2
1998	16.2	44.7	142.1	145.5	261.2	147.2	50.4	22.4	16.5	15.0	13.3	11.6
1999	23.6	33.3	258.3	531.6	414.7	632.1	293.0	77.0	31.9	19.5	15.2	20.0
2000	32.2	43.4	80.2	142.4	113.8	102.0	60.9	27.9	19.4	19.0	18.6	18.8
2001	34.6	296.4	262.5	152.4	96.4	147.1	65.0	29.7	25.7	37.5	69.7	67.3
2002	29.0	25.8	34.3	55.1	42.7	62.6	44.5	22.4	18.0	15.8	14.4	17.9
2003	17.6	24.1	21.9	30.1	65.5	113.7	74.9	21.2	17.4	29.2	27.8	59.4
2004	38.5	71.0	129.2	197.5	118.3	79.6	42.6	19.5	15.9	14.3	13.6	11.5
Average	44.3	75.1	99.4	132.9	181.4	181.1	92.3	40.7	34.0	30.5	24.9	34.2
Min	13.1	22.5	21.2	23.9	20.1	28.9	25.6	16.6	14.7	13.5	12.6	11.4
Max	328.9	445.3	400.7	612.7	677.5	1000.6	521.4	408.7	294.2	313.8	153.7	800.2

Scenario 32 (m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	128.8	25.8	29.8	31.0	83.2	197.3	118.9	44.7	22.6	15.8	12.9	15.4
1921	22.7	240.3	214.4	70.3	31.4	29.1	22.7	78.0	75.4	41.1	40.2	27.3
1922	49.5	168.9	73.5	193.6	513.7	278.0	69.4	18.6	17.0	207.2	99.1	18.0
1923	15.0	20.0	26.8	90.7	123.2	100.5	47.9	19.4	18.5	15.3	14.7	18.4
1924	19.6	32.5	290.8	151.1	56.5	590.2	309.3	59.4	21.7	15.9	13.1	15.5
1925	17.1	34.4	29.5	64.4	43.3	254.1	112.2	26.4	31.3	25.4	15.8	25.5
1926	39.9	41.6	58.6	43.5	48.3	573.0	255.2	22.3	15.1	15.7	17.0	14.1
1927	28.0	28.7	81.0	270.4	177.4	92.6	44.4	19.2	16.6	14.5	19.4	16.9
1928	21.0	33.2	52.0	41.2	38.1	213.4	99.6	25.2	47.9	52.9	31.3	75.7
1929	93.1	82.3	140.8	150.5	57.7	112.0	79.9	30.9	25.2	22.7	41.6	35.6
1930	25.0	24.4	33.7	293.1	334.6	287.3	117.5	29.7	16.5	313.6	140.2	17.3
1931	21.8	32.7	62.4	40.5	273.1	129.8	34.1	22.4	22.9	27.2	20.7	35.1
1932	37.5	175.0	176.0	52.0	25.7	43.8	40.2	18.9	14.2	14.4	13.0	11.3
1933	11.9	256.5	321.7	578.7	238.8	151.0	72.2	23.5	17.7	26.6	21.8	13.1
1934	35.1	67.0	145.6	78.8	36.9	69.2	130.7	100.7	85.3	40.3	33.5	24.0
1935	17.5	23.0	18.9	24.1	231.9	143.4	47.3	65.1	41.6	24.7	17.5	13.2
1936	27.0	413.8	178.1	66.8	512.0	219.5	45.2	17.6	14.7	14.0	12.6	12.1
1937	16.0	23.2	37.5	92.1	201.8	83.8	96.4	50.5	28.1	29.4	25.9	18.6
1938	22.1	39.1	196.4	231.0	677.5	218.5	35.3	27.1	22.7	25.9	23.8	101.8
1939	66.9	54.8	40.1	34.3	360.8	221.4	65.1	123.4	63.6	22.4	14.9	27.0
1940	25.6	34.3	78.9	106.6	126.2	69.0	52.7	29.7	17.0	16.9	15.8	12.8
1941	19.9	25.3	19.9	65.4	300.9	217.4	94.7	48.6	24.9	15.9	18.4	20.1
1942	34.6	220.2	311.5	179.1	53.3	153.7	204.8	81.7	39.7	31.9	150.4	84.4
1943	77.3	310.1	300.1	156.9	115.1	147.6	59.7	19.5	26.4	24.8	16.4	149.8
1944	92.5	29.0	18.0	49.3	184.9	224.5	82.7	20.7	16.4	14.3	12.4	10.7
1945	31.6	26.8	22.0	85.8	76.9	119.8	70.4	33.5	23.1	17.3	13.6	11.6
1946	15.8	37.5	43.8	86.9	125.8	167.3	90.5	30.4	49.2	36.3	18.6	17.9
1947	22.4	272.0	192.4	174.7	304.0	277.8	102.1	30.3	17.3	14.5	12.5	10.6
1948	19.0	25.0	23.1	50.5	69.7	65.1	47.6	26.2	16.8	15.6	13.9	12.5
1949	14.8	25.6	32.8	40.8	203.5	364.9	139.1	46.7	29.6	23.8	55.0	36.3
1950	28.5	28.6	173.1	92.6	118.1	72.6	37.3	20.0	15.9	14.1	18.6	26.7
1951	45.0	30.3	20.1	50.4	169.3	90.3	44.9	27.9	21.0	19.6	15.6	20.7
1952	21.9	35.1	80.5	62.0	63.1	52.8	50.0	31.1	16.5	13.7	14.5	28.1
1953	46.7	56.9	58.9	52.7	63.3	86.0	55.5	60.4	51.1	30.1	17.1	16.1
1954	49.0	48.4	34.6	450.7	475.3	151.4	59.2	30.7	27.0	20.9	13.9	14.1
1955	21.0	42.1	35.8	28.2	144.8	250.0	102.0	27.2	24.5	18.9	14.1	15.7
1956	22.5	86.1	361.4	331.8	160.5	236.6	121.5	33.9	20.8	18.5	23.4	79.0
1957	73.4	43.4	39.4	165.7	124.9	48.5	66.5	42.9	21.5	16.4	13.8	12.3
1958	13.8	101.3	194.9	79.8	74.1	58.3	58.9	396.4	155.6	37.6	34.2	23.8
1959	21.0	37.3	37.7	55.0	53.1	50.0	46.7	31.6	19.0	15.2	17.3	22.4
1960	22.4	46.8	124.7	72.9	53.3	116.5	137.4	58.7	24.7	16.5	15.5	13.1
1961	12.8	44.4	54.5	51.5	178.6	193.7	73.4	27.5	17.7	14.1	14.7	12.5
1962	16.5	71.5	63.8	347.7	232.5	516.6	210.9	34.6	18.6	42.7	28.7	13.0
1963	77.6	137.8	71.8	134.8	71.3	137.3	109.6	40.9	286.7	117.3	22.6	19.5
1964	82.6	48.3	29.2	48.3	71.8	42.4	28.2	21.7	178.9	115.2	59.3	33.2
1965	64.3	90.8	36.8	226.2	152.1	33.0	24.1	54.9	37.2	18.4	19.6	20.5
1966	18.2	22.9	39.1	158.5	147.9	452.3	266.7	63.2	34.3	36.5	24.4	13.2
1967	16.2	28.5	28.2	27.5	30.3	58.5	44.4	21.3	14.5	13.9	16.3	19.3
1968	18.7	25.9	25.1	22.7	55.2	182.8	89.7	42.3	26.1	18.1	15.4	12.7
1969	33.0	32.2	36.3	32.2	54.9	36.5	22.6	17.3	22.3	18.2	47.5	46.8
1970	99.0	61.7	30.8	94.4	82.1	53.3	43.1	55.0	35.9	32.8	46.7	29.3
1971	132.2	76.3	39.6	127.4	380.1	287.8	77.5	23.5	18.9	15.9	13.4	12.0
1972	15.5	78.3	44.8	28.6	228.6	167.4	78.1	31.1	16.5	16.4	17.8	19.2
1973	20.5	60.0	45.3	358.7	467.1	528.9	189.4	69.7	43.7	24.8	17.6	12.3
1974	14.1	59.5	60.6	45.8	55.2	54.6	44.0	21.6	14.8	13.6	13.0	52.9
1975	33.4	32.0	398.7	581.4	531.7	1000.6	349.7	72.4	36.1	21.3	15.6	25.9
1976	253.0	111.2	26.4	70.0	107.0	81.8	49.1	24.5	17.2	17.8	16.2	22.3
1977	52.3	50.4	65.2	69.5	62.6	162.7	508.9	202.4	27.3	16.5	18.4	33.5
1978	58.2	66.8	148.6	66.6	83.3	57.0	42.7	24.6	18.1	31.1	32.2	22.7
1979	21.1	23.9	26.4	96.1	122.7	62.9	33.2	18.7	15.0	14.0	12.4	88.5
1980	50.4	55.2	37.6	98.2	183.3	78.3	30.7	30.6	26.3	18.5	25.0	23.4
1981	18.0	27.8	34.9	57.3	67.7	234.7	114.6	31.0	25.8	27.4	19.6	17.1
1982	42.3	40.4	21.6	20.6	18.2	25.6	29.3	20.2	15.2	27.4	18.9	17.3
1983	23.2	65.0	163.4	109.5	83.3	120.3	99.8	41.4	25.6	32.1	22.8	13.9
1984	29.0	45.0	27.7	118.1	489.6	161.1	26.7	16.1	13.7	13.0	11.6	10.8
1985	187.9	120.2	101.5	215.7	126.5	62.2	38.3	19.3	16.2	15.6	21.9	26.0
1986	89.3	113.2	52.4	35.9	45.2	71.6	45.9	19.3	18.6	16.1	30.1	795.7
1987	328.9	61.6	40.3	59.0	549.7	385.7	108.4	46.3	31.1	25.2	21.3	18.4
1988	21.2	51.0	146.8	120.4	501.4	182.9	134.7	59.8	23.8	21.8	16.2	11.0
1989	37.4	376.1	185.7	79.1	38.5	277.7	132.0	31.1	20.2	17.9	20.4	15.6
1990	21.1	23.0	46.6	135.5	163.1	67.8	27.5	15.3	14.1	13.1	11.6	14.6
1991	179.6	101.5	121.1	64.8	86.8	59.3	39.0	21.0	14.4	12.8	13.9	13.6
1992	15.3	29.6	23.0	22.5	55.9	113.4	60.2	20.9	13.8	12.1	13.4	16.9
1993	97.2	66.6	133.0	158.5	205.3	254.5	97.5	18.7	15.4	21.2	21.2	13.3
1994	14.0	31.8	31.0	62.5	40.2	142.9	104.4	39.7	33.1	25.8	15.1	14.5
1995	24.3	32.1	285.8	530.3	543.1	165.9	51.7	23.1	18.4	34.0	24.4	14.5
1996	19.4	145.0	184.4	316.1	179.3	115.7	104.9	50.1	289.8	135.6	32.1	18.0
1997	22.8	40.6	28.2	75.0	602.4	401.5	105.9	32.3	20.9	17.8	19.0	15.1
1998	15.4	52.6	129.5	144.1	261.2	147.2	49.8	21.4	16.0	15.1	12.5	10.8
1999	27.9	35.4	265.0	522.2	414.7	632.1	293.0	77.0	34.9	19.7	14.3	21.0
2000	32.4	45.3	81.4	150.4	116.5	96.6	64.2	31.4	18.8	18.4	17.8	19.3
2001	37.9	281.1	257.7	152.4	96.4	147.1	66.3	33.2	28.0	40.5	74.2	60.2
2002	29.9	23.3	35.9	56.2	42.6	61.8	44.2	25.9	19.8	15.3	14.3	19.9
2003	17.2	21.9	19.7	40.5	72.6	134.3	69.7	22.0	16.7	31.8	29.1	65.9
2004	42.7	68.5	130.5	142.9	118.3	79.6	44.0	20.6	15.4	13.4	13.6	10.8
Average	45.9	75.9	97.3	130.7	180.5	180.7	92.2	42.2	34.6	31.0	25.2	34.8
Min	11.9	20.0	18.0	20.6	18.2	25.6	22.6	15.3	13.7	12.1	11.6	10.6
Max	328.9	413.8	398.7	581.4	677.5	1000.6	508.9	396.4	289.8	313.6	150.4	795.7

Scenario 33 (m³/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	128.8	26.4	28.7	29.9	83.7	198.4	118.9	45.2	23.0	16.3	13.3	15.8
1921	23.1	229.6	222.4	69.1	32.0	29.9	23.5	76.9	73.8	39.6	43.5	26.5
1922	49.1	170.1	73.5	193.6	513.7	278.0	68.9	19.1	17.4	206.9	99.1	18.3
1923	15.4	20.7	26.9	90.0	121.3	97.4	47.3	19.9	19.0	15.7	15.1	18.8
1924	20.0	32.4	293.0	151.3	57.1	589.4	309.3	59.4	22.1	16.3	13.5	15.9
1925	17.5	33.6	30.1	64.2	42.2	250.2	110.9	26.9	31.2	25.6	16.2	25.0
1926	38.7	41.0	57.4	43.4	47.1	581.2	255.2	22.8	15.6	16.1	17.4	14.4
1927	26.8	29.3	71.2	278.8	177.4	93.2	45.2	19.7	17.1	14.9	19.8	17.2
1928	21.4	31.9	45.3	39.8	36.7	220.3	99.6	25.7	47.3	52.2	31.5	74.2
1929	95.1	82.3	140.8	150.5	57.7	112.0	79.9	31.4	25.6	23.1	40.0	34.5
1930	25.4	25.1	32.2	294.9	334.6	287.3	117.5	30.1	17.0	312.7	140.2	17.6
1931	22.3	32.6	60.1	39.3	276.3	129.8	34.9	22.9	23.3	27.6	21.1	32.9
1932	35.3	176.9	176.0	52.2	26.3	42.3	39.6	19.4	14.6	14.8	13.4	11.6
1933	12.3	237.6	338.8	578.7	238.8	151.0	72.2	23.9	18.1	26.0	21.8	13.5
1934	34.9	65.4	143.7	81.7	37.5	68.6	130.7	100.7	85.3	40.7	33.7	24.3
1935	17.9	23.7	19.6	24.8	220.3	140.0	48.1	63.9	41.7	25.1	17.9	13.5
1936	25.9	425.0	178.1	66.8	512.0	219.5	45.3	18.0	15.2	14.4	13.0	12.4
1937	16.4	24.0	36.4	88.3	190.8	81.8	103.1	49.4	28.5	29.7	26.3	18.9
1938	21.8	37.4	202.8	233.5	677.5	218.5	36.1	27.5	23.2	26.3	24.2	98.2
1939	64.7	53.4	40.8	34.8	364.7	221.4	64.5	124.0	63.8	22.8	15.3	27.3
1940	26.0	34.3	78.4	105.4	124.9	69.5	53.3	30.2	17.4	17.3	16.2	13.1
1941	20.2	26.0	20.6	65.4	295.3	208.5	93.3	49.1	25.4	16.3	18.8	20.5
1942	32.3	203.6	328.5	189.9	52.7	154.3	204.8	81.7	40.0	32.3	149.8	84.4
1943	77.3	310.1	300.1	157.1	115.0	147.5	58.6	19.9	26.8	25.2	16.8	149.2
1944	92.5	29.7	18.6	50.1	180.2	226.7	82.2	21.2	16.8	14.7	12.8	11.0
1945	30.2	27.4	22.7	80.9	73.6	118.3	69.7	34.0	23.5	17.7	14.0	12.0
1946	16.2	37.8	44.4	84.3	120.6	163.9	95.5	30.9	49.6	36.6	19.0	18.2
1947	22.8	259.7	213.0	174.7	304.0	277.8	102.1	30.8	17.7	14.9	12.9	10.9
1948	19.4	25.7	23.8	50.9	68.3	64.3	48.3	26.6	17.2	16.0	14.3	12.8
1949	15.2	26.3	33.5	40.7	193.6	350.6	137.5	45.5	30.0	24.2	53.7	35.4
1950	27.2	29.2	157.5	97.8	141.5	77.4	38.0	20.5	16.4	14.5	19.0	27.0
1951	43.1	30.0	20.8	51.1	159.6	88.0	45.7	28.4	21.5	20.0	15.9	19.7
1952	21.7	33.6	78.8	60.9	59.6	51.4	50.2	31.5	16.9	14.1	14.9	26.7
1953	44.6	55.5	57.3	51.4	61.9	82.9	54.5	59.3	49.4	30.2	17.6	16.5
1954	48.4	48.0	35.3	439.6	525.3	151.4	59.2	31.1	27.4	21.3	14.3	14.4
1955	21.4	41.3	34.6	28.9	142.5	238.2	100.5	27.7	24.9	19.3	14.5	16.1
1956	22.9	83.3	367.1	340.6	160.5	236.6	121.5	34.4	21.3	18.9	23.8	77.4
1957	71.6	43.3	40.1	161.9	130.1	49.1	66.6	43.4	21.9	16.8	14.2	12.7
1958	14.3	90.7	187.3	78.7	72.8	59.1	63.0	408.7	155.6	37.6	34.1	24.2
1959	21.4	36.0	36.4	53.3	50.8	49.5	47.6	32.2	19.4	15.6	17.7	22.0
1960	22.8	45.2	120.4	71.3	53.6	114.2	150.6	58.3	25.1	16.9	15.9	13.4
1961	13.2	42.2	52.2	50.3	183.1	193.7	73.4	28.0	18.1	14.5	15.1	12.8
1962	16.9	69.0	61.2	350.3	232.5	516.6	210.9	35.1	19.1	42.8	29.1	13.4
1963	75.4	133.6	74.1	133.7	71.8	140.2	109.6	41.3	286.2	117.3	23.0	19.8
1964	80.4	47.5	28.3	47.3	76.3	42.4	29.0	22.2	177.6	115.2	58.6	33.5
1965	62.9	92.7	35.5	227.5	152.1	32.6	24.8	55.3	37.7	18.8	20.0	20.8
1966	18.6	23.6	38.5	156.9	140.2	458.1	266.7	63.2	34.7	36.5	24.8	13.5
1967	16.7	28.7	28.9	28.3	30.9	59.2	45.2	21.8	14.9	14.3	16.7	19.4
1968	19.1	26.6	25.8	23.4	55.5	167.3	87.6	42.7	26.5	18.5	15.8	13.1
1969	31.6	31.7	35.2	32.9	53.7	37.2	23.3	17.8	22.8	18.6	43.4	44.1
1970	95.1	60.1	31.5	91.2	80.4	53.8	43.9	55.5	36.4	33.1	44.6	28.0
1971	128.5	74.4	37.9	123.7	408.8	296.0	77.5	24.0	19.3	16.4	13.8	12.3
1972	16.0	76.1	43.5	29.3	220.4	175.1	78.1	31.6	16.9	16.8	18.2	19.5
1973	20.9	58.5	44.2	358.8	467.1	528.9	189.4	70.2	44.1	25.2	18.0	12.6
1974	14.5	58.0	59.2	46.0	55.8	53.3	43.7	22.1	15.2	14.0	13.4	51.4
1975	32.1	31.3	387.0	596.1	531.7	1000.6	349.7	72.4	35.8	21.7	16.0	25.0
1976	253.4	111.2	27.1	70.3	105.4	82.3	49.3	24.9	17.7	18.2	16.6	21.7
1977	51.1	49.2	64.1	68.3	62.2	162.0	513.6	202.4	27.7	17.0	18.8	32.7
1978	56.0	65.4	145.4	65.3	87.9	57.5	43.5	25.1	18.5	30.2	31.5	23.0
1979	21.5	24.6	27.1	96.6	122.3	62.1	34.0	19.2	15.4	14.4	12.8	86.7
1980	49.0	54.6	36.4	94.4	166.4	75.3	31.5	31.1	26.8	18.9	25.4	23.8
1981	18.4	28.5	33.7	55.7	66.6	229.6	112.8	31.4	26.2	27.5	20.0	17.5
1982	41.0	38.6	21.5	21.4	18.9	26.4	30.0	20.7	15.6	27.8	19.3	17.6
1983	23.6	62.0	158.4	106.4	81.7	116.8	98.1	41.8	26.0	32.6	23.2	14.2
1984	27.6	43.6	28.4	114.1	484.8	186.8	27.5	16.5	14.1	13.4	12.0	11.1
1985	181.9	116.7	129.3	221.5	126.5	62.2	39.0	19.8	16.7	16.0	22.3	25.4
1986	86.5	109.3	53.0	36.4	44.4	70.4	46.7	19.8	19.0	16.6	30.5	799.0
1987	328.9	61.6	40.2	59.1	549.7	385.7	108.4	46.8	31.5	25.6	21.7	18.6
1988	21.1	49.4	146.7	120.4	501.4	182.9	134.7	59.8	24.2	22.2	16.6	11.4
1989	36.1	375.8	185.7	79.1	38.3	277.9	132.0	31.6	20.6	18.3	20.7	16.0
1990	21.3	23.7	47.3	134.8	161.8	68.5	28.3	15.7	14.6	13.5	12.0	14.9
1991	175.3	98.4	117.5	63.5	85.7	60.0	39.8	21.4	14.8	13.2	14.3	14.0
1992	15.7	30.3	23.6	23.3	56.1	112.5	60.7	21.4	14.3	12.5	13.8	17.2
1993	93.1	64.2	130.4	154.3	195.7	238.0	95.7	19.2	15.9	21.6	21.6	13.6
1994	14.4	32.5	29.9	60.7	39.6	137.6	102.4	40.2	33.6	26.2	15.5	14.9
1995	24.7	32.6	266.9	592.8	543.1	165.9	52.5	23.5	18.8	34.4	24.8	14.8
1996	19.8	128.0	197.7	316.1	179.3	115.7	104.9	50.6	289.3	135.6	31.8	18.3
1997	22.0	39.3	28.4	71.2	608.5	401.5	105.9	32.8	21.3	18.2	19.4	15.4
1998	15.8	49.3	128.9	145.5	261.2	147.2	50.6	21.9	16.5	15.5	13.0	11.1
1999	26.4	34.1	262.4	524.7	414.7	632.1	293.0	77.0	35.3	20.2	14.7	21.3
2000	32.8	44.1	80.2	147.6	114.1	95.2	63.7	31.9	19.3	18.8	18.2	19.6
2001	36.6	282.9	262.5	152.4	96.4	147.1	66.4	33.7	28.5	40.3	72.2	58.3
2002	30.0	24.0	34.7	55.1	42.5	61.3	44.8	26.4	20.3	15.7	14.7	19.7
2003	17.7	22.6	20.4	36.7	70.2	124.5	67.9	22.4	17.2	32.0	29.5	62.6
2004	41.2	66.9	129.0	167.7	118.3	79.6	44.1	21.0	15.8	13.8	14.0	11.1
Average	45.3	74.5	97.4	131.7	180.5	180.1	92.6	42.6	34.9	31.3	25.4	34.7
Min	12.3	20.7	18.6	21.4	18.9	26.4	23.3	15.7	14.1	12.5	12.0	10.9
Max	328.9	425.0	387.0	596.1	677.5	1000.6	513.6	408.7	289.3	312.7	149.8	799.0

Scenario 41 (m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	128.8	27.5	29.1	30.0	82.0	198.4	118.9	39.8	22.6	16.6	13.8	15.9
1921	22.3	224.5	232.8	69.3	32.9	32.5	25.7	70.5	69.7	36.5	51.1	26.5
1922	47.8	171.4	73.5	193.6	513.7	278.0	65.1	19.5	17.1	210.3	99.1	17.5
1923	16.1	22.5	27.7	90.8	117.2	96.3	43.6	20.1	17.5	15.1	14.9	17.5
1924	19.9	33.1	300.8	151.3	58.0	588.5	309.3	59.4	21.0	16.6	14.1	14.9
1925	18.0	33.7	31.2	65.2	41.9	242.4	104.8	23.7	27.4	22.8	16.1	22.9
1926	36.9	41.6	56.9	44.4	46.7	605.9	255.2	22.2	16.0	16.6	17.0	14.3
1927	25.0	30.4	64.2	286.8	177.4	95.2	46.8	19.9	17.0	15.2	18.3	16.5
1928	21.7	31.1	38.8	36.1	34.9	230.9	99.6	23.1	43.4	54.1	29.4	81.0
1929	95.1	82.3	140.8	150.5	57.7	112.0	79.9	26.8	23.8	21.9	37.8	32.0
1930	24.6	26.9	30.6	307.5	334.6	287.3	117.5	28.7	17.4	313.8	140.2	16.8
1931	22.0	33.3	56.6	39.1	280.7	129.8	35.6	22.9	22.3	24.8	20.0	29.7
1932	32.1	187.7	176.0	53.4	27.5	42.2	36.0	19.1	15.1	15.2	13.9	12.1
1933	13.1	236.9	338.7	578.7	238.8	151.0	72.2	23.9	18.1	23.2	19.6	13.9
1934	33.7	63.2	151.6	81.7	38.4	67.9	130.7	100.7	85.3	37.9	31.5	22.9
1935	18.6	25.6	22.2	27.4	210.7	141.0	48.0	58.1	39.5	22.3	16.5	13.8
1936	24.3	445.3	178.1	66.8	512.0	219.5	43.7	18.6	15.6	14.8	13.6	12.7
1937	16.8	25.8	36.7	81.9	180.7	89.4	107.7	49.0	25.7	26.9	24.3	17.9
1938	20.6	35.0	215.2	233.5	677.5	218.5	37.4	25.3	21.2	23.5	22.7	95.2
1939	65.7	54.1	42.0	36.1	371.1	221.4	64.5	124.0	61.7	22.1	15.7	26.0
1940	25.4	35.1	79.0	105.2	124.0	71.3	52.8	27.1	17.7	16.9	15.8	13.7
1941	19.2	27.3	23.2	66.5	287.8	197.7	86.7	44.7	24.4	16.8	17.7	19.0
1942	29.1	199.0	369.2	189.9	52.6	154.3	204.8	81.7	38.8	29.5	153.7	84.4
1943	77.3	310.1	300.1	157.1	115.0	147.5	58.6	20.1	24.0	23.8	16.9	153.1
1944	92.5	31.3	21.2	52.3	173.4	226.6	79.1	21.4	17.1	15.1	13.4	11.8
1945	27.8	28.5	24.6	71.6	69.9	129.7	65.9	29.5	20.2	17.1	14.5	12.7
1946	16.6	38.6	45.5	79.4	113.4	184.5	96.1	26.6	46.0	33.9	18.9	17.1
1947	22.3	269.4	215.8	174.7	304.0	277.8	102.1	27.1	17.8	15.3	13.5	11.7
1948	19.2	27.3	25.6	52.1	67.0	65.4	48.7	25.9	17.4	15.8	14.4	13.2
1949	15.8	27.6	34.5	41.8	184.5	338.5	128.0	39.2	26.2	23.0	51.5	33.0
1950	25.2	30.2	177.1	117.7	141.5	77.4	39.0	20.6	16.4	14.8	17.9	25.6
1951	39.9	30.6	23.0	52.8	150.0	83.8	46.5	27.7	20.6	18.8	16.0	17.2
1952	20.5	31.9	76.2	60.9	53.5	51.2	48.7	27.4	17.4	14.8	14.8	24.0
1953	41.2	54.0	55.4	51.0	60.0	85.3	53.0	65.9	56.2	27.4	17.4	16.6
1954	47.1	48.6	36.4	464.7	530.8	151.4	59.2	28.7	24.3	20.1	14.8	14.7
1955	21.2	41.2	34.3	30.7	138.0	242.6	104.5	27.3	22.8	18.5	15.1	14.6
1956	22.8	79.5	375.4	340.6	160.5	236.6	121.5	29.1	20.3	18.5	21.8	74.6
1957	68.4	44.0	41.3	174.6	130.1	51.1	65.1	38.3	20.5	16.8	14.7	13.1
1958	15.0	85.6	189.4	78.9	77.4	61.8	63.0	408.7	155.6	37.6	32.0	22.9
1959	21.7	35.0	36.0	51.2	57.6	50.7	48.0	29.7	19.2	15.8	16.7	20.0
1960	22.4	43.0	114.9	68.3	54.2	129.0	150.6	58.3	22.2	17.1	15.8	13.8
1961	14.0	38.9	48.7	50.0	192.6	193.7	73.4	23.6	17.7	15.0	15.3	13.4
1962	17.1	65.3	57.3	361.0	232.5	516.6	210.9	30.6	18.9	40.0	27.6	14.0
1963	72.1	145.6	74.2	134.1	72.4	139.3	109.6	36.4	291.3	117.3	22.1	18.4
1964	78.9	47.5	28.7	48.1	79.1	42.4	30.2	21.3	177.2	115.2	57.9	32.0
1965	60.6	97.3	35.2	227.8	152.1	33.9	26.9	49.6	34.0	18.5	18.6	19.4
1966	18.9	25.1	39.0	153.8	131.9	475.4	266.7	63.2	31.0	33.7	23.3	14.2
1967	16.9	29.6	30.4	30.5	32.0	61.4	46.4	21.8	15.6	14.8	16.0	17.7
1968	18.7	27.9	27.1	25.6	55.9	155.0	77.7	39.9	25.5	17.8	15.5	13.4
1969	29.1	32.2	35.4	34.4	53.3	39.4	25.5	18.2	19.9	17.3	40.8	40.9
1970	91.8	58.2	32.7	85.7	77.0	55.7	44.4	49.6	32.6	30.3	42.1	25.4
1971	125.5	71.8	35.7	117.9	481.3	296.0	77.5	23.6	18.6	16.4	14.3	13.0
1972	16.4	72.9	43.1	31.1	211.5	184.4	78.1	27.7	17.1	16.1	17.2	18.9
1973	20.7	57.0	44.3	366.3	467.1	528.9	189.4	65.4	40.5	23.9	17.5	13.2
1974	15.2	56.2	57.8	47.2	56.9	53.7	41.6	22.0	15.8	14.5	13.9	48.5
1975	30.4	31.4	400.7	596.1	531.7	1000.6	349.7	72.4	35.8	20.5	16.1	22.6
1976	256.9	111.2	28.4	71.5	102.1	82.8	48.0	23.3	18.1	17.3	15.8	19.4
1977	49.4	48.4	63.9	68.5	62.3	163.0	521.4	202.4	25.2	17.3	17.9	30.3
1978	52.8	64.4	150.0	66.3	92.2	57.5	44.4	24.9	18.5	27.3	29.3	21.9
1979	20.6	25.9	28.5	98.0	122.3	63.0	34.2	19.8	16.1	14.9	13.4	83.9
1980	46.7	55.1	36.4	87.8	153.8	92.0	32.6	25.5	23.0	17.7	23.7	22.4
1981	19.0	30.0	33.6	54.3	66.1	220.4	112.2	27.8	23.8	24.7	18.6	16.9
1982	39.3	36.2	22.2	23.9	20.3	28.9	30.7	19.5	15.6	26.5	19.1	17.9
1983	22.7	57.8	152.2	101.0	78.2	108.9	90.6	37.2	23.4	29.8	21.9	14.5
1984	25.2	42.5	29.7	107.1	581.6	186.8	29.1	17.1	14.7	14.0	12.7	11.4
1985	178.3	116.1	129.3	221.5	126.5	62.2	39.3	20.3	17.1	15.8	20.4	23.1
1986	83.4	115.5	53.0	37.7	44.4	71.1	46.1	20.0	18.2	16.4	28.9	799.9
1987	328.9	61.6	40.2	59.1	549.7	385.7	108.4	41.9	29.1	24.4	20.5	17.0
1988	19.9	47.3	160.9	120.4	501.4	182.9	134.7	59.8	23.2	19.7	15.7	12.0
1989	34.2	381.6	185.7	79.1	38.4	277.8	132.0	28.9	19.7	17.9	18.6	14.5
1990	20.3	25.2	48.7	135.6	160.9	70.7	30.3	16.6	15.1	14.2	12.6	13.9
1991	171.9	94.3	112.6	63.2	85.3	62.0	41.2	21.7	15.5	14.0	14.9	13.6
1992	16.0	32.0	25.8	25.4	56.5	113.4	59.8	20.9	15.0	13.5	14.3	15.8
1993	89.6	60.7	126.1	146.7	186.4	251.6	92.8	19.4	16.0	19.6	20.1	13.9
1994	15.1	34.5	30.1	59.0	39.6	128.0	92.6	34.9	31.1	25.0	16.0	14.8
1995	23.9	33.5	291.4	612.7	543.1	165.9	53.6	23.5	19.0	33.2	24.5	15.3
1996	20.0	122.9	202.2	316.1	179.3	115.7	104.9	45.9	294.2	135.6	29.6	18.0
1997	20.6	38.4	29.3	71.3	612.7	401.5	105.9	27.9	19.4	17.2	18.1	15.2
1998	16.2	44.7	142.1	145.5	261.2	147.2	50.4	22.4	16.5	15.0	13.3	11.6
1999	23.6	33.3	258.3	531.6	414.7	632.1	293.0	77.0	31.9	19.5	15.2	20.0
2000	32.2	43.4	80.2	142.4	113.8	102.0	61.0	27.9	19.3	19.0	18.6	18.8
2001	34.6	296.4	262.5	152.4	96.4	147.1	65.0	29.7	25.7	37.5	69.7	67.3
2002	29.0	25.8	34.3	55.1	42.7	62.6	44.6	22.4	18.0	15.8	14.4	17.8
2003	17.6	24.1	21.9	30.1	65.5	113.7	74.9	21.2	17.4	29.2	27.8	59.4
2004	38.5	71.0	129.2	197.5	118.3	79.6	42.5	19.5	15.9	14.3	13.8	11.3
Average	44.3	75.1	99.3	132.9	181.4	181.3	92.1	40.8	34.0	30.5	24.9	34.2
Min	13.1	22.5	21.2	23.9	20.3	28.9	25.5	16.6	14.7	13.5	12.6	11.3
Max	328.9	445.3	400.7	612.7	677.5	1000.6	521.4	408.7	294.2	313.8	153.7	799.9

Scenario 42 (m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	128.8	26.4	28.7	29.9	83.7	198.4	118.9	45.2	23.0	16.3	13.3	15.8
1921	23.1	229.6	222.4	69.1	32.0	29.9	23.4	76.9	73.8	39.6	43.5	26.5
1922	49.1	170.1	73.5	193.6	513.7	278.0	68.9	19.1	17.4	206.9	99.1	18.3
1923	15.4	20.6	26.9	90.0	121.3	97.4	47.3	19.9	19.0	15.7	15.1	18.8
1924	20.0	32.5	292.9	151.3	57.1	589.4	309.3	59.4	22.1	16.3	13.5	15.9
1925	17.5	33.6	30.1	64.2	42.2	250.2	110.9	26.9	31.2	25.6	16.2	25.0
1926	38.6	41.0	57.4	43.4	47.1	581.2	255.2	22.8	15.6	16.1	17.4	14.4
1927	26.7	29.3	71.2	278.8	177.4	93.2	45.2	19.7	17.1	14.9	19.8	17.2
1928	21.4	31.9	45.3	39.8	36.6	220.3	99.6	25.7	47.3	52.2	31.5	74.2
1929	95.1	82.3	140.8	150.5	57.7	112.0	79.9	31.4	25.6	23.1	40.0	34.5
1930	25.4	25.1	32.2	294.9	334.6	287.3	117.5	30.1	17.0	312.7	140.2	17.6
1931	22.2	32.5	60.1	39.3	276.3	129.8	34.9	22.9	23.3	27.6	21.1	32.9
1932	35.3	176.9	176.0	52.2	26.3	42.3	39.6	19.4	14.6	14.8	13.4	11.6
1933	12.3	237.6	338.8	578.7	238.8	151.0	72.2	23.9	18.1	26.0	21.8	13.5
1934	34.9	65.4	143.8	81.7	37.5	68.6	130.7	100.7	85.3	40.7	33.7	24.3
1935	17.9	23.7	19.6	24.8	220.3	140.0	48.1	63.9	41.7	25.1	17.9	13.5
1936	25.9	425.0	178.1	66.8	512.0	219.5	45.3	18.0	15.2	14.4	13.0	12.4
1937	16.4	23.9	36.4	88.3	190.8	81.8	103.1	49.4	28.5	29.7	26.3	18.9
1938	21.8	37.4	202.8	233.5	677.5	218.5	36.1	27.5	23.2	26.3	24.2	98.2
1939	64.7	53.4	40.8	34.8	364.7	221.4	64.5	124.0	63.8	22.8	15.3	27.3
1940	26.0	34.3	78.4	105.4	124.9	69.5	53.3	30.2	17.4	17.3	16.2	13.1
1941	20.2	26.0	20.6	65.4	295.3	208.5	93.3	49.1	25.4	16.3	18.8	20.5
1942	32.3	203.6	328.6	189.9	52.6	154.3	204.8	81.7	40.0	32.3	149.8	84.4
1943	77.3	310.1	300.1	157.1	115.0	147.5	58.6	19.9	26.8	25.2	16.8	149.2
1944	92.5	29.7	18.6	50.1	180.2	226.7	82.2	21.2	16.8	14.7	12.8	11.0
1945	30.2	27.4	22.7	80.9	73.6	118.3	69.7	34.0	23.5	17.7	14.0	12.0
1946	16.2	37.7	44.4	84.3	120.6	163.9	95.5	30.9	49.6	36.6	19.0	18.2
1947	22.8	259.6	213.0	174.7	304.0	277.8	102.1	30.8	17.7	14.9	12.9	10.9
1948	19.4	25.7	23.8	50.9	68.3	64.3	48.3	26.6	17.2	16.0	14.3	12.8
1949	15.2	26.3	33.5	40.7	193.6	350.6	137.5	45.5	30.0	24.2	53.7	35.4
1950	27.2	29.2	157.5	97.9	141.5	77.4	38.0	20.5	16.4	14.5	19.0	27.0
1951	43.1	30.0	20.8	51.1	159.6	88.0	45.7	28.4	21.5	20.0	15.9	19.7
1952	21.7	33.5	78.8	60.9	59.6	51.4	50.2	31.5	16.9	14.1	14.9	26.7
1953	44.6	55.5	57.3	51.4	61.8	82.9	54.5	59.3	49.4	30.2	17.6	16.5
1954	48.4	48.0	35.3	439.6	525.4	151.4	59.2	31.1	27.4	21.3	14.3	14.4
1955	21.4	41.3	34.6	28.9	142.5	238.2	100.5	27.7	24.9	19.3	14.5	16.1
1956	22.9	83.3	367.1	340.6	160.5	236.6	121.5	34.4	21.3	18.9	23.8	77.4
1957	71.6	43.3	40.1	162.0	130.1	49.1	66.6	43.4	21.9	16.8	14.2	12.7
1958	14.2	90.7	187.3	78.7	72.8	59.1	63.0	408.7	155.6	37.6	34.1	24.2
1959	21.4	36.0	36.4	53.3	50.8	49.5	47.6	32.2	19.4	15.6	17.7	22.0
1960	22.8	45.2	120.4	71.3	53.6	114.3	150.6	58.3	25.1	16.9	15.9	13.4
1961	13.2	42.2	52.2	50.3	183.1	193.7	73.4	28.0	18.1	14.5	15.1	12.8
1962	16.9	69.0	61.2	350.3	232.5	516.6	210.9	35.1	19.1	42.8	29.1	13.4
1963	75.4	133.6	74.2	133.7	71.8	140.2	109.6	41.3	286.2	117.3	23.0	19.8
1964	80.4	47.5	28.3	47.3	76.3	42.4	29.0	22.2	177.6	115.2	58.6	33.5
1965	62.9	92.7	35.5	227.5	152.1	32.6	24.8	55.3	37.7	18.8	20.0	20.8
1966	18.6	23.6	38.5	156.9	140.2	458.1	266.7	63.2	34.7	36.5	24.8	13.5
1967	16.7	28.7	28.9	28.3	30.9	59.2	45.2	21.8	14.9	14.3	16.7	19.4
1968	19.1	26.6	25.8	23.4	55.5	167.3	87.6	42.7	26.5	18.5	15.8	13.1
1969	31.5	31.6	35.2	32.9	53.7	37.2	23.3	17.8	22.8	18.6	43.4	44.1
1970	95.1	60.1	31.5	91.2	80.4	53.8	43.9	55.5	36.4	33.1	44.6	28.0
1971	128.5	74.4	37.9	123.7	408.7	296.0	77.5	24.0	19.3	16.4	13.8	12.3
1972	15.9	76.1	43.5	29.3	220.4	175.1	78.1	31.6	16.9	16.8	18.2	19.5
1973	20.9	58.5	44.2	358.8	467.1	528.9	189.4	70.2	44.1	25.2	18.0	12.6
1974	14.5	57.9	59.2	46.0	55.8	53.3	43.7	22.1	15.2	14.0	13.4	51.4
1975	32.1	31.3	387.0	596.1	531.7	1000.6	349.7	72.4	35.8	21.7	16.0	25.0
1976	253.4	111.2	27.1	70.3	105.4	82.3	49.3	24.9	17.7	18.2	16.6	21.7
1977	51.1	49.1	64.1	68.3	62.2	162.0	513.6	202.4	27.7	17.0	18.8	32.7
1978	56.0	65.4	145.4	65.3	87.9	57.5	43.4	25.1	18.5	30.2	31.5	23.0
1979	21.5	24.6	27.1	96.6	122.3	62.1	34.0	19.2	15.4	14.4	12.8	86.7
1980	49.0	54.6	36.4	94.4	166.4	75.3	31.5	31.1	26.8	18.9	25.4	23.8
1981	18.4	28.5	33.7	55.7	66.5	229.6	112.8	31.4	26.2	27.5	20.0	17.5
1982	41.0	38.6	21.5	21.4	18.9	26.4	30.0	20.7	15.6	27.8	19.3	17.6
1983	23.6	62.0	158.4	106.4	81.7	116.8	98.0	41.8	26.0	32.6	23.2	14.2
1984	27.6	43.6	28.4	114.1	484.9	186.8	27.5	16.5	14.1	13.4	12.0	11.1
1985	181.9	116.7	129.3	221.5	126.5	62.2	39.0	19.8	16.7	16.0	22.3	25.4
1986	86.5	109.3	53.0	36.4	44.4	70.4	46.7	19.8	19.0	16.6	30.5	799.0
1987	328.9	61.6	40.2	59.1	549.7	385.7	108.4	46.8	31.5	25.6	21.7	18.6
1988	21.0	49.4	146.7	120.4	501.4	182.9	134.7	59.8	24.2	22.2	16.6	11.4
1989	36.1	375.8	185.7	79.1	38.3	277.9	132.0	31.6	20.6	18.3	20.7	16.0
1990	21.3	23.7	47.3	134.8	161.8	68.5	28.3	15.7	14.6	13.5	12.0	14.9
1991	175.3	98.4	117.5	63.5	85.7	60.0	39.8	21.4	14.8	13.2	14.3	14.0
1992	15.7	30.3	23.6	23.3	56.1	112.5	60.7	21.4	14.3	12.5	13.8	17.2
1993	93.1	64.2	130.4	154.3	195.7	238.0	95.7	19.2	15.9	21.6	21.6	13.6
1994	14.4	32.5	29.9	60.7	39.6	137.6	102.4	40.2	33.6	26.2	15.5	14.9
1995	24.7	32.5	266.9	592.7	543.1	165.9	52.5	23.5	18.8	34.4	24.8	14.8
1996	19.8	128.0	197.7	316.1	179.3	115.7	104.9	50.6	289.3	135.6	31.8	18.3
1997	22.0	39.3	28.4	71.2	608.5	401.5	105.9	32.8	21.3	18.2	19.4	15.4
1998	15.8	49.3	128.9	145.5	261.2	147.2	50.6	21.9	16.5	15.5	13.0	11.1
1999	26.4	34.1	262.4	524.8	414.7	632.1	293.0	77.0	35.3	20.2	14.7	21.3
2000	32.8	44.1	80.2	147.6	114.1	95.2	63.7	31.9	19.3	18.8	18.2	19.6
2001	36.5	282.9	262.5	152.4	96.4	147.1	66.4	33.7	28.5	40.3	72.2	58.3
2002	30.0	24.0	34.7	55.1	42.5	61.3	44.8	26.4	20.3	15.7	14.7	19.7
2003	17.6	22.6	20.4	36.7	70.2	124.5	67.9	22.4	17.1	32.0	29.5	62.6
2004	41.2	66.9	129.0	167.8	118.3	79.6	44.1	21.0	15.8	13.8	14.0	11.1
Average	45.3	74.5	97.4	131.7	180.4	180.1	92.6	42.6	34.9	31.3	25.4	34.7
Min	12.3	20.6	18.6	21.4	18.9	26.4	23.3	15.7	14.1	12.5	12.0	10.9
Max	328.9	425.0	387.0	596.1	677.5	1000.6	513.6	408.7	289.3	312.7	149.8	799.0

Scenario 51 (m^3/s)

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	128.8	27.9	29.5	30.5	80.6	198.4	118.9	39.4	21.8	15.8	13.5	16.1
1921	22.5	224.9	234.3	69.7	33.3	33.0	26.2	70.2	68.9	35.6	51.4	26.5
1922	48.0	171.2	73.5	193.6	513.7	278.0	65.6	19.1	16.3	211.0	99.1	17.7
1923	16.3	22.9	28.1	91.3	117.6	94.2	44.1	19.7	16.6	14.3	14.6	17.7
1924	20.2	33.6	301.9	151.3	58.4	588.1	309.3	59.4	20.2	15.8	13.8	15.1
1925	18.2	34.1	31.6	65.7	42.3	242.9	105.3	23.3	26.5	21.9	15.8	23.1
1926	37.2	42.0	57.4	44.8	47.1	605.1	255.2	21.8	15.2	15.8	16.7	14.5
1927	25.2	30.8	64.6	287.8	177.4	95.7	47.2	19.5	16.2	14.4	18.0	16.7
1928	22.0	31.5	39.2	36.5	35.3	230.2	99.6	22.7	43.4	54.5	29.1	81.4
1929	95.1	82.3	140.8	150.5	57.7	112.0	79.9	26.4	23.0	21.0	37.5	32.2
1930	24.9	27.3	31.0	308.6	334.6	287.3	117.5	28.3	16.6	315.0	140.2	17.0
1931	22.2	33.7	57.0	39.6	278.8	129.8	36.0	22.5	21.5	24.0	19.7	29.9
1932	32.3	189.2	176.0	53.8	27.9	42.7	36.5	18.7	14.2	14.4	13.6	12.3
1933	13.3	237.1	338.7	578.7	238.8	151.0	72.2	23.6	17.3	22.3	19.3	14.1
1934	33.9	63.6	153.1	81.7	38.8	67.5	130.7	100.7	85.3	37.1	31.2	23.1
1935	18.8	26.0	22.6	27.8	211.1	140.0	48.5	57.7	39.5	21.4	16.2	14.0
1936	24.5	446.0	178.1	66.8	512.0	219.5	44.2	18.2	14.7	14.0	13.2	12.9
1937	17.0	26.3	37.2	82.4	181.1	89.2	107.7	49.0	24.9	26.1	24.0	18.1
1938	20.9	35.4	216.2	233.5	677.5	218.5	37.8	24.9	20.4	22.6	22.3	95.4
1939	67.4	54.1	42.4	36.6	370.2	221.4	64.5	124.0	61.7	21.3	15.4	26.2
1940	25.6	35.5	79.4	105.6	124.5	71.8	53.3	26.7	16.8	16.1	15.5	13.9
1941	19.4	27.8	23.6	67.0	288.2	198.2	87.1	44.4	23.5	16.0	17.4	19.2
1942	29.3	199.4	368.1	189.9	53.0	153.9	204.8	81.7	38.8	28.7	154.5	84.4
1943	77.3	310.1	300.1	157.1	115.0	147.5	58.6	19.7	23.2	22.9	16.6	155.5
1944	92.5	31.7	21.7	52.8	173.8	224.9	79.6	21.0	16.3	14.3	13.1	12.0
1945	28.1	28.9	25.0	72.0	70.0	129.7	66.1	29.2	19.4	16.2	14.2	12.9
1946	16.8	39.0	45.9	79.9	113.8	184.3	96.1	26.2	45.2	33.0	18.6	17.3
1947	22.5	271.3	215.8	174.7	304.0	277.8	102.1	26.7	16.9	14.5	13.2	11.9
1948	19.4	27.7	26.0	52.6	67.4	65.9	49.2	25.6	16.6	15.0	14.1	13.4
1949	16.1	28.0	34.9	42.3	184.9	339.0	128.4	38.8	25.4	22.2	51.1	33.2
1950	25.5	30.6	177.1	117.7	141.5	77.4	39.5	20.3	15.6	14.0	17.5	25.8
1951	40.2	31.1	23.4	53.2	150.4	84.3	47.0	27.3	19.8	18.0	15.7	17.4
1952	20.7	32.3	76.6	61.3	53.9	51.7	49.2	27.0	16.5	14.0	14.5	24.2
1953	41.4	54.5	55.8	51.5	60.4	83.7	53.0	65.9	56.2	26.5	17.1	16.8
1954	47.3	49.0	36.9	464.6	530.8	151.4	59.2	28.7	23.4	19.2	14.4	14.9
1955	21.5	41.6	34.7	31.1	138.4	242.4	104.5	26.9	22.0	17.7	14.7	14.9
1956	23.0	79.9	376.9	340.6	160.5	236.6	121.5	28.7	19.5	17.6	21.4	74.8
1957	68.9	44.5	41.7	175.4	130.1	51.7	65.6	37.9	19.7	15.9	14.3	13.3
1958	15.2	86.0	189.9	79.3	76.9	61.8	63.0	408.7	155.6	37.6	31.7	23.1
1959	21.9	35.4	36.4	51.6	56.0	51.2	48.5	29.3	18.4	15.0	16.3	20.2
1960	22.7	43.4	115.3	68.8	54.6	128.3	150.6	58.3	21.4	16.2	15.5	14.0
1961	14.3	39.3	49.1	50.4	192.8	193.7	73.4	23.3	16.9	14.2	15.0	13.6
1962	17.3	65.7	57.7	362.1	232.5	516.6	210.9	30.2	18.1	39.2	27.3	14.2
1963	72.4	147.5	74.2	134.5	72.8	138.5	109.6	36.0	291.7	117.3	21.7	18.6
1964	79.1	48.0	29.1	48.5	77.7	42.4	30.7	20.9	177.1	115.2	57.9	32.2
1965	60.8	96.9	35.6	227.4	152.1	34.4	27.4	49.2	33.2	17.7	18.2	19.6
1966	19.1	25.5	39.4	154.2	132.4	474.7	266.7	63.2	30.2	32.8	23.0	14.4
1967	17.1	30.0	30.8	31.0	32.4	61.9	46.9	21.4	14.8	14.0	15.7	18.0
1968	19.0	28.3	27.5	26.1	56.3	155.5	78.2	39.6	24.6	17.0	15.2	13.6
1969	29.3	32.6	35.8	34.8	53.7	39.9	26.0	17.9	19.1	16.5	40.5	41.1
1970	92.1	58.6	33.1	86.1	77.4	56.2	44.8	49.2	31.8	29.5	41.8	25.6
1971	125.8	72.3	36.1	118.0	478.8	296.0	77.5	23.3	17.8	15.6	14.0	13.2
1972	16.6	73.3	43.5	31.5	211.9	184.7	78.1	27.3	16.3	15.3	16.9	19.1
1973	20.9	57.4	44.8	367.3	467.1	528.9	189.4	65.4	39.7	23.1	17.2	13.5
1974	15.5	56.6	58.2	47.6	57.3	54.2	42.0	21.6	15.0	13.7	13.6	48.7
1975	30.6	31.9	401.1	596.1	531.7	1000.6	349.7	72.4	35.8	19.7	15.7	22.8
1976	257.9	111.2	28.8	71.9	102.5	81.6	48.5	22.9	17.3	16.5	15.4	19.6
1977	49.6	48.9	64.4	68.9	62.8	163.5	520.6	202.4	24.3	16.4	17.6	30.5
1978	53.0	64.8	151.1	66.3	92.2	57.6	44.8	24.5	17.7	26.5	29.0	22.1
1979	20.8	26.3	28.9	98.4	122.8	63.5	34.6	19.4	15.2	14.0	13.1	84.1
1980	47.0	55.5	36.8	88.2	154.2	90.9	33.1	25.1	22.1	16.9	23.3	22.7
1981	19.3	30.5	34.1	54.8	66.5	220.9	111.5	27.4	23.0	23.9	18.2	17.1
1982	39.5	36.6	22.6	24.3	20.7	29.4	31.2	19.1	14.8	25.7	18.8	18.1
1983	22.9	58.2	152.6	101.5	78.7	109.4	91.0	36.8	22.6	28.9	21.5	14.8
1984	25.5	42.9	30.1	107.6	580.7	186.8	29.5	16.8	13.9	13.2	12.4	11.6
1985	178.5	117.6	129.3	221.5	126.5	62.2	39.7	20.0	16.3	15.0	20.1	23.3
1986	83.7	117.0	53.0	38.1	44.8	71.6	46.6	19.6	17.4	15.6	28.6	800.5
1987	328.9	61.6	40.2	59.1	549.7	385.7	108.4	41.5	28.3	23.6	20.2	17.2
1988	20.1	47.7	162.4	120.4	501.4	182.9	134.7	59.8	22.4	18.9	15.4	12.3
1989	34.4	383.1	185.7	79.1	38.8	277.4	132.0	28.5	18.9	17.1	18.3	14.8
1990	20.5	25.6	49.1	136.0	161.3	71.2	30.8	16.2	14.3	13.3	12.3	14.1
1991	172.2	94.7	113.0	63.7	85.7	62.5	41.6	21.3	14.7	13.2	14.6	13.8
1992	16.2	32.4	26.2	25.8	56.9	113.9	60.3	20.5	14.1	12.6	14.0	16.0
1993	89.9	61.1	126.5	147.1	186.8	249.7	92.8	19.0	15.2	18.8	19.8	14.1
1994	15.3	34.9	30.5	59.4	40.0	128.5	93.1	34.5	30.3	24.2	15.7	15.0
1995	24.1	33.9	292.1	612.7	543.1	165.9	54.0	23.1	18.2	32.4	24.2	15.5
1996	20.3	123.3	203.2	316.1	179.3	115.7	104.9	45.5	294.5	135.6	29.3	18.2
1997	20.8	38.8	29.7	70.4	612.7	401.5	105.9	27.5	18.6	16.4	17.7	15.5
1998	16.4	45.1	143.5	145.5	261.2	147.2	50.9	22.0	15.7	14.2	13.0	11.8
1999	23.8	33.8	258.8	532.2	414.7	632.1	293.0	77.0	31.1	18.6	14.9	20.2
2000	32.4	43.8	80.6	142.8	114.0	102.0	61.5	27.6	18.5	18.2	18.3	19.0
2001	34.8	297.9	262.5	152.4	96.4	147.1	65.5	29.3	24.9	36.6	69.9	68.7
2002	29.2	26.2	34.8	55.5	43.1	63.1	45.1	22.1	17.2	14.9	14.0	18.0
2003	17.9	24.5	22.3	30.5	65.9	114.2	71.7	20.8	16.6	28.4	27.4	59.7
2004	40.6	71.0	129.2	197.5	118.3	79.6	43.0	19.1	15.0	13.5	13.5	11.5
Average	44.6	75.5	99.7	133.2	181.5	181.3	92.3	40.5	33.3	29.8	24.6	34.4
Min	13.3	22.9	21.7	24.3	20.7	29.4	26.0	16.2	13.9	12.6	12.3	11.5
Max	328.9	446.0	401.1	612.7	677.5	1000.6	520.6	408.7	294.5	315.0	154.5	800.5

Scenario 52 (m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	128.8	27.7	30.0	31.2	82.7	195.5	118.9	42.7	21.2	14.5	12.4	16.4
1921	23.8	230.9	226.7	70.5	33.1	31.4	24.8	74.3	71.9	37.8	44.4	26.7
1922	49.8	169.1	73.5	193.6	513.7	278.0	70.3	16.5	15.6	209.9	99.1	19.0
1923	16.1	21.9	28.1	91.3	122.4	98.9	48.7	17.4	17.0	14.0	14.3	19.4
1924	20.8	33.7	288.3	151.3	58.2	588.3	309.3	59.4	20.3	14.5	12.6	16.5
1925	18.2	34.8	31.4	65.6	43.3	251.7	112.3	24.4	29.4	23.8	15.3	25.6
1926	39.4	42.3	58.6	44.7	48.3	577.2	255.2	20.3	13.7	14.4	16.5	15.0
1927	27.5	30.6	72.5	281.8	177.4	94.7	46.6	17.1	15.2	13.2	18.9	17.9
1928	22.1	33.1	46.6	41.1	37.8	218.2	99.6	23.1	45.5	52.1	30.6	79.8
1929	95.1	82.3	140.8	150.5	57.7	112.0	79.9	28.9	23.8	21.3	39.2	35.1
1930	26.1	26.4	33.5	297.9	334.6	287.3	117.5	27.6	15.1	317.0	140.2	18.2
1931	23.0	33.8	61.4	40.7	270.6	129.8	36.3	20.3	21.5	25.8	20.2	33.5
1932	36.1	181.3	176.0	53.6	27.4	43.8	41.0	16.9	12.8	13.1	12.5	12.3
1933	13.1	238.0	338.8	578.7	238.8	151.0	72.2	21.4	16.3	24.3	20.9	14.1
1934	35.6	66.6	148.1	81.7	38.7	67.6	130.7	100.7	85.3	38.9	32.8	24.9
1935	18.7	25.0	20.9	26.2	221.4	141.5	49.5	61.3	39.9	23.3	17.0	14.1
1936	26.6	424.1	178.1	66.8	512.0	219.5	46.7	15.5	13.3	12.6	12.1	13.0
1937	17.1	25.2	37.7	89.6	191.9	83.3	100.8	49.0	26.7	28.0	25.4	19.5
1938	22.6	38.6	205.0	233.5	677.5	218.5	37.5	25.0	21.3	24.5	23.3	98.9
1939	65.4	54.7	42.1	36.1	365.1	221.4	65.4	123.1	61.9	21.0	14.4	28.0
1940	26.8	35.6	79.7	106.8	126.0	71.0	54.7	27.6	15.6	15.6	15.3	13.8
1941	20.9	27.2	21.9	66.8	296.5	210.0	94.7	46.5	23.5	14.5	17.9	21.1
1942	33.1	204.8	326.1	189.9	53.8	153.2	204.8	81.7	38.8	30.6	152.7	84.4
1943	77.3	310.1	300.1	157.1	115.0	147.5	60.0	17.4	25.0	23.5	15.9	155.0
1944	92.5	31.0	19.9	51.4	181.3	221.8	83.6	18.6	15.0	13.0	11.9	11.6
1945	30.9	28.7	23.9	82.3	74.7	119.8	71.1	31.4	21.6	16.0	13.1	12.6
1946	16.9	39.0	45.7	85.7	121.8	165.3	90.9	28.3	47.8	34.8	18.1	18.9
1947	23.6	262.5	215.8	174.7	304.0	277.8	102.1	28.2	15.9	13.2	12.0	11.6
1948	20.2	27.0	25.1	52.2	69.4	65.8	49.7	24.1	15.4	14.3	13.4	13.4
1949	15.9	27.6	34.7	42.1	194.8	352.0	138.9	43.0	28.2	22.5	52.8	36.0
1950	28.0	30.5	158.8	96.5	141.5	77.4	39.4	17.9	14.5	12.7	18.1	27.6
1951	43.8	31.3	22.1	52.4	160.7	89.4	47.1	25.9	19.6	18.2	15.1	20.3
1952	22.4	34.8	80.0	62.2	60.7	52.9	51.6	29.0	15.1	12.4	14.1	27.3
1953	45.3	56.8	58.6	52.8	63.0	84.4	55.9	56.8	47.6	28.4	16.7	17.1
1954	49.2	49.3	36.5	440.9	518.8	151.4	59.2	28.7	25.6	19.6	13.4	15.1
1955	22.1	42.5	35.8	30.3	143.6	239.7	101.9	25.1	23.1	17.5	13.6	16.7
1956	23.7	84.6	369.1	340.6	160.5	236.6	121.5	31.9	19.4	17.2	22.9	78.0
1957	72.3	44.6	41.4	165.0	130.1	50.6	68.0	40.8	20.1	15.1	13.3	13.1
1958	15.0	92.0	188.7	80.1	74.0	58.5	61.4	408.7	155.6	37.6	33.2	24.8
1959	22.2	37.3	37.7	54.6	52.0	51.0	49.0	29.6	17.6	13.9	16.8	22.6
1960	23.6	46.4	121.7	72.7	54.8	114.6	142.6	58.3	23.3	15.1	15.1	14.1
1961	14.0	43.5	53.5	51.6	182.2	193.7	73.4	25.5	16.3	12.8	14.2	13.4
1962	17.6	70.2	62.5	353.3	232.5	516.6	210.9	32.5	17.2	41.1	28.2	14.0
1963	76.1	139.3	74.2	135.0	72.9	137.8	109.6	38.8	288.9	117.3	22.1	20.5
1964	81.1	48.8	29.6	48.7	71.6	42.4	30.4	19.6	178.8	115.2	57.9	34.1
1965	63.6	92.0	36.8	226.2	152.1	34.1	26.2	52.8	35.8	17.1	19.1	21.5
1966	19.4	24.8	39.8	158.3	141.3	455.9	266.7	63.2	32.9	34.7	23.9	14.2
1967	17.4	30.0	30.2	29.6	32.1	60.7	46.6	19.2	13.1	12.6	15.8	20.1
1968	19.8	27.9	27.0	24.8	56.6	168.8	89.0	40.2	24.7	16.8	14.9	13.7
1969	32.3	32.9	36.5	34.2	54.9	38.7	24.7	15.3	20.9	16.9	42.5	44.7
1970	95.8	61.4	32.7	92.5	81.6	55.3	45.3	52.9	34.5	31.4	43.8	28.6
1971	129.2	75.6	39.2	125.1	398.5	296.0	77.5	21.5	17.5	14.6	12.9	12.9
1972	16.7	77.4	44.8	30.6	221.6	175.8	78.1	29.1	15.0	15.0	17.3	20.1
1973	21.6	59.8	45.4	361.9	467.1	528.9	189.4	67.6	42.3	23.5	17.1	13.2
1974	15.3	59.2	60.4	47.4	56.9	54.7	45.1	19.5	13.3	12.3	12.5	52.1
1975	32.9	32.5	389.1	596.1	531.7	1000.6	349.7	72.4	35.8	20.0	15.2	25.6
1976	255.4	111.2	28.4	71.7	106.5	80.2	50.7	22.4	15.8	16.5	15.7	22.3
1977	51.9	50.4	65.3	69.7	63.4	163.4	509.7	202.4	25.9	15.2	17.9	33.3
1978	56.7	66.7	146.7	66.6	87.0	57.7	44.8	22.5	16.7	28.5	30.6	23.6
1979	22.2	25.8	28.3	97.9	123.4	63.5	35.4	16.6	13.5	12.7	11.9	87.3
1980	49.7	55.8	37.7	95.7	167.6	76.7	32.9	28.6	24.9	17.1	24.5	24.4
1981	19.1	29.8	35.0	57.0	67.7	231.1	114.2	28.9	24.4	25.8	19.1	18.1
1982	41.8	39.9	22.8	22.7	20.0	27.9	31.4	18.1	13.8	26.0	18.4	18.2
1983	24.3	63.2	159.6	107.8	82.8	118.3	99.4	39.3	24.2	30.8	22.4	14.8
1984	28.4	44.8	29.7	115.5	473.5	186.8	28.9	14.0	12.3	11.7	11.1	11.6
1985	182.8	121.0	129.3	221.5	126.5	62.2	40.4	17.2	14.8	14.3	21.4	26.0
1986	87.2	113.6	53.0	37.7	45.6	71.9	48.1	17.2	16.9	14.8	29.7	801.1
1987	328.9	61.6	40.3	59.0	549.7	385.7	108.4	44.2	29.7	23.9	20.8	19.2
1988	21.8	50.6	151.0	120.4	501.4	182.9	134.7	59.8	22.3	20.5	15.7	12.0
1989	36.9	379.0	185.7	79.1	39.4	276.9	132.0	29.0	18.8	16.6	19.8	16.6
1990	22.0	25.0	48.6	136.1	163.0	70.0	29.7	13.2	12.7	11.8	11.1	15.6
1991	176.1	99.7	118.8	64.9	86.8	61.5	41.2	18.9	13.0	11.5	13.4	14.6
1992	16.4	31.6	24.9	24.6	57.2	114.0	62.1	18.8	12.4	10.8	12.9	17.8
1993	93.9	65.4	131.6	155.6	196.8	239.5	97.1	16.6	14.0	19.9	20.7	14.2
1994	15.2	33.7	31.1	62.1	40.7	139.1	103.8	37.6	31.7	24.4	14.6	15.5
1995	25.5	33.8	268.2	585.3	543.1	165.9	53.9	21.0	16.9	32.7	23.9	15.5
1996	20.5	129.3	200.7	316.1	179.3	115.7	104.9	48.1	291.9	135.6	30.9	18.9
1997	22.8	40.6	29.7	72.5	603.7	401.5	105.9	30.3	19.5	16.5	18.5	16.0
1998	16.6	50.5	133.2	145.5	261.2	147.2	52.0	19.3	14.6	13.8	12.1	11.7
1999	27.1	35.4	263.6	526.5	414.7	632.1	293.0	77.0	33.5	18.4	13.8	21.9
2000	33.5	45.4	81.5	148.9	115.2	96.6	65.1	29.4	17.4	17.1	17.3	20.2
2001	37.3	283.8	262.5	152.4	96.4	147.1	67.8	31.2	26.6	38.5	71.3	59.2
2002	30.8	25.3	36.0	56.4	43.6	62.8	46.2	23.8	18.4	14.0	13.8	20.3
2003	18.4	23.9	21.7	38.0	71.3	126.0	69.3	19.9	15.3	30.2	28.6	63.2
2004	41.9	68.1	130.3	164.9	118.3	79.6	45.5	18.5	14.0	12.1	13.1	11.7
Average	46.0	75.8	98.6	132.6	180.6	180.5	93.2	40.5	33.3	29.8	24.6	35.5
Min	13.1	21.9	19.9	22.7	20.0	27.9	24.7	13.2	12.3	10.8	11.1	11.6
Max	328.9	424.1	389.1	596.1	677.5	1000.6	509.7	408.7	291.9	317.0	152.7	801.1

Scenario 53 (m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	128.8	31.9	33.4	34.6	82.1	185.2	118.9	39.0	17.8	11.8	9.5	12.1
1921	24.8	232.8	240.5	73.9	37.1	37.6	30.6	66.2	64.9	31.6	46.9	26.5
1922	50.3	168.8	73.5	193.6	513.7	278.0	70.0	15.1	12.3	214.7	99.1	13.7
1923	18.6	26.9	31.9	95.4	121.4	96.0	48.5	15.7	12.6	10.3	10.6	13.7
1924	22.5	37.5	295.9	151.3	62.2	584.7	309.3	59.4	16.2	11.8	9.8	11.1
1925	20.5	38.1	35.5	69.8	46.1	247.4	109.7	19.3	22.5	17.9	11.8	19.2
1926	39.5	45.9	61.2	49.0	50.9	596.4	255.2	17.8	11.2	11.8	12.7	10.5
1927	27.5	34.7	68.5	297.4	177.4	100.2	51.6	15.5	12.2	10.4	14.0	12.7
1928	24.3	35.5	43.1	40.7	39.0	223.5	99.6	18.7	47.5	54.5	26.5	84.0
1929	95.1	82.3	140.8	150.5	57.7	112.0	79.9	23.3	19.0	17.0	42.5	35.0
1930	27.2	31.3	34.9	301.8	334.6	287.3	117.5	24.3	12.6	322.8	140.2	13.0
1931	24.5	37.7	60.9	43.7	267.6	129.8	40.4	18.5	17.5	20.0	15.7	25.9
1932	35.6	201.8	176.0	58.0	31.7	47.3	40.9	14.7	10.2	10.4	9.6	8.3
1933	15.6	238.3	338.7	578.7	238.8	151.0	72.2	19.6	13.3	18.4	15.4	10.1
1934	36.2	67.6	166.5	81.7	42.5	64.1	130.7	100.7	85.3	34.1	28.5	19.1
1935	21.1	30.0	26.5	32.0	214.9	137.6	52.9	53.5	33.6	19.3	12.2	10.0
1936	26.8	453.9	178.1	66.8	512.0	219.5	48.6	14.3	10.7	10.0	9.2	8.9
1937	19.3	30.2	41.1	86.5	184.9	86.9	107.7	49.0	21.3	23.5	21.3	14.1
1938	23.1	39.4	222.7	233.5	677.5	218.5	42.2	20.9	16.4	18.6	18.3	92.0
1939	82.3	56.6	46.3	40.7	358.7	221.4	64.5	124.0	61.7	17.3	11.4	22.2
1940	27.9	39.5	83.3	109.8	128.2	76.4	57.7	22.7	12.8	12.1	11.5	9.9
1941	21.7	31.7	27.5	71.1	291.9	202.7	91.5	40.3	19.5	12.0	13.4	15.2
1942	31.6	203.4	360.6	189.9	56.8	150.5	204.8	81.7	38.8	26.4	156.8	84.4
1943	77.3	310.1	300.1	157.1	115.0	147.5	58.6	15.7	19.2	18.9	12.6	171.9
1944	92.5	35.6	25.5	56.9	177.5	211.4	84.0	17.0	12.3	10.3	9.1	8.0
1945	30.4	32.9	28.9	76.2	71.9	127.5	70.5	25.0	16.9	12.2	10.2	8.9
1946	19.1	43.0	49.8	84.0	117.5	180.9	96.1	22.2	45.0	30.7	14.6	13.3
1947	24.8	283.8	215.8	174.7	304.0	277.8	102.1	22.7	13.0	10.5	9.2	7.9
1948	21.7	31.7	29.9	56.7	71.2	70.4	53.5	21.6	12.6	11.0	10.1	9.4
1949	18.4	31.9	38.8	46.4	188.6	343.6	132.8	34.8	21.4	18.2	47.2	29.2
1950	27.7	34.6	177.1	117.7	141.5	77.4	43.9	16.2	11.6	10.0	13.5	21.8
1951	42.4	35.0	27.3	57.4	154.2	88.8	51.4	23.3	15.8	14.0	11.7	13.4
1952	23.0	36.3	80.5	65.5	57.6	56.2	53.6	23.0	12.5	10.0	10.5	20.2
1953	43.7	58.4	59.7	55.6	64.2	81.6	53.7	51.9	56.2	25.4	13.1	12.8
1954	49.6	53.0	40.7	463.5	530.8	151.4	59.2	28.7	20.8	15.2	10.5	10.9
1955	23.7	45.6	38.5	35.3	142.2	239.1	104.5	22.9	18.0	13.7	10.7	10.9
1956	25.3	83.9	390.3	340.6	160.5	236.6	121.5	28.5	15.5	13.6	17.4	77.4
1957	78.4	48.4	45.6	167.7	130.1	56.2	69.9	33.9	15.7	11.9	10.3	9.3
1958	17.5	89.9	194.6	83.5	75.8	62.5	59.1	408.7	155.6	37.6	31.6	19.2
1959	24.2	39.4	40.3	55.8	50.9	55.8	52.9	25.3	14.4	11.0	12.3	16.2
1960	24.9	47.4	119.2	72.9	58.3	116.2	150.6	58.3	18.3	12.2	11.5	10.0
1961	16.5	43.3	53.0	54.6	193.4	193.7	73.4	19.7	12.9	10.2	11.0	9.6
1962	19.6	69.7	61.6	371.2	232.5	516.6	210.9	26.9	14.1	35.2	23.3	10.2
1963	74.7	164.6	74.2	138.6	76.5	130.9	109.6	33.7	294.2	117.3	17.7	14.6
1964	86.9	51.9	33.0	52.7	66.7	46.6	35.1	16.9	170.6	115.2	57.9	28.4
1965	63.4	97.9	39.5	223.5	152.1	39.0	31.8	45.2	29.2	13.7	14.3	15.6
1966	21.4	29.5	43.3	158.4	136.1	467.9	266.7	63.2	29.5	32.1	19.0	10.4
1967	19.4	34.0	34.7	35.1	36.2	66.4	51.3	17.4	10.8	10.0	11.7	14.0
1968	21.3	32.2	31.4	30.2	60.1	160.1	82.6	35.6	20.6	13.0	11.2	9.6
1969	31.6	36.6	39.7	39.0	57.5	44.5	30.4	13.9	15.1	12.5	36.5	37.1
1970	94.3	62.6	37.0	90.3	81.2	60.7	49.2	45.2	27.8	25.5	37.8	21.6
1971	128.1	76.2	40.0	122.1	445.0	296.0	77.5	19.3	13.8	11.6	10.0	9.2
1972	18.9	77.2	47.4	35.7	215.7	186.6	78.1	23.3	12.3	11.3	12.9	15.1
1973	23.2	61.4	48.6	376.9	467.1	528.9	189.4	65.4	38.2	19.1	13.2	9.5
1974	17.7	60.6	62.1	51.8	61.1	58.8	46.5	17.6	11.0	9.7	9.6	44.6
1975	32.9	35.8	401.6	596.1	531.7	1000.6	349.7	72.4	35.8	15.7	11.7	18.8
1976	269.8	111.2	32.7	76.1	106.3	83.6	52.9	18.9	13.3	12.5	11.4	15.6
1977	51.9	52.8	68.2	73.1	66.5	168.1	499.8	202.4	20.3	12.4	13.6	26.5
1978	56.6	68.7	159.3	69.3	88.9	62.2	49.2	20.5	13.7	22.5	25.0	18.1
1979	23.1	30.3	32.8	102.6	126.5	68.1	39.0	15.4	11.2	10.0	9.1	80.1
1980	49.3	59.4	40.7	92.4	157.9	77.7	37.5	21.1	18.1	12.9	19.3	18.7
1981	21.5	34.4	37.9	58.9	70.3	225.5	109.0	23.4	19.0	19.9	14.2	13.1
1982	41.8	40.6	26.5	28.5	24.5	33.9	35.6	15.1	10.8	21.7	14.8	14.1
1983	25.2	62.1	156.5	105.6	82.4	114.0	95.4	32.8	18.5	24.9	17.5	10.8
1984	27.8	46.9	34.0	111.7	567.6	186.8	33.9	12.8	9.8	9.2	8.3	7.6
1985	180.8	131.2	129.3	221.5	126.5	62.9	44.1	16.0	12.3	11.0	16.1	19.3
1986	86.0	129.9	53.0	42.3	48.5	76.2	51.0	15.6	13.4	11.6	24.6	800.1
1987	328.9	61.6	42.6	56.7	549.7	385.7	108.4	39.6	24.3	19.6	16.2	13.2
1988	22.4	51.7	173.8	120.4	501.4	182.9	134.7	59.8	18.4	14.9	11.4	8.3
1989	36.7	397.0	185.7	79.1	42.6	274.0	132.0	24.5	14.9	13.1	14.3	10.8
1990	22.8	29.6	53.0	140.2	165.1	75.7	35.2	12.2	10.3	9.3	8.3	10.1
1991	174.5	98.7	116.9	67.8	89.5	67.1	46.0	17.3	10.7	9.2	10.6	9.8
1992	18.5	36.4	30.1	30.0	60.7	118.5	64.7	16.5	10.1	8.6	10.0	12.0
1993	92.1	65.1	130.4	151.3	190.5	232.1	92.8	15.1	11.2	14.8	15.7	10.1
1994	17.6	38.9	34.4	63.6	43.8	133.0	97.5	30.5	26.3	20.2	11.7	11.0
1995	26.4	37.9	298.7	612.7	543.1	165.9	58.4	19.1	14.2	28.4	20.2	11.5
1996	22.6	129.0	210.8	316.1	179.3	115.7	104.9	43.0	297.2	135.6	28.9	14.2
1997	23.1	42.8	33.6	69.5	607.4	401.5	105.9	26.5	14.6	12.4	13.7	11.5
1998	18.7	49.1	154.1	145.5	261.2	147.2	55.3	18.0	11.7	10.2	9.0	7.8
1999	26.1	37.7	262.6	537.6	414.7	632.1	293.0	77.0	28.1	14.6	10.9	16.2
2000	34.7	47.8	84.5	147.0	114.6	102.0	65.8	23.6	14.5	14.2	14.3	15.0
2001	37.1	311.5	262.5	152.4	96.4	147.1	69.8	25.3	20.9	32.6	77.5	68.7
2002	31.5	30.2	38.6	59.7	46.8	67.6	49.5	18.1	13.2	10.9	10.0	14.0
2003	20.2	28.5	26.2	34.7	69.6	118.8	64.1	16.8	12.6	24.3	23.5	55.7
2004	40.9	69.4	131.8	194.9	118.3	79.6	47.4	15.1	11.0	9.5	9.5	7.5
Avera	47.1	80.0	103.3	135.9	182.5	181.6	94.3	37.2	29.9	26.4	21.2	31.1
Min	15.6	26.9	25.5	28.5	24.5	33.9	30.4	12.2	9.8	8.6	8.3	7.5
Max	328.9	453.9	401.6	612.7	677.5	1000.6	499.8	408.7	297.2	322.8	156.8	800.1

Scenario Dam (1.5 MAR)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	14.6	14.4	18.9	19.8	127.6	215.6	124.8	42.3	16.8	10.0	7.1	11.9
1921	16.7	270.1	234.6	66.0	21.2	15.8	9.5	76.4	73.6	35.7	39.2	26.2
1922	64.6	168.3	76.6	225.8	530.2	272.2	60.8	12.0	11.3	232.6	95.9	14.2
1923	9.9	8.6	15.9	90.6	121.0	86.7	31.4	11.8	10.5	8.0	8.8	15.3
1924	14.8	21.7	332.9	131.6	46.7	585.8	343.9	67.1	15.6	10.0	7.3	11.3
1925	12.1	19.6	18.4	63.7	35.9	282.1	109.6	18.8	25.2	18.4	9.7	26.7
1926	36.0	31.5	49.7	33.2	36.6	633.1	234.9	14.6	8.9	9.7	11.4	10.1
1927	29.2	21.6	87.4	288.0	165.4	83.4	32.1	12.2	10.5	8.3	13.7	12.8
1928	15.7	21.4	47.2	38.3	29.5	235.8	91.4	16.8	46.7	50.5	26.5	100.0
1929	83.1	81.5	131.1	136.1	43.9	84.8	52.6	20.3	18.1	16.4	42.9	33.5
1930	22.3	13.8	27.3	300.0	298.9	289.3	105.6	22.0	10.5	363.6	135.9	13.0
1931	18.0	21.2	90.0	40.5	268.3	110.8	21.7	15.3	16.6	20.2	14.5	46.5
1932	39.1	209.2	179.6	43.3	17.1	41.8	26.9	11.1	7.8	8.2	7.1	6.1
1933	5.2	322.9	371.0	600.3	212.1	141.8	58.4	16.3	11.9	22.0	16.2	8.3
1934	30.5	73.7	143.7	65.6	27.9	59.3	118.5	91.1	80.3	34.9	29.6	20.2
1935	12.6	11.4	6.4	11.2	243.8	155.3	38.5	61.3	37.8	18.0	10.5	9.0
1936	20.8	507.8	176.3	60.8	499.8	203.6	34.7	10.3	8.4	7.6	6.4	7.7
1937	11.4	12.9	32.2	98.1	242.2	85.1	115.0	48.9	21.5	24.1	21.5	14.1
1938	17.7	35.0	238.4	231.8	709.4	210.6	22.2	18.6	15.9	19.8	18.2	121.4
1939	76.7	52.1	32.0	21.6	416.5	219.6	57.7	122.8	62.0	16.6	9.3	25.6
1940	21.6	23.1	73.7	104.3	125.7	58.5	41.4	20.8	10.7	10.3	9.6	7.8
1941	20.0	16.0	7.2	56.5	319.0	241.2	89.3	39.6	18.7	9.6	12.3	18.1
1942	33.9	269.3	349.3	170.5	47.4	145.4	188.3	73.5	33.9	25.3	164.8	77.3
1943	72.7	351.3	284.5	115.3	94.3	131.0	48.1	12.0	19.8	19.6	10.6	178.5
1944	82.8	17.4	5.6	44.4	200.7	222.3	71.7	13.5	10.2	7.8	6.0	5.2
1945	29.2	16.8	10.7	103.2	84.7	138.1	64.6	24.0	14.8	10.4	7.4	6.4
1946	9.7	31.7	42.2	86.4	134.1	187.4	77.0	17.5	44.5	31.5	12.8	13.9
1947	18.2	310.7	217.1	162.7	291.4	256.5	88.6	20.7	11.3	8.3	6.2	5.1
1948	10.8	12.9	10.9	41.7	52.4	48.2	35.0	18.8	10.1	8.8	7.4	7.6
1949	8.5	14.1	22.0	22.9	224.8	377.0	128.1	43.1	25.0	17.6	52.2	32.8
1950	23.7	17.9	185.6	90.4	120.0	62.3	23.8	12.1	9.0	7.3	12.6	24.4
1951	41.3	19.8	7.0	36.9	175.9	80.1	32.3	19.9	14.1	12.5	9.0	15.7
1952	15.9	23.9	75.8	49.8	39.0	34.9	33.7	19.5	9.6	6.8	7.8	25.4
1953	49.5	51.6	46.2	34.3	48.6	93.3	45.2	60.8	50.1	23.8	10.6	12.4
1954	42.1	37.1	23.6	495.4	497.8	124.0	35.8	21.0	20.1	14.5	7.5	10.3
1955	16.4	32.4	23.0	15.0	155.2	267.9	95.9	19.9	17.4	11.9	7.7	11.0
1956	21.3	83.1	392.8	312.2	148.4	239.6	105.4	22.2	14.0	12.0	17.9	82.9
1957	70.8	32.3	34.9	177.4	116.8	35.9	58.2	35.0	14.0	9.8	7.2	7.3
1958	7.4	108.6	213.7	75.5	74.0	48.6	55.0	409.6	155.3	31.2	30.4	19.3
1959	15.5	24.3	29.2	52.7	38.0	35.3	33.2	22.2	12.4	8.5	10.4	17.2
1960	17.6	44.5	144.5	65.7	49.6	119.6	130.7	51.2	16.7	9.9	9.1	8.2
1961	5.8	65.3	45.6	41.6	195.0	175.3	59.6	16.5	10.6	7.3	8.5	7.0
1962	10.8	95.9	59.0	361.8	197.6	535.0	195.9	24.4	12.0	36.7	22.6	7.7
1963	111.3	157.9	63.2	128.5	62.8	133.3	97.7	31.2	303.8	116.3	16.7	15.3
1964	86.6	39.9	17.5	37.8	81.7	33.5	14.5	15.4	185.9	102.1	55.6	30.1
1965	70.7	80.0	26.9	254.9	124.7	13.5	9.7	44.3	30.0	11.7	13.3	17.1
1966	12.4	11.2	29.2	182.5	130.0	447.1	256.3	58.0	27.0	28.8	17.5	7.6
1967	11.3	15.3	14.1	14.9	24.4	49.2	32.0	12.7	7.4	6.9	9.6	14.3
1968	12.8	14.7	12.1	9.0	52.8	205.3	84.6	33.6	19.4	11.0	8.8	7.0
1969	28.9	21.3	26.9	20.3	52.4	24.9	8.3	9.4	14.8	11.2	59.9	61.3
1970	103.1	50.7	19.0	92.6	80.6	41.9	32.0	49.4	29.9	27.8	38.4	22.4
1971	160.9	76.8	25.8	124.1	415.3	244.8	63.0	15.4	11.8	9.0	6.6	6.6
1972	9.8	79.4	37.4	17.3	249.1	153.2	58.5	20.6	9.8	9.3	11.1	14.7
1973	14.1	57.4	36.7	363.0	396.0	492.7	164.1	61.2	37.1	18.1	11.0	6.5
1974	7.4	67.5	56.3	35.2	45.8	49.9	31.3	13.0	7.7	6.4	6.2	55.1
1975	28.2	17.3	434.1	546.6	525.9	1017.8	326.4	61.5	30.6	14.5	9.1	21.6
1976	298.9	110.8	13.4	62.8	114.7	76.3	35.9	14.4	11.0	9.9	8.7	15.6
1977	56.2	37.2	65.6	60.5	51.7	168.9	480.3	164.9	18.7	9.3	11.3	28.8
1978	59.8	55.6	162.1	61.3	83.8	46.2	28.2	20.1	12.5	26.6	25.9	27.1
1979	17.9	11.2	13.2	85.2	127.0	51.1	17.3	9.7	7.3	7.1	4.8	94.7
1980	45.9	42.9	22.3	107.2	181.4	62.5	15.9	21.8	18.5	10.0	19.1	17.9
1981	10.1	15.1	23.5	50.5	83.7	250.6	104.3	19.9	18.5	20.4	11.4	11.6
1982	76.4	31.6	2.6	7.3	5.3	10.3	15.0	10.2	7.4	21.1	11.1	11.5
1983	18.3	80.9	172.1	97.7	70.5	115.2	93.2	33.1	17.3	24.5	15.1	7.3
1984	26.9	37.1	14.9	146.3	561.4	167.7	12.3	6.6	5.6	4.8	2.8	3.6
1985	254.5	118.9	109.1	209.3	98.3	46.7	25.5	10.0	8.4	7.3	15.5	21.3
1986	110.5	103.1	37.8	23.2	34.2	61.4	32.2	9.6	10.5	7.9	24.7	869.8
1987	320.6	50.0	26.8	45.1	568.9	366.8	95.5	35.9	22.8	17.5	12.9	11.9
1988	14.0	46.5	169.3	100.6	544.0	182.8	132.6	51.7	15.9	12.4	6.4	2.9
1989	30.2	434.4	170.9	66.7	27.1	294.6	131.2	22.0	12.3	9.6	12.7	7.3
1990	15.8	9.4	37.4	134.5	154.4	52.3	11.3	5.5	6.1	4.5	2.6	7.8
1991	223.0	106.3	139.2	64.1	81.5	46.9	25.9	11.5	6.1	4.2	6.3	6.6
1992	7.0	16.2	8.4	9.7	52.8	115.9	51.9	11.7	5.6	3.6	5.5	18.6
1993	125.4	73.4	144.1	186.2	222.4	295.9	96.6	9.8	8.0	13.6	13.9	5.8
1994	6.4	18.6	19.8	68.1	35.8	159.0	97.6	29.5	25.4	17.7	7.1	7.9
1995	21.1	31.2	335.7	623.2	541.5	159.1	39.4	14.5	11.2	27.1	16.7	8.2
1996	13.9	179.5	217.3	325.5	168.6	115.8	94.8	40.0	319.6	127.3	25.0	12.3
1997	16.5	33.3	17.2	90.6	667.6	421.2	94.2	19.6	11.6	8.8	11.2	9.0
1998	8.6	69.5	147.8	140.6	250.6	128.2	40.4	13.2	8.4	6.9	4.4	3.1
1999	20.6	23.2	305.3	591.4	449.2	643.0	288.0	71.0	28.5	12.5	7.0	17.3
2000	28.1	35.6	76.7	151.8	118.3	92.6	53.0	20.8	11.8	11.6	11.6	14.7
2001	39.4	330.6	252.3	153.4	88.7	146.7	57.6	33.0	24.2	43.0	101.6	71.7
2002	25.4	11.8	26.8	47.4	34.0	62.2	36.6	16.1	11.9	8.3	7.3	17.4
2003	11.8	10.7	6.9	4.6	63.3	138.1	57.3	13.1	10.0	33.2	27.1	80.3
2004	41.8	63.5	142.8	174.1	96.6	75.8	34.3	11.6	8.5	6.4	6.3	4.5
Average	44.7	76.4	97.6	129.4	180.5	178.0	81.2	34.2	29.0	25.5	19.8	33.3
Min	5.2	8.6	2.6	4.6	5.3	10.3	8.3	5.5	5.6	3.6	2.6	2.9
Max	320.6	507.8	434.1	623.2	709.4	1017.8	480.3	409.6	319.6	363.6	164.8	869.8

APPENDIX B: SUMMARY OF HYDRODYNAMIC AND WATER QUALITY CHARACTERISTICS FOR ABIOTIC STATES (EXTRACTED FROM DWS, 2014a)

PARAMETER	STATE 1: Significant saline penetration	STATE 2: Intermediate saline penetration	STATE 3: Limited saline penetration	STATE 4: Freshwater dominated
Flow range (m^3/s)	1–3	3–10	10–30	> 30
Mouth condition	Open, but constricted	Open	Open	Wide open
Water level	None	None	None	Extensive during floods
Tidal range	< 1.0 m	1.5 m	1.5 m	2.0 m
Dominant circulation process	Tide	Tide and Fluvial	Fluvial	Fluvial
Retention	2 – 4 weeks	1 – 2 weeks	1 – 5 days	Less than 1 day
Stratification	Relatively well mixed	Strong stratification on middle and lower reaches	Strong stratification on lower reaches	Limited in mouth area
Salinity	30 | 20 | 10	25 | 15 | 0	20 | 0 | 0	5 | 0 | 0
DO (mg/ℓ)	8 | 8 | 7	8 | 8 | 7	8 | 8 | 8	8 | 8 | 8
Turbidity (NTU)	Reference: 30 | 30 | 50 Present and Future: 40 | 40 | 60	Reference: 30 | 40 | 60 Present and Future: 40 | 50 | 70	Reference: 80 | 150 | 150 Present and Future: 90 | 160 | 160	Reference: 230 | 230 | 230 Present and Future: 250 | 250 | 250
DIN (µg/ℓ)	Reference: 100 | 100 | 80 Present and Future: 100 | 130 | 150	Reference: 100 | 80 | 80 Present and Future: 120 | 140 | 180	Reference: 80 | 80 | 80 Present and Future: 130 | 180 | 180	Reference: 100 | 100 | 100 Present and Future: 180 | 180 | 180
DIP (µg/ℓ)	Reference: 10 | 10 | 10 Present and Future: 10 | 15 | 25	Reference: 10 | 10 | 10 Present and Future: 15 | 20 | 30	Reference: 10 | 10 | 10 Present and Future: 15 | 30 | 30	Reference: 15 | 15 | 15 Present and Future: 30 | 30 | 30

NOTE: For the purposes of this assessment the estuary was sub-divided into three zones representing from left to right: Lower, Middle and Upper Zones (see **Figure 3.2**)